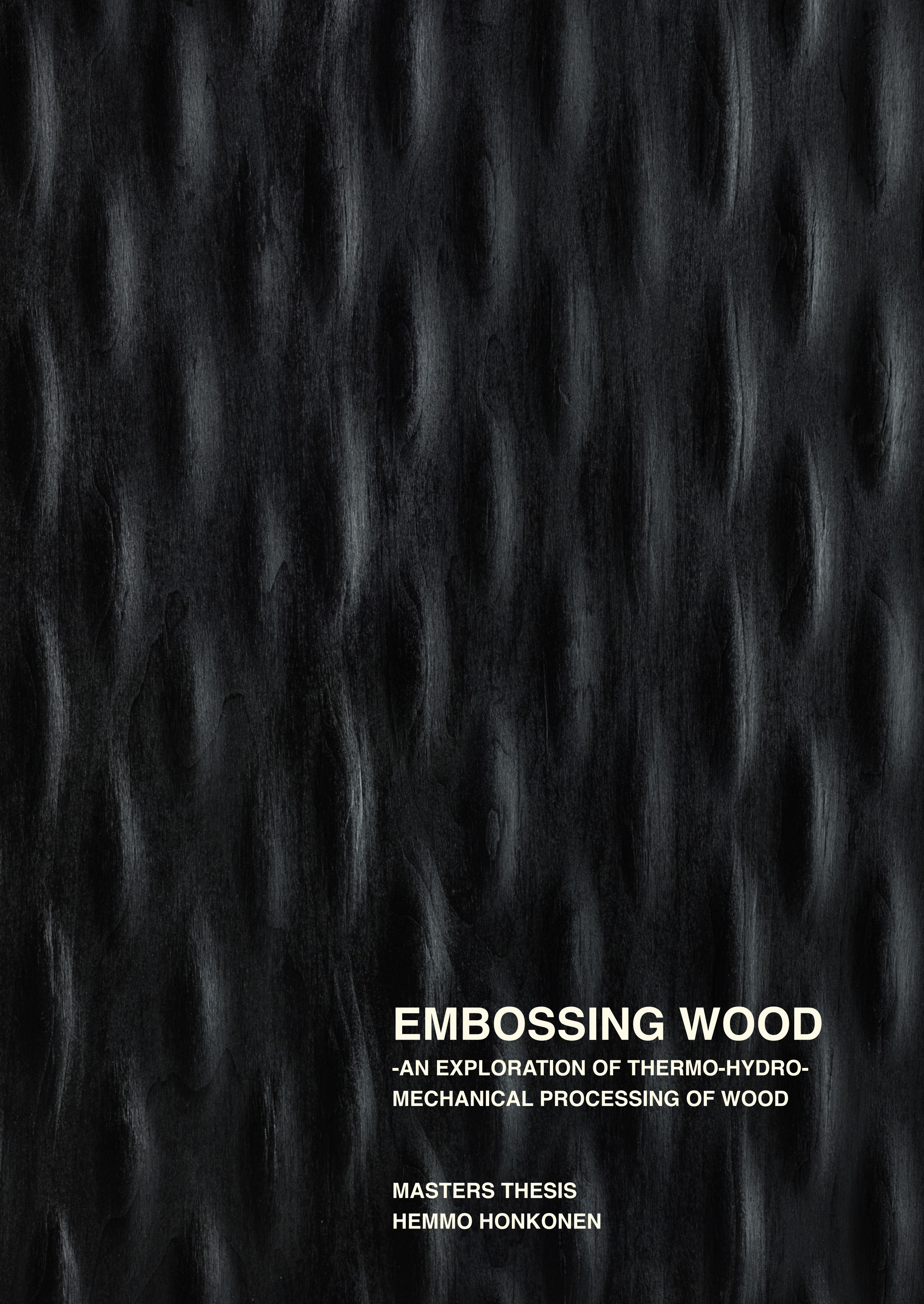
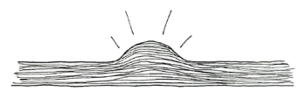


EMBOSSING WOOD

-AN EXPLORATION OF THERMO-HYDRO-MECHANICAL PROCESSING OF WOOD

MASTERS THESIS

HEMMO HONKONEN



Masters thesis
Hemmo Honkonen
2021

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AB-STRACT

ENGLISH

This thesis investigates a solid wood embossing technique and its implementation on product and interior design. The technique is based on a phenomena commonly known and used among wood workers - a woodworking trick used to repair small flaws in wooden surfaces. Although the trick is well known, using it for creating embossments instead of flattening out indents has not been widely explored. With an aim to create a recipe for the technique empirical experiments are carried out to explore the potential and the variables of the phenomena. These results are then taken into a design process aimed at finding an application for the method in the field of product and interior design.

Further experiments are thereafter carried out in order to test two different end applications for the embossing method, joinery and surface texturing, of which the latter proves to show more potential. To deepen the knowledge and understanding of the possibilities and limitations of the method a new set of experiments is carried out. The geometrical constraints of the embossments are explored using 3D-printed and CNC-milled pressing tools. A variety of shapes and patterns are tested to find out the optimal balance for parameters, such as height and intensity, of the embossed pattern.

Finally, to demonstrate the potential of the method, a set of furniture incorporating embossed surfaces are designed and built. The set consists of a chair, a cabinet and a wall which are all covered with the embossments and communicate different qualities of the surface.

Another design outcome, maybe even more important than the sample furniture, is the method itself. By no means ready for large scale industrial implementation but sophisticated enough to serve as a proof of concept and a prototype of an industrial embossing method. A textured wooden surface is nothing new in itself but this way of making them is. Compared to conventional alternatives the advantage of this method lies in its efficiency and relatively low technical requirements which offers a cost-efficient way to cover large wooden surfaces with embossments.

AB-STRACT

SWEDISH

Detta examensarbete undersöker en präglingsteknik för massivträ och dess implementering i möbel- och interiördesign. Tekniken baserar sig på ett välkänt och använt fenomen bland trähantverkare – ett snickartrick som kan användas för att reparera små bucklor eller repor i träytor. Trots att tekniken är välkänd har dess potential som en präglingsteknik, istället för en reparationsteknik, inte utforskats utförligt. Med målsättningen att skapa ett recept för tekniken, utforskas fenomenets potential och variabler genom empiriska experiment. Resultaten av dessa experiment tas därefter in i en designprocess med målet att finna en tillämpning för metoden inom produkt- och interiördesign.

Ytterligare experiment utförs därefter för att pröva präglingsmetoden inom två olika tillämpningsområden, sammanfogning och ytstrukturering, av vilka den senare visar sig ha mer potential. En ny omgång experiment genomförs med syftet att förstå och fördjupa kunskapen om metodens möjligheter och begränsningar. Det geometriska ramverket för de präglade formerna utforskas med hjälp av 3D-utskrivna och CNC-frästa tryckverktyg. Ett urval former och mönster prövas för att finna den optimala balansen mellan de olika parametrarna, så som höjd och intensitet, hos det präglade mönstret.

Slutligen, för att demonstrera metodens potential, formges och skapas en kollektion med möbler där den präglade ytstrukturen tillämpas. Kollektionen består av en stol, ett skåp och en vägg varav alla är täckta med det präglade mönstret och framhäver ytans olika kvaliteter.

Det andra, och möjligtvis även det viktigare, resultatet i detta projekt är präglingsmetoden i sig. Metoden är långt ifrån färdigt för storskalig industriell implementering, men dock tillräckligt sofistikerat för att agera som ett bevis på koncept samt som en prototyp på en industriell präglingsmetod. En strukturerad träyta är inget nytt i sig men det är däremot denna tillverkningsmetod. I jämförelse med konventionella alternativ ligger fördelen med denna metod i dess effektivitet och relativt låga tekniska förutsättningar. Dessa fördelar erbjuder i sin tur ett kostnadseffektivt sätt att täcka stora träytor med präglade mönster.

AC-
KNOW-
LEDGE-
MENTS

First of all I want to thank Aalto University and all the workshop staff that have helped and supported me along this project. A special thanks to Kari Kääriäinen and his contributions on the CNC, without whom this project would not have been possible to develop this far. Also, a special thanks to Manuel Fonseca Martinez for all the help with the 3D-printing.

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I also want to thank mark Mark Hughes who early on in the process introduced me to the Aalto Bioproduct Centre lab and its equipment. Also thank you Timo Kotilahti for all the technical support at the lab.

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Finally, thank you Jessica for all the support and for being my sounding board throughout the process.

INDEX

INTRO-DUCTION

Wood is one of the oldest materials used by mankind. Since the dawn of man, wood has been used for different purposes. Wood has served as construction material for shelter and weapons and it has probably been the fuel for the first bonfires. According to the findings of a study published in the Journal of Human Evolution wood has been manipulated using stone tools as early as 1.5 million years ago. (Wong, 2001) Today wood is still a popular material and a widely used resource. As a material wood has not changed much since we started using it but the industry around it is constantly evolving. New techniques and innovations are developed to get the most out of the material.

Apart from the traditional woodworking techniques, such as sawing, planing and joining, wood can also be manipulated by other means. The structure of wood allows it to be manipulated on molecular and cellular levels using temperature, moisture, chemicals etc. Manipulating wood on a cellular level allows you to do things with wood that are not possible otherwise or are too time consuming by traditional means.

The technique investigated in this thesis project is based on a cellular level phenomena in wood called shape memory. The phenomena is well known and commonly used among woodworkers for restoration. This project introduces an alternative application of the phenomena. This alternative way of taking advantage of the phenomena allows a low tech and cost efficient way of producing embossed shapes on wooden surfaces.

BACK-
GROUND

The phenomena that is being investigated in this thesis project is commonly known among woodworkers and often used in restoration of damaged wooden surfaces. It is a simple woodworking trick that takes advantage of the so called shape memory of wood fibers. The phenomena allows you to repair indents by swelling the indented fibers back up with the help of moisture and heat.

I personally came across the technique the first time during my luthier studies in 2011. The trick came in handy when you had been working on an instrument for the past few weeks or months, shaping and sanding that piece of wood to the finest detail and then on your way to the lacquer booth you bump the fine sanded surface into a corner of a table. To make that indent disappear you could either fill the indent with wood filler or sand the whole surrounding area down until the indent has disappeared. Sanding would not be an option since you would end up changing the shape and the dimensions of the whole piece and filling the dent with wood filler would not end up looking pretty. But luckily applying some moisture and heat on the indent makes the indented wood fibers swell back up and the indent just magically disappears.

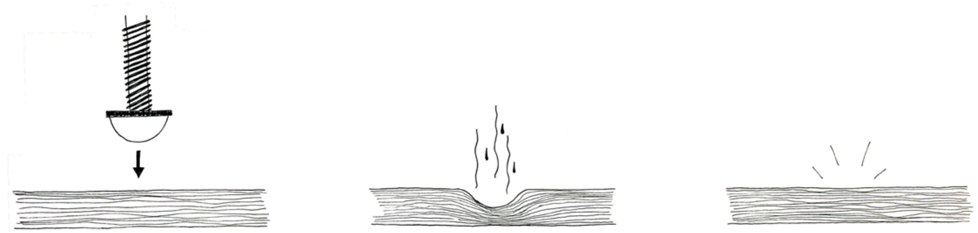


Fig. 1. The phenomna called shape memory can be used to repair indents in wooden surfaces.

The experiments that I will conduct in this thesis take advantage of this exact same phenomena but instead of making an indent disappear from a wooden surface, I will try to create embossed shapes on a surface. I have previously seen a few experiments done in that manner but not anything on a larger scale or on an industrial level.

The aim of the project is to explore and develop the technique and find an aesthetical or functional application for it in the interior industry. The category of the final product is still open however. The application might be a piece of furniture or a component such as wall panels or sheet material.

METHOD-OLOGY

This thesis project utilizes the following design research methodologies: practice-led research, empirical research, experimental design, material research. Before moving on to the actual research it is important to give a short description of these methodologies and their relation to this research project.

Fig. 2.

RESEARCH

Research
noun

> a detailed study of a subject, especially in order to discover (new) information or reach a (new) understanding (Cambridge Dictionary, 2021)

All research strives to increase or expand the knowledge of the topic that is being studied. This work can be qualitative or quantitative depending on the subject and type of research that is being conducted. Quantitative research focuses on collecting numerical data and making generalizations through analysis and statistics. Quantitative research strives to explain how things work in detail. Qualitative research on the other hand focuses on collecting qualitative data often in the form of words, experiences or observations. Qualitative research strives to explain and understand a certain topic or phenomenon in depth without necessarily aiming for a generalizable conclusion.(Crouch and Pearce, 2012, pp. 68-75) In the context of this thesis project the research is mostly quantitative and deals with testing and observing a phenomena and collecting numerical data.

Fig. 3.

PRACTICE-LED RESEARCH

Practice
noun

> action rather than thought or ideas (Cambridge Dictionary, 2021)

Practice-led research is a common and widely used research methodology within the fields of arts and design. Practice-based research, practice as research, creative research and practice-led research are all very closely related and are in many cases used interchangeably. Despite of some minor differences in approach they all describe the same methodology of creative work within the university environment.

As Smith and Dean (2010, p.5) explain the aforementioned terms are used to make two statements about practice. Firstly, that creative work or practice is a form of research in itself and leads to detectable research outputs, and secondly, that the knowledge and craftsmanship that practitioners have and the creative process that they use it in can lead to insights that can then be generalized and treated as research.

Documentation is one of the most important methods of practice-led research. The creative work is documented or captured by filming, photographing, recording, writing or by any other suitable means and can later on be used to generate research outcomes. Alongside with the knowledge gained out of the documented practice, the final artefact might also be a documentation in itself and may contribute to the final research outcome.

In the context of this thesis project practice-led research has played a central role despite the not so artistic nature of the project. Practice-led research is more relevant in a purely artistic practice than it is in a more pragmatic design practice. Nevertheless many of the methods and approaches of practice-led research fit very well in the context of this research project due to its practical nature and the “trial and error” type of work flow.

EMPIRICAL RESEARCH

Empirical
noun

Based on what is experienced or seen rather than on theory (Cambridge Dictionary, 2021)

As expressed by Crouch and Pearce (2012, p.26) ”Empirical research is the name given to a way of gaining information through the observation of observable phenomena.” The Dutch psychologist and chess expert A.D. de Groot (1969) created the so called empirical cycle, a model demonstrating how empirical research should be conducted. The model is based on five subsequent steps that are all equally important. Information is gained by evaluating the results of tests that are carried out based on a hypothesis. Empirical research turned out to be one of the most dominant methodologies in this thesis project due to the subject and research questions.

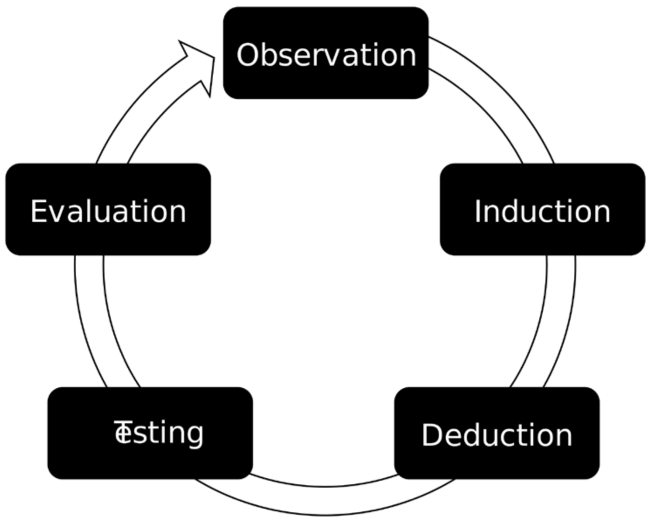


Fig. 4.

MATERIAL RESEARCH

Material
noun

a physical substance that things can be made from (Cambridge Dictionary, 2021)

Material research is a study focusing on the properties of materials. Material research might focus on investigating an existing material or on creating new ones by modifying or merging several materials or substances. Material research is a vast field of study with numerous different applications and can be conducted with different levels of precision. (Venables et al., 2018) In the traditional sense material research is conducted in laboratory conditions by a scientist in order to gain reliable and reproduceable results. In the context of this project the goals are more or less the same but the material research is done by a designer in a studio environment and might hence not reach that laboratory level precision.

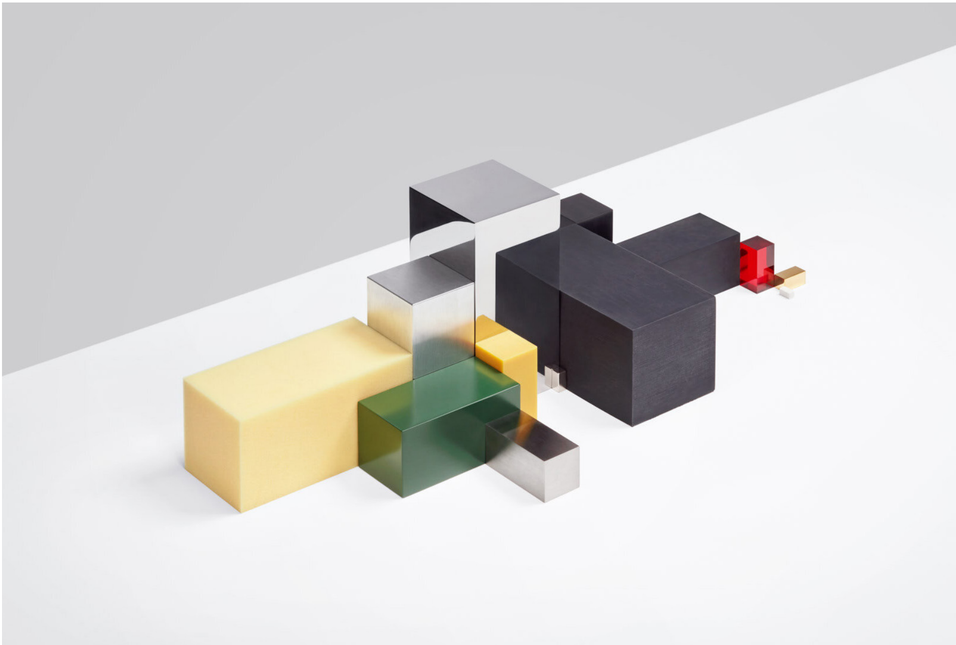


Fig. 5.

EXPERIMENTAL DESIGN RESEARCH

Experiment
noun

a test done in order to learn something or discover if something works (Cambridge Dictionary, 2021)

Experimental design is a term that is increasingly used in the contemporary design field and people seem to have very different perspectives on the meaning of it. Some people understand the term experimental as “trying out” as in doing a bunch of random experiments and seeing where it leads them. In the field of free arts the term is often used to describe content that does not quite fit in any other category or that challenges the commonly known and accepted boundaries of art. (Lindauer and Müller, 2015, p.16) As further explained by Lindauer and Müller (2015, p.16) experimental design can also be interpreted as a methodology that uses similar test setups as in scientific experiments. In the context of this thesis, experimental design is interpreted according to the latter, as a research methodology similar to empirical research where experiments are carried out in a scientific manner with the aim of gaining a favorable design outcome.

Fig. 6.

Fig. 7.

WOOD

Wood has played an important role in the history of mankind. It is one of, if not the oldest construction material ever used by man. Wooden objects, tools and buildings can be dated back to the very beginning of human civilization. Despite of modern material innovations wood remains as one of the most widely used materials still today. We are all familiar with the main characteristics of wood as a material, it is warm, smooth and visually appealing. But what is it actually made of and what can you do with it?
In order to understand what the phenomena investigated in this thesis is based on and how it works one needs to have a basic understanding of wood as a material.

THE STRUCTURE OF WOOD

Wood is the fibrous material found in the stems, trunks, roots and branches of trees. It is a bio-polymeric composite material with a porous cellular structure consisting of three main components, cellulose, hemicellulose and lignin. (Navi and Sandberg, 2012, pp.55, 90) The composite could be compared to reinforced concrete where the cellulose and hemicellulose fibers act as the reinforcement bars and the lignin acts as the surrounding hardened concrete.

The three main components of wood:

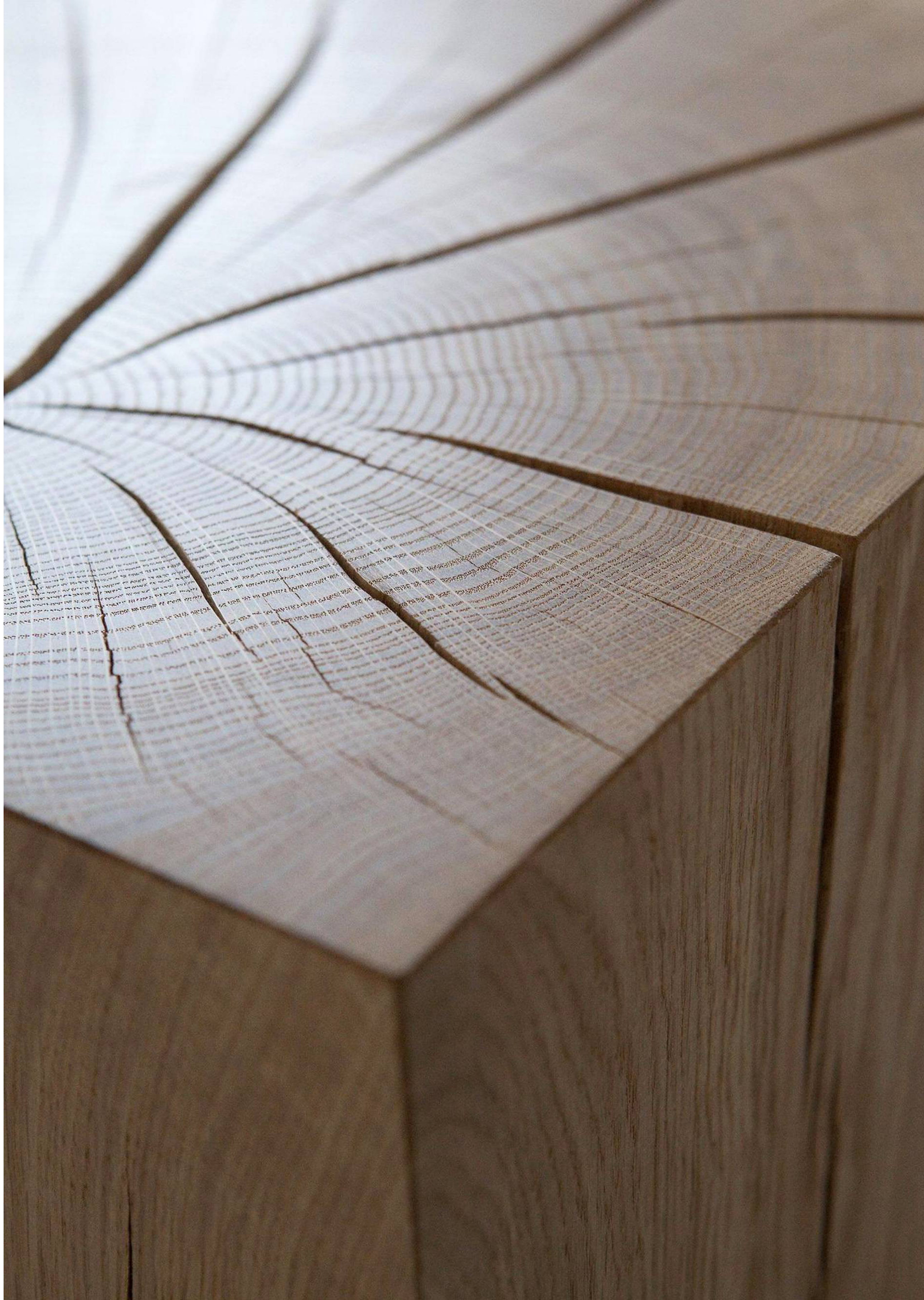
- Cellulose 45-50%
- Hemicellulose 20-25%
- Lignin 20-30%

Cellulose is an organic compound, a linear natural polymer consisting of a chain of D-glucose units that form cellulose polymers or fibers. Cellulose is the most abundant material in nature. It is found for instance in plants, algae, fungi and even some animals. In wood cellulose stands for 40-50% of the dry substance. (Navi and Sandberg, 2012, p.91)

In contrast to cellulose, hemicellulose polymers consist of a variety of sugars in addition to glucose. Hemicellulose polymers are significantly shorter than cellulose polymers and may be branched whereas cellulose polymers are not. Hemicelluloses comprise 20-25% of the dry substance in most wood species. (Navi and Sandberg, 2012, pp.90, 94)

Lignin is the next most abundant material in wood after cellulose and acts like a glue surrounding the cellulose fibers. Lignin increases the mechanical resistance of wood and allows hence certain wood species to reach heights over one hundred meters. The amount of lignin varies among wood species. In hardwoods 18-25% and in softwoods 25-35% of the dry substance is lignin. (Navi and Sandberg, 2012, p.98)

Fig. 8.



THE STRUCTURE OF A TREE

Basically all known plants have three main components: roots, stems and leaves. What separates trees from other plants is that trees have only one main stem and branches that grow out of it. Trees and all other plants grow larger by primary growth i.e. growing longer from the tips of their branches. Trees are however also capable of secondary growth i.e. increasing their diameter by adding new layers of tissue under the bark. The growth cycle varies depending on where we are on the planet. In tropical forests near the equator the growth rate is controlled by the dry and rainy seasons while in the temperate zone the growth is controlled by the seasons. In the temperate zone trees grow during the spring and summer moths and during the winter months the growth stalls. The tissue generated during the spring is called earlywood and that during the summer is called latewood. The properties and the quality of earlywood and latewood differ between softwoods and hardwoods but in general latewood is denser, harder and darker in color than earlywood. These differences are in most cases visible in the cross section of a tree trunk and are called annual rings. (Navi and Sandberg, 2012, pp.60-72)

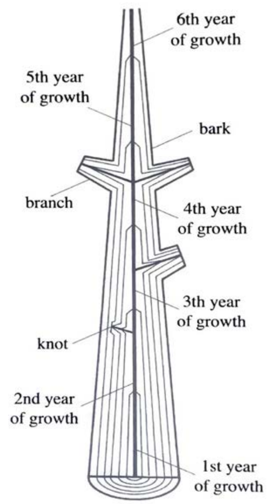


Fig. 9. Diagrammatic representation of the annual growth of a tree stem.

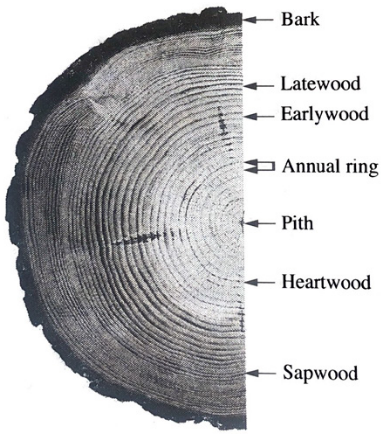


Fig. 10. The wood macrostructure visible in the cross section of Scots pine.

Fig.11. Pine tree.

CLASSIFICATION OF WOOD

Trees and wood species are generally divided into two categories, softwoods and hardwoods. The composition of softwood is more simple and uniform compared to hardwood. The terms softwood and hardwood can be misleading since they do not always accurately describe the actual hardness of the wood material. In fact some hardwoods such as aspen and balsa are softer and less dense than many softwoods. (Navi and Sandberg, 2012, p.56)

Botanically all trees belong to the botanic division spermatophytes, seed plants. Spermatophytes are further divided into gymnosperms i.e. plants with naked seeds and angiosperms, i.e. plants with covered seeds. Needle-like leaves or needles are characteristic for most softwood trees. These trees are also called evergreens since they only loose a portion of their needles during the winter and stay green all year round. Most softwoods also produce their seeds in scaly pods and are hence also called conifers. Hardwoods, also called broad-leaved trees bear broad leaves instead of needles and usually loose all of them during the cold months of the year. Hardwoods produce their seeds within different kinds of fruit bodies such as acorns and pods. (Navi and Sandberg, 2012, p.56)

Although both softwoods and hardwoods consist of the same ingredients and compounds they differ significantly in microscopic structure and material properties. Hardwoods use vessel elements or pores to transport water and nutrients in the tree while softwoods use elongated cells called tracheids.

Most softwoods have a faster growth rate and a lower density compared to hardwoods. A vast majority of all the timber in the world comes from the softwoods. Softwoods are widely used in different applications varying from paper industry to building and construction materials. Due to the fast growth rate softwoods are often significantly cheaper than hardwoods and make up the bulk of all wood used in the world.

Hardwoods on the other hand grow slower and denser than softwoods and are hence also more expensive. Due to their higher density most hardwoods are more durable than softwoods and are mainly used in high quality applications such as furniture, interiors, flooring, etc.

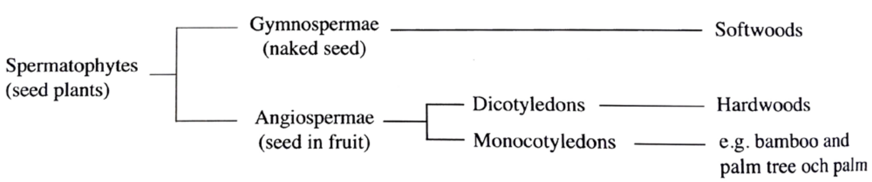


Fig. 12. Botanical classification of wood

Fig. 13. Spruce (softwood) and oak (hardwood)

WOOD SPECIES

According to a recent study there are over 60,000 known wood species today. (Beech E. et al., 2017) Of those 60,000 species only a fraction are commonly used by the wood industry. The choice of wood species has traditionally been driven by the local supply and the different properties among species. Woodworkers have strived to choose the best suited available material for the application. Globalization and global trade has changed the game to some extent during the past century. Exotic wood species are nowadays easily available around the globe which has opened up many new possibilities but also caused a lot of problems and driven some of the most desirable species close to extinction.

Fig.14.

Fig. 15.

WORKING WITH WOOD

Wood is probably the oldest material used by man. Many of the techniques and principles used today can be dated back to ancient civilizations. Even though the industrialization has made woodworking a lot easier and increased precision and production speed the basic principles of woodworking remain the same. The world around the material has changed significantly but wood as a material remains the same and still obeys the same principles as it did thousands of years ago. In the end there are basically three things you can do when working with solid wood, it can be cut, joined and bent.

CUTTING

Cutting is usually the first action when working with solid wood. Unless the tree trunk is to be used as it is in its natural state it needs to be cut in the dimensions and shapes needed for whatever is being constructed. A tree trunk can basically be cut in three different directions that give us three different sections of the trunk. These are tangential, radial and cross cut.

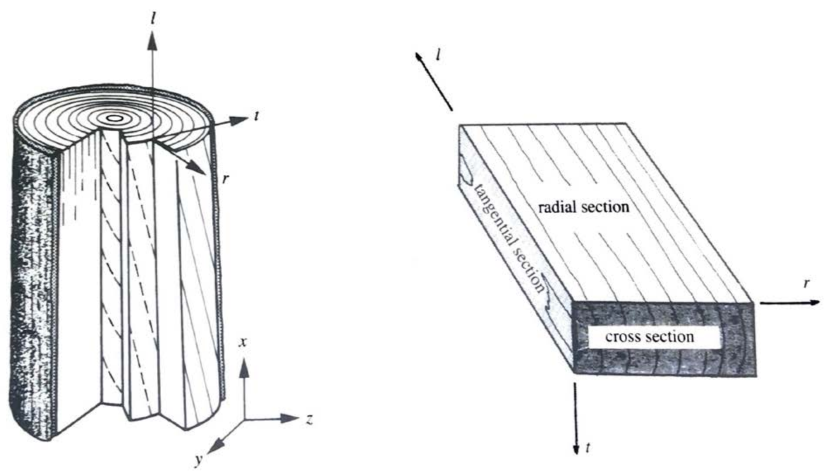


Fig.16. The three sections of a tree trunk

Cutting can be done with a variety of tools of which probably the most stereotypical would be a saw or an axe. With the help of these tools the tree trunk can be squared and cut up to the desired dimensions and shapes. The cut up pieces can then be straightened up by using different planers whereafter more advanced shapes and functions can be achieved by the use of drills and routers. Although not that evident all these tools count as cutting tools due to the cutting action they perform on wood.

JOINING

In many cases the object that is being constructed is larger than the tree trunk which means that it needs to be constructed out of several pieces joined together. Joining pieces of wood together can generally be done by two means, mechanically or by using adhesives. The most common mechanical joinery would be the use of fasteners such as screws or nails. A more sophisticated example of mechanical joinery would be the use of different self-closing joints that lock the pieces together due to their geometrical shape. Using complicated and detailed joinery is in many cultures a tradition and a way to demonstrate the skill and the precision of a craftsman.

Joining wood with adhesives is done by applying the adhesive on one or both of the surfaces that are to be joined whereafter the pieces are clamped together. There is a wide range of adhesives with different ingredients and purposes but the principle is the same for all of them.

Fig. 17. Traditional japanese joinery

Fig. 18. Application of glue

BENDING

In addition to cutting and joining, solid wood can also be bent by exposing it to moisture and heat. This technique is called steam bending or more scientifically thermo-hydro-mechanical manipulation of wood. Steam bending also dates back to ancient civilizations and has been used extensively by boatbuilders to achieve arched frames. Exposing wood for moisture and heat will liquify the lignin in the wood which will allow the piece of wood to be bent in tighter curves than it would if it was dry. After the piece is bent and cooled down it will stay in its new shape. By steam bending curved pieces of wood can be created where the grain follows the bend resulting in a stronger piece compared to a curve cut out from a straight piece of wood.

Fig.19. Steam bending at the Thonet factory

THERMO-HYDRO-MECHANICAL PROCESSING

The phenomena ivestigated in this thesis is a form of thermo-hydro-mechanical processing. Therefore let us go through the basics of thermo-hydro-mechanical (THM) processing of wood.

The structure and properties of wood allows it to be modified and manipulated by the use of temperature, moisture and mechanical force. There are numerous thermo-hydro-mechanical processing techniques that can be used for manipulating wood and for improving certain qualities of wood as a material. The basic principles of the techniques has been known and used by craftsmen for thousands of years. Some of the earliest examples of bending wood with the aid of heat and moisture dates back to northern Sweden over 5000 years ago. Ancient findings have shown that the Saami people took advantage of the phenomena for bending the tips of their skis. Other examples of the use of the technique can be found in ancient Egyptian tombs where furniture and tomb-drawings indicate the use of the technique. (Navi and Sandberg, 2012, pp.1-19)

THM processes can be divided into thermo-hydro(TH) processes and thermo-hydro-mechanical(THM) processes. TH processes are based on manipulating wood with temperature and moisture and can be used for example to release internal stress, improve stability and increase resistance against micro organisms etc. The most common industrial TH process would be the seasoning of sawn wood in kilns which is performed to the vast majority of lumber that is sold by wood suppliers. Fresh sawn planks are exposed to temperatures up to 100 degrees for a period of time to make the lumber dry faster than by traditional air drying. (Navi and Sandberg, 2012, pp.1-13)

A THM processes introduces an additional mechanical force to the process. These processes can be used to manipulate properties such as density and shape. As mentioned earlier, steam bending would probably be the oldest and most well known example of a THM process. Other examples of THM processes are densification of wood by which the density of a low density wood can be increased by mechanical compression. Wood welding is another example of a THM process which allows joining two pieces of wood by friction welding. (Navi and Sandberg, 2012, pp.1-13)

PLASTICIZATION

“The word “plastic” comes from the Greek word plastikos meaning “to form”.”(Navi and Sandberg, 2012, p. 292) Wood can be rendered plastic or semi-plastic with the help of chemicals or a THM process which allows wood to be softened and bent so that it retains its bent shape when cooled and dried. As earlier mentioned wood is a composite material consisting of cellulose, hemicellulose and lignin polymers of which lignin can be plasticized with moisture and heat. The plasticization of lignin allows the cellulose polymers to slide past each other and to be rearranged in a new shape. When the plasticized lignin cools down it crystallizes and the composite freezes into its new shape. (Navi and Sandberg, 2012, pp.216, 291-292)

SHAPE MEMORY

If the bent piece of wood, after it has cooled down, is exposed to moisture and heat again without any mechanical constraints it will generally return to its original shape due to a phenomena called “shape memory”. The reasons for the phenomena are found on the molecular level. In the process of plasticization of wood only part of the composite, lignin, gets plasticized. The cellulose polymers are almost unaffected by the moisture and heat and allow to be displaced and bent to a certain extent due to their elastic properties. Cooling down the composite freezes the lignin and locks the cellulose fibers to their new shape. However, once the composite is humidified and heated up again it will almost completely recover to its original shape due to the elastic energy stored in the fibers. (Navi and Sandberg, 2012, p.216)

EXPERI- MENTS

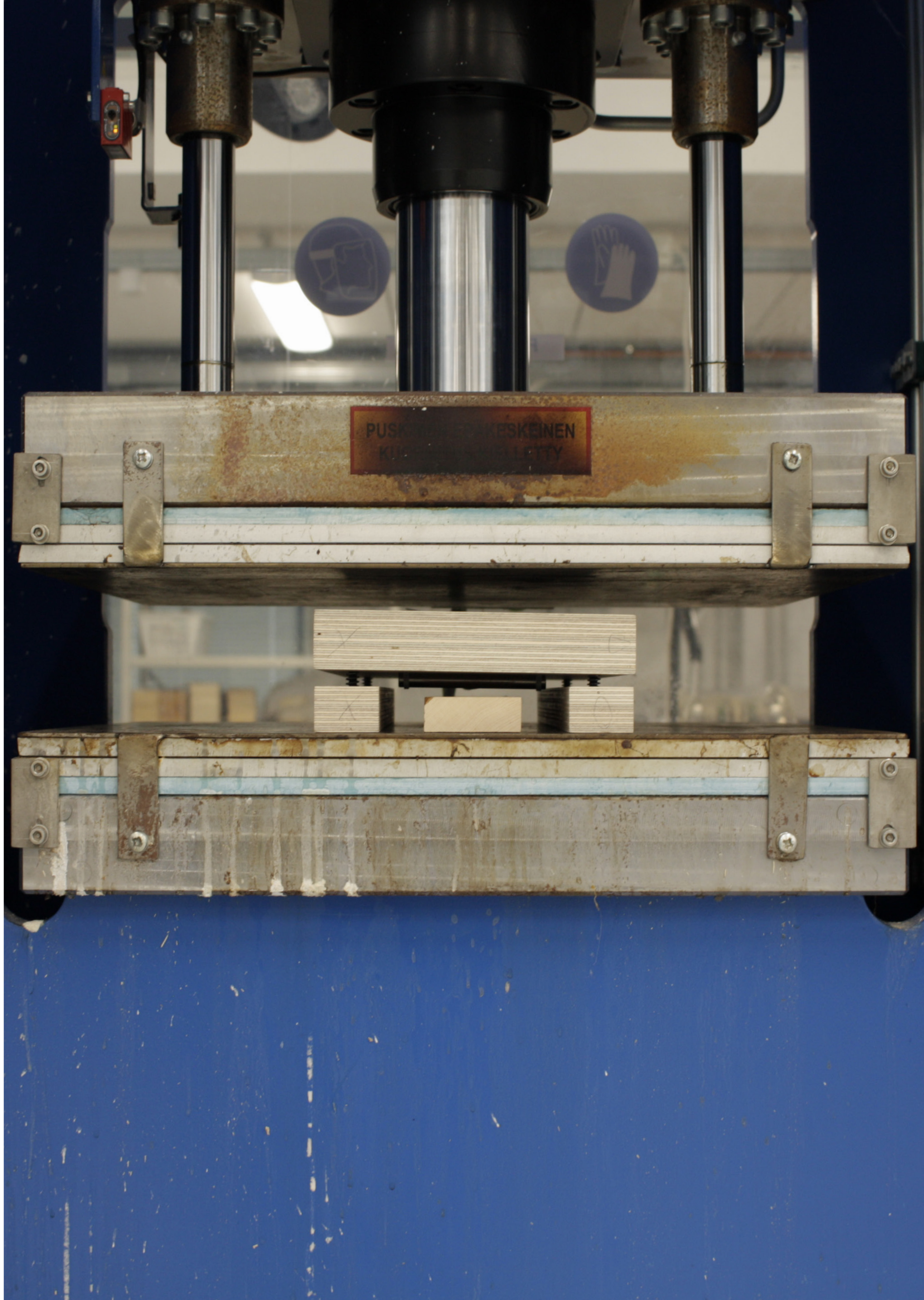
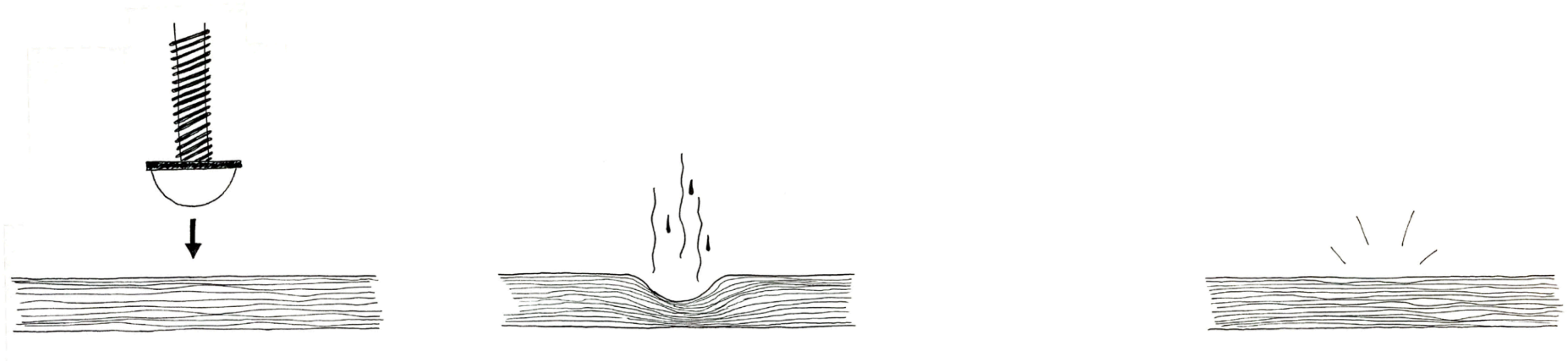


Fig.20.

THE PHENOMENA

The phenomena that is being investigated in this thesis is an old carpentry trick used to repair indents in wooden surfaces. The trick is commonly known among woodworkers and used widely in different disciplines. The phenomena works as follows.



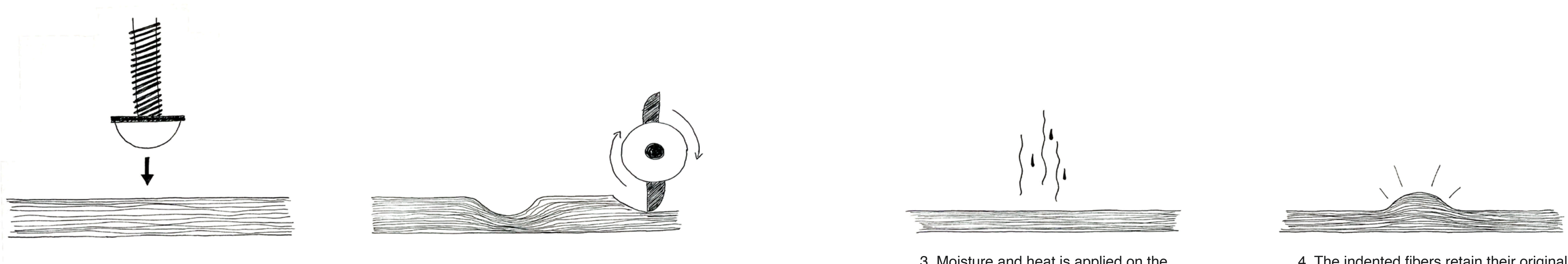
1. A wooden surface gets hit by something. An indent is created, i.e. the fibers get bent.

2. Moisture and heat is applied on the indent.

3. The indent swells up again, i.e. the bent fibers recover to their original shape.

Fig.21.

The plan is to use this phenomena for creating embossments on the wood surface by planing the surface before applying moisture and heat. By doing so, the moisture and heat will make the wood fibers swell back up again creating an embossment.



1. An indent is created with a tool.

2. The surface is planed until the indent disappears.

3. Moisture and heat is applied on the indented area.

4. The indented fibers retain their original shape creating an embossment.

Fig.22.

GOALS AND LIMITATIONS

The goal set for the experiments is to develop a recipe for the technique that gives the most favorable outcomes. Favorable in this context means biggest and nicest embossments. To get started I have set up an experiment that will hopefully point me in the right direction in regards of wood species and the shape and size of embossment.

The range of wood species included in these tests will be limited to the most common species used by the wood industry in Northern Europe. The goal is to find one or several species that respond well to the technique. It might be that some rare wood species would be more suitable for the technique than the more common ones that can be found at local wood suppliers but from an industrial perspective it makes more sense to stick to species that can easily be obtained from local suppliers. The species included in these tests are the following:

- Alder
- Ash
- Aspen
- Beech
- Birch
- Elm
- Goat willow
- Larch
- Linden
- Maple
- Mountain ash
- Oak
- Pine
- Spruce

Fig.23. Samples of different wood species for the experiments.

SETUP

The experiment will be conducted using a hydraulic press and a pressing tool with three different sizes of spheres and one cylindrical profile. The shapes will be pressed down to the same depth on each of the wood species using a hydraulic press. After pressing, the indented surfaces will be planed down and thereafter steamed in a steam box for 10min to make the embossments rise up. After the whole process the resulting embossments will be evaluated on the basis of height and cleanliness of the embossments as well as the ease of pressing. The tests will be conducted on both dry and pre-steamed wood and on both radial and tangential faces of each species. Pre-steaming means that the samples are steamed for 30 minutes prior to pressing the indents. The aim with the experiment is to answer the following questions:

- Which wood species respond best to the method?
- Is there a difference in the size and shape of the indent?
- Is there a difference in grain orientation, tangential or radial?
- Does steaming the wood before pressing make a difference?

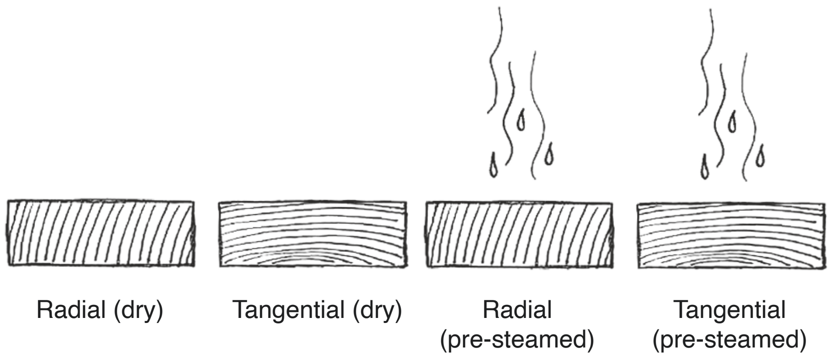


Fig.24.

Fig.25. Pressing tool with three different sized spheres and one cylindrical profile

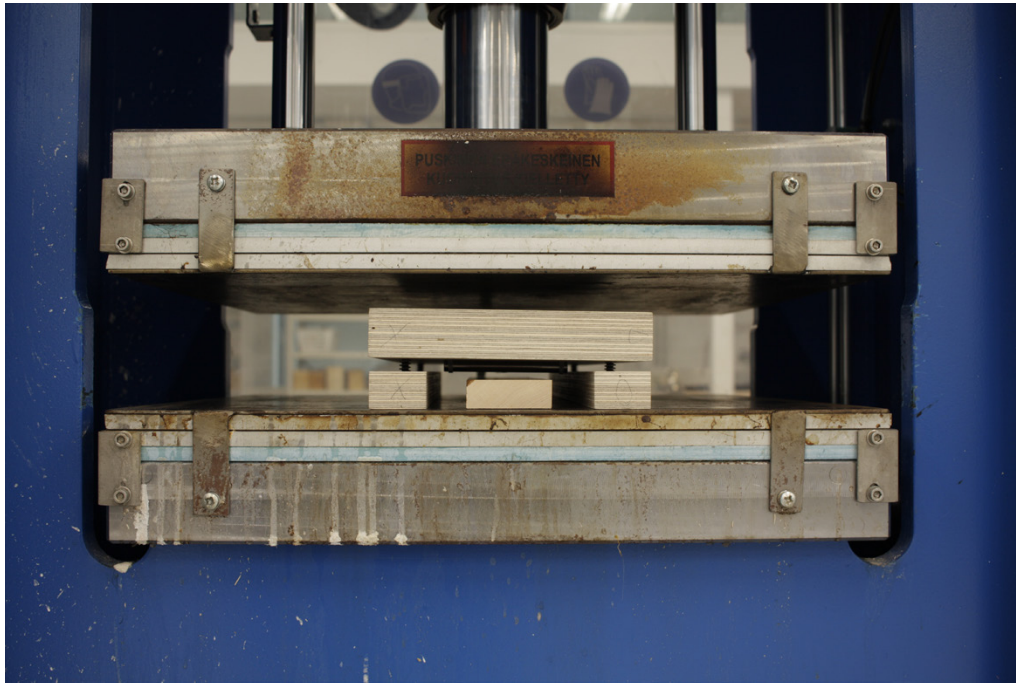


Fig.26. Pressing tool inside the hydraulic press

Fig.27. Test pieces inside the steam box

EVALUATION

The test results of the experiments are evaluated on the following premisses:

Height

How high is the embossment?

1= low, 5= high

Cleanliness

How clean is the embossment? Does the wood crack or get any other defects?

1= a lot of defects, 5= clean

Pressing force

How much force is needed to press the indent. A wood that presses easily is more attractive than a wood that needs a lot of force. A wood that needs a lot of force might be a problem when developing further embossment machinery.

1= requires a lot of force, 5= does not require a lot of force

Ideal

The ideal wood species would have the following characteristics: It would be relatively hard and dense but still easy to press. The embossments would be high and clean and the grain pattern would be calm and even making the embossments easy to distinguish.

ROUND I

The first round of experiments will be conducted on four samples of each wood species. Dry and pre-steamed samples with both radial and tangential grain orientations. The depth of indent will be set to 2mm.

SETUP

Depth of indent:	2mm
Species:	Alder, Ash, Aspen, Beech, Birch, Elm, Goat willow, Larch, Linden, Maple, Mountain ash, Oak, Pine, Spruce
Orientation:	Radial(dry), Tangential(dry), Radial(steamed), Tangential(steamed)

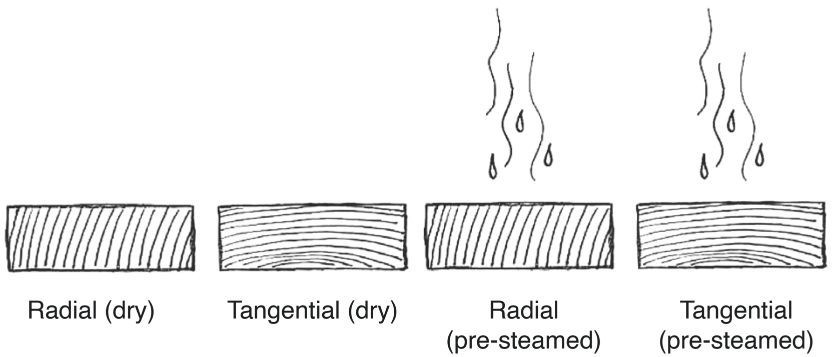


Fig.28.

Fig.29. Linden samples after the press

OBSERVATIONS ON ROUND I

- Pressing the indents in a steamed piece of wood requires significantly less force compared to a dry one. The perimeter of the indent on the steamed pieces is more soft and round. The fibers seem to start bending already outside of the actual indent.
- Less cracking occurs in steamed pieces.
- Smaller radius indents are more prone to cracking fibers than larger ones.
- There seems not to be any significant difference between tangential and radial faces.
- Steaming seems not to affect the height of the embossment, only the sharpness and cleanliness of it.

The embossments resulting from the first pressing round turned out too shallow for an objective comparison, and hence I have decided not to validate them. The contrast of the results needs to be increased so that the differences become more evident. This can be done by increasing the depth of indent when pressing which will make the results easier to compare.

Fig.30. Linden samples after planing and steaming

ROUND II

Since the first round of experiments did not give clear enough results for a proper evaluation of the tested species I have decided to double the depth of indent and repeat the experiment. Since steaming did not have a significant effect on the height of the embossment in the previous test I am going to conduct this round of the experiments only on dry pieces and focus on the differences between species and tangential and radial cuts.

SETUP

Depth of indent:	4mm
Species:	Alder, Ash, Aspen, Beech, Birch, Elm, Goat willow, Larch, Linden, Maple, Mountain ash, Oak, Pine, Spruce
Orientation:	Radial(dry), Tangential(dry)

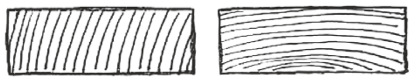
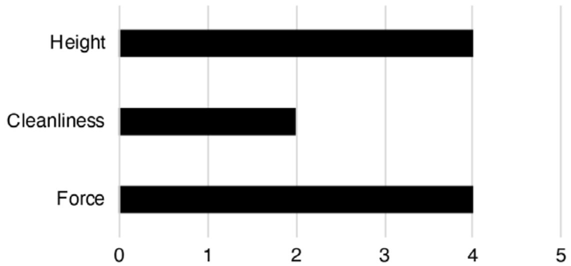


Fig.31.

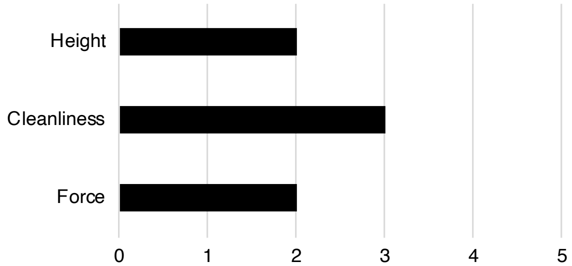
Radial (dry) Tangential (dry)

Fig.32. Alder samples after the press

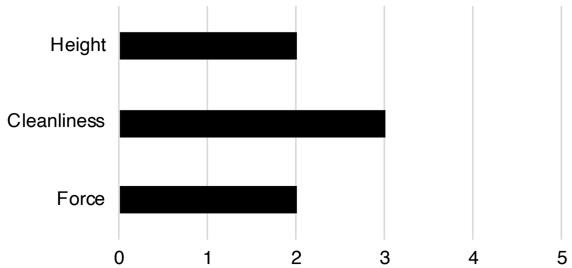
Pine and spruce
Relatively high embossments, easy to press but the embossments are not that clean and pretty. A lot of cracked fibers and height differences in early and late wood. Easily sourceable. Embossments are hard to distinguish due to grain pattern.



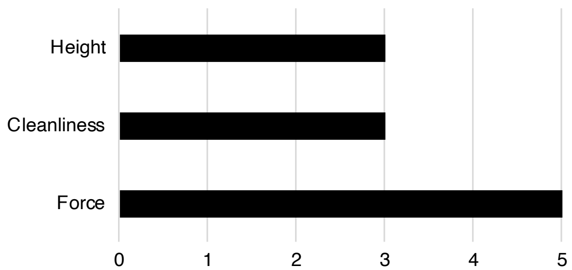
Larch
Quite low embossments, very hard to press, medium clean embossments. Not that much cracked fibers but clear height differences between early and late wood. Easily sourceable. Embossments are hard to distinguish due to grain pattern.



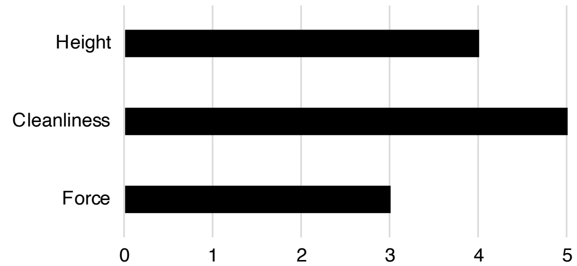
Elm, Ash and Oak
Medium high embossments, very hard to press, medium clean embossments, some cracked fibers but not as much as pine and spruce. Easily sourceable. Embossments are hard to distinguish due to grain pattern.



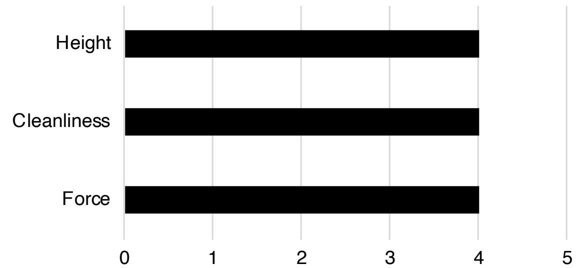
Goat Willow
Medium high embossments, very easy to press, not that clean embossments. Relatively much cracked fibers and hairiness. Hard to resource.



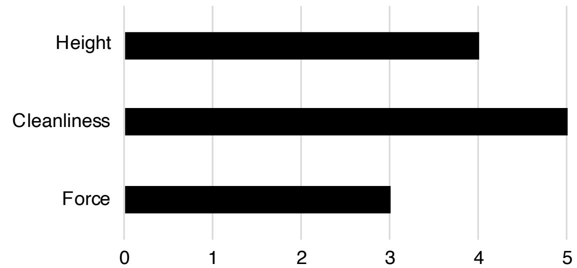
Mountain ash
Relatively high and clean embossments, relatively hard to press. Hard to resource. Embossments are hard to distinguish due to grain pattern.



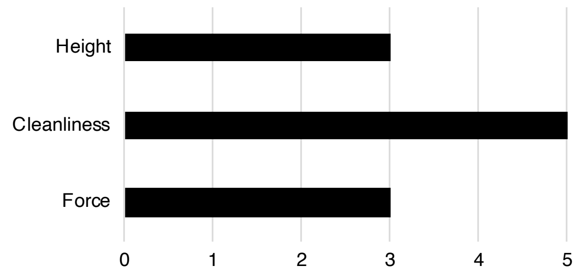
Birch
Relatively high and clean embossments, medium hard to press, almost no cracked fibers. Easily sourceable.



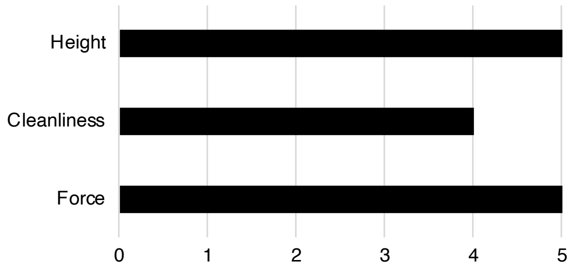
Maple
Relatively high and clean embossments, hard to press, some cracked fibers. Easily sourceable.



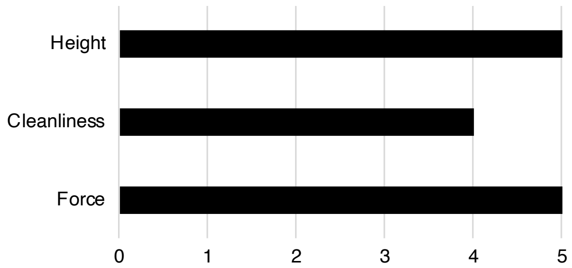
Beech
Relatively high and clean embossments, hard to press, some cracked fibers. Easily sourceable.



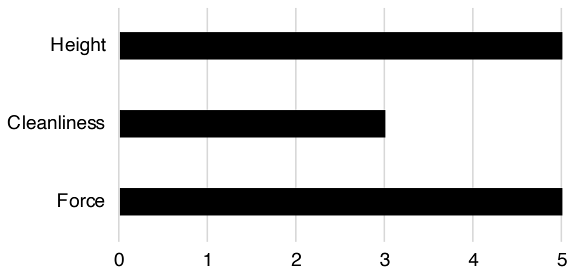
Linden
Very high and medium clean embossments, easy to press, some cracked fibers. Easily sourceable.



Alder
Very high and medium clean embossments, easy to press, some cracked fibers. Easily sourceable.



Aspen
Very high and medium clean embossments, easy to press, some cracked fibers. Easily sourceable.



OBSERVATIONS ON ROUND II

- The embossments are clearly higher and clearer on this round but the differences are still quite subtle.
- There is no significant coherent difference between the radial and tangential cuts. Tangential surfaces tend however to give a little bit cleaner results than radial surfaces.
- Some differeneces between species start to occur.

Fig.33. Alder samples after planing and steaming

ROUND III

Based on the results of the previous experiment I have decided to go further with the following six species: Aspen, Alder, Linden, Beech, Maple and Birch. These species gave the most promising results and will hence be tested further both dry and steamed and with deeper indents. Since the tangential surfaces performed slightly better in the previous round I have chosen to test only tangential surfaces in this round of tests. The goal is to find out how deep you can go and whether steaming before the pressing makes a difference.

SETUP

Depth of indent:	6mm
Species:	Alder, Aspen, Beech, Birch, Linden, Maple
Orientation:	Tangential(dry), Tangential(steamed)

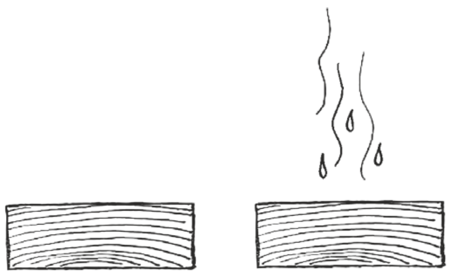
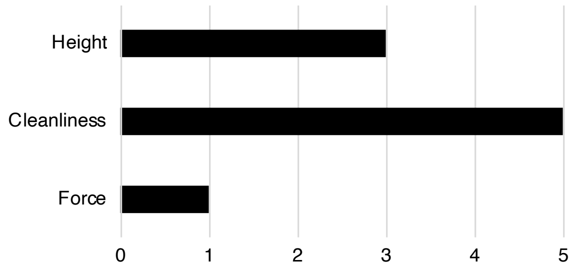


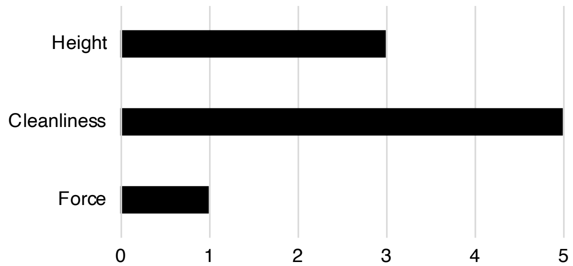
Fig.34.

Fig.35. Beech samples after the press

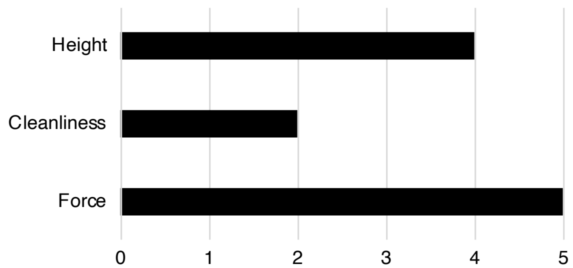
Beech
Very clean but not that high embossments. No cracks and no hairiness. Hard to press.The homogenous grain pattern makes the embossments easily distinguishable.



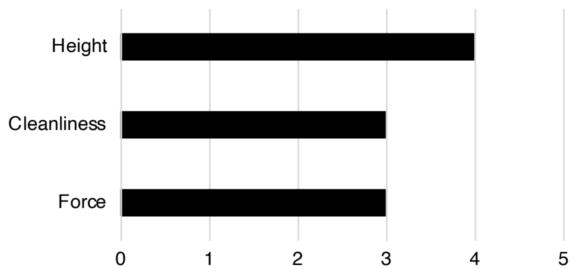
Maple
Very clean but not that high embossments. No cracks and no hairiness. Hard to press. Grain pattern is a bit more lively than on beech.



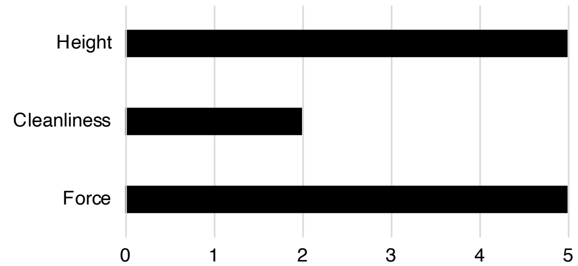
Aspen
Medium high embossments. Some cracks and hairiness. Easy to press.



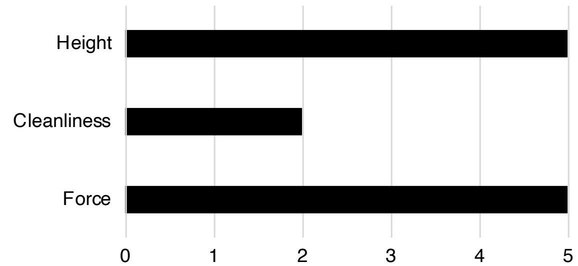
Birch
Medium high embossments. Some cracks and chip offs. Moderately easy to press.



Alder
Very high embossments but quite a lot of cracks. Easy to press.



Linden
Very high embossments but quite a lot of cracks. Easy to press.



OBSERVATIONS ON ROUND III

- With this deep indents the pressing force becomes more evident, maple and beech were really testing the limits of my pressing tool and did eventually not press all the way.
- Steaming before pressing does make a significant difference, pressing is a lot easier and the embossment shows less cracking. The drawback is however that the embossings are less sharp and less distinctive than on the dry pressed pieces. Steaming before the pressing is also a bit more challenging from an industrial point of view.

So far, on basis of the results it seems that there are several species that have potential for this treatment. As in many other applications of wood different species seem to have different properties and give different results. Birch does not seem to give that impressive results. The embossments are medium high and a bit hairy and cracky. The same goes for aspen. Alder and linden give the highest embossments and are very easy to press which makes them attractive. They do however also show some cracking. Maple and Beech give the smoothest and nicest embossments but they remain significantly lower than the aforementioned species and are also very hard to press. Beech is maybe visually most appealing due to its calm and homogenous grain. Beech would be the optimal candidate if only the embossments were higher and the pressing easier. Thats why I will try to increase the height of the embossments on beech by applying more force in the coming experiments.

At the same time it is maybe time to realize that there is probably not going to be a candidate that would be superior in every aspect. There is probably a handful of species that respond well to the treatment and have some differing properties. Then it is just a matter of choosing one or a few of them to go forward with. It all eventually comes down to the end application. What is it going to be used for? Which qualities are the most important, height or aesthetics?

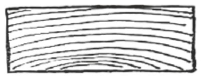
Fig.36. Beech samples after planing and steaming

ROUND IV

As mentioned earlier, in the last round of tests, maple and beech were the most promising candidates if only the embossments were a bit higher. Hence the goal for this round of experiments will be to try to create as high embossments as possible on maple and beech. These tests will be conducted less systematically than the previous ones using a new set of different sized cylindrical and spherical pressing tools.

SETUP

Depth of indent:	As deep as possible
Species:	Beech, Maple
Orientation:	Tangential(dry)



Tangential (dry)

Fig.37.

Fig.38. Beech sample after the press

OBSERVATIONS ON ROUND IV

- High embossments are doable also on maple and beech. The pressing force required is however manifold compared to the other species tested earlier. Some of the pressing tools also broke under the immense pressure. The resulting embossments are however high and relatively clean.

CONCLUSION

The results of these experiments show that relatively high embossments are possible to produce also on beech and maple, they just require somewhat higher pressure when pressing the indents. The embossments are high and clean and show least cracks and hairiness among all the tested wood species. Judging only by visual aspects makes maple and beech the winners of these experiments. However, as stated before, the optimal choice of wood species for the treatment depends on the end application. All wood species have different properties which make them suitable for different applications. Maple and beech might be well suited for furniture production for instance but due to their relatively high density, weight and price, using them for constructing large wooden building elements for instance would be hard to justify.

Even though maple and beech showed the most promising results there were a few other species, such as alder and aspen that performed decently as well. These species might have other properties that make them more suitable for the end application than the official winners of the test. Therefore the next step in the process will be to start developing ideas for the application of the treatment.

Fig.39. Beech sample after planing and steaming

APPLI-
CATION

What could this treatment be used for in the interior and furniture industry? In my opinion the technique shows potential in two different areas of applications. The swelling effect could be used in joinery or for creating embossed surfaces.

Fig.40.

JOINERY

The phenomena could potentially be used in a wooden joint where the application of steam would make one of the components swell and fix the components together permanently. This technique could be used in various different applications, for instance a series of flat pack furniture that are assembled without any glue or fixtures, only steam.

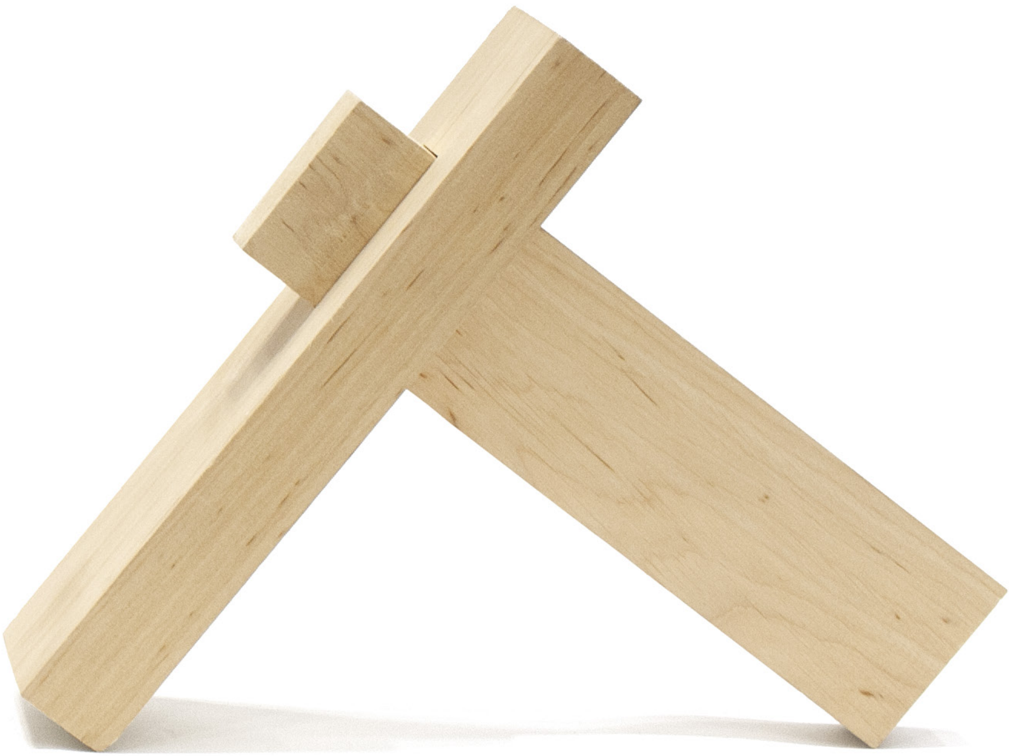


Fig.41.

COMPRESSION AND EXPANSION IN JOINERY

Taking advantage of swelling or expanding components in joinery is not a new idea. The phenomena has been used for thousands of years for instance in boat building and carpentry. Wooden boats have traditionally been made watertight by soaking them in water and letting the boards swell tightly together. Expansion and shrinkage has also been used in the metal industry where expansion occurs due to changes in temperature instead of moisture. Before going further with the experiments let us take a look at a few contemporary applications of swelling in wooden joinery.

Fig.42. Wooden boats are made watertight by letting the seams swell together in water.

DOWELS AND BISCUITS

Wooden dowels and biscuits are probably the most common application of this phenomena. The surface of dowels and biscuits is compressed in the manufacturing process. When the dowels are inserted in a hole with water based glue they suck up the moisture from the glue and expand resulting in a very tight fit. Even though the moisture expansion plays a central role in making the join tight, the element joining the two pieces together is still the glue.

Fig.43. Wooden dowels

KIGOROSHI

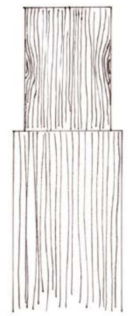
Kigoroshi is a Japanese woodworking technique used for creating very tight fits in wooden joinery. In a mortise and tenon type of joint the tenon is made slightly too big for the mortise and then compressed by hitting it with a round end hammer until it fits the mortise. Before assembling, the tenon is moistured with water which will then cause the tenon to expand inside the mortise creating a very tight fit. As with the dowels, kigoroshi in itself will not fix the pieces together permanently. The join still needs to be locked with glue, dowels, wedges etc.

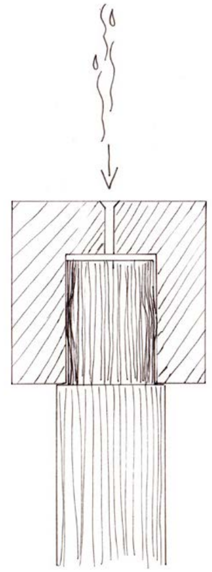
Fig.44. Kigoroshi used in a halving joint

JOINERY TESTS

In order to test the idea I have designed a few different types of basic wooden joints where steam works as the bonding agent. The tests will be conducted in both alder and beech in order to see if the choice of wood species makes a difference.

JOINT#1
Basic mortise and tenon joint with pressed indents on both sides of the tenon.





1. Indents are pressed on both sides of the tenon blank.

2. Tenon blank with indents on two sides.

3. The tenon is cut to size and the indents disappear.

4. The joint is assembled whereafter steam is injected in to the joint through a hole.The indented fibers on the tenon retain their original shape and lock the two pieces together.

Fig.45.

Verdict
Did not work. Steaming the joint made it a little bit tighter but not significantly, the joint was relatively easy to pull apart afterwards. It seems that since the joint is quite tight already from the start the force of the swelling fibers is not enough to push against the walls of the mortise. The walls of the mortise are keeping the bent fibers down and the force of the swelling fibers is not enough to counteract that force. Maybe if there was empty space inside of the mortise in to which the bent fibers could expand?

Fig.46.

JOINT#2
Through mortise and tenon with pressed indents on both sides of the tenon.

1. Indents are pressed on both sides of the tenon blank.

2. Tenon blank with indents on two sides.

3. The tenon is cut to size and the indents disappear.

4. The joint is assembled whereafter steam is applied on to the indents on the tenon. The indented fibers retain their original shape and lock the two pieces together.

Fig.47.

Verdict
This joint worked a lot better than the previous one. After steaming the joint felt incredibly strong, it did not move in any direction no matter how much force you applied to it. After letting it dry for a few days however it started to loosen up. There is no chance that the tenon would come out but there is a millimeter play in the joint.

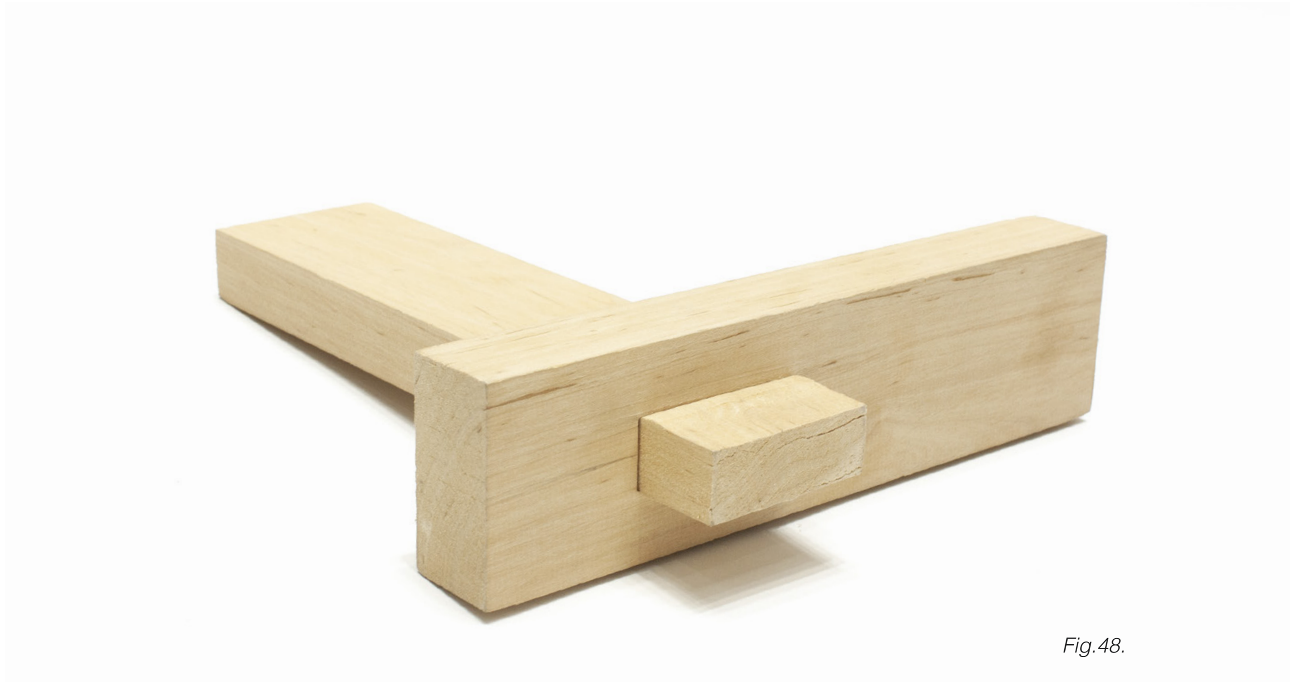


Fig.48.

JOINT#3
Dovetail mortise and tenon with pressed indents on both sides of the tenon.

1. Indents are pressed on both sides of the tenon blank.

2. Tenon blank with indents on two sides.

3. The tenon is cut to size and the indents disappear.

4. The joint is assembled whereafter steam is injected in to the joint through a hole.The indented fibers on the tenon retain their original shape and lock the two

Fig.49.

Verdict
This joint worked pretty much just like the previous one. Very promising directly after steaming but as it dries it starts to loosen up. As with the previous joint the tenon is definitely stuck and does not come out but there is a millimetetr or two of play.

Fig.50.

CONCLUSION

The results of the experiments show that using steam as the bonding agent in wooden joinery does not work as well as I was hoping for. Some of the joints show a tiny bit of potential in the sense that the pieces get locked inside each other although there is a significant amount of play in the joint. Compression and expansion of wood is definitely something that can be and is being taken advantage of in joinery. However, the idea of permanently fixing two pieces of wood together using only steam and moisture expansion is probably too optimistic. The idea could probably be developed further and maybe some additional elements or factors could be introduced to create a joinery method where steam would be one of the bonding agents. In the context of this thesis project however I feel that such experiments go too far outside of the line of study and I have hence decided to continue exploring the possibilities the technique has to offer in creating embossed surfaces.

Fig.51.

SURFACE

The second option for the technique would be to apply it on a surface. The technique could be used to create visually interesting and tactile surfaces. The surface could maybe even have an added function such as friction due to its three-dimensional texture. The scale of the surface could be anything from small handheld objects to sheet material or wall panels.

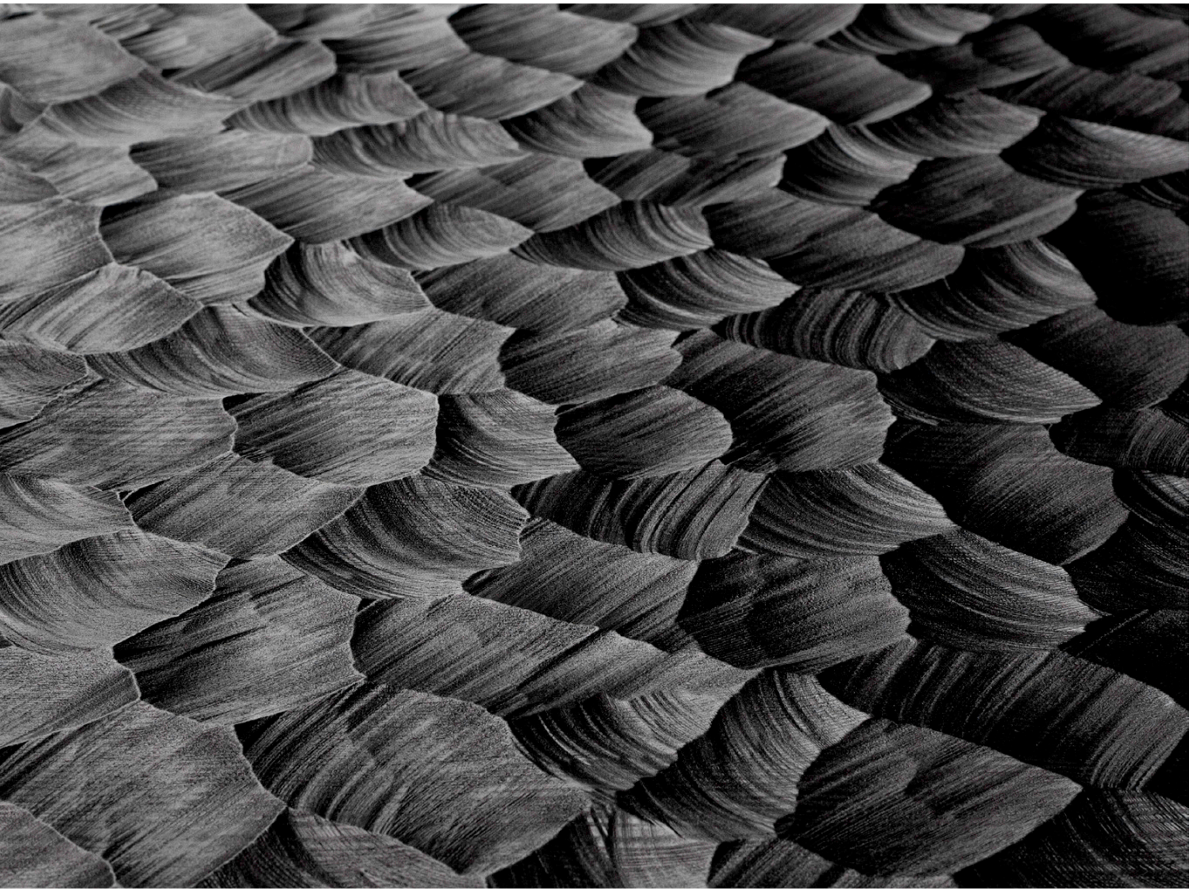


Fig.52. The delicate surface of "Havet" cabinet by Snickeriet

TEXTURED SURFACES

Before going further with the experiments let us take a look at what is on the market today. Texturized surfaces in itself is nothing new. Surfaces with synthetic textures can be found in a variety of materials and with many different functions. The function of a texturized surface might just be purely its visual expression or its tactile qualities but it might also be more technical such as acoustic properties or friction. There are many ways to create textures on wooden surfaces of which the following ones are the most common.

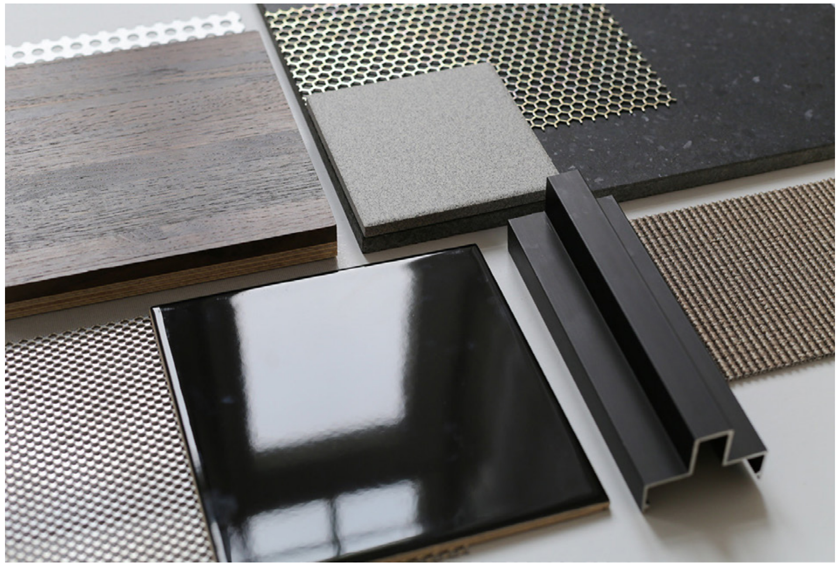


Fig.53. Material samples with different surface textures

CARVING
The most traditional and simple way to texturize a surface would probably be carving. Carving is a method of shaping or sculpting something by removing material with different tools such as chisels. This method has been used for thousands of years for sculpting different patterns or motifs in to wood and is still in use today. Hand carving is often seen as a traditional craft that you would be more likely to find in a souvenir shop rather than in contemporary design which is partially true at least in Northern Europe. Carving is primarily a handcraft and is hence quite laborious and therefore usually also expensive. Hence, hand carved objects from our part of the world usually tend to be luxurious and of artistic nature. Part of the charm with hand carving is the variation in the end result caused by the human factor. No matter how well trained and accurate a craftsman is, hand carved products will never be completely identical.

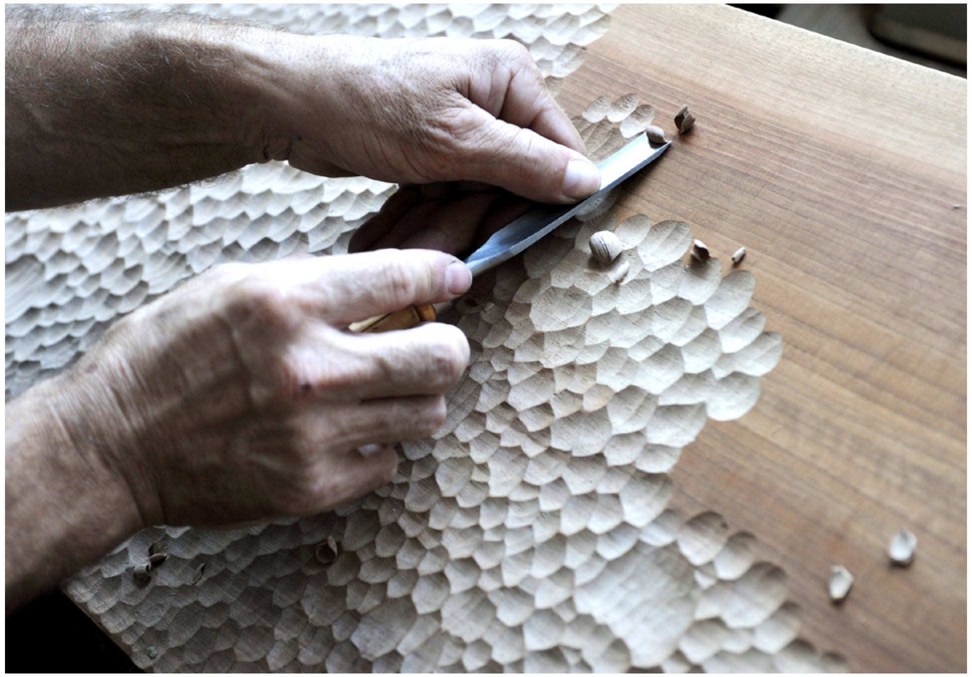


Fig.54. Hand carving

CNC-MILLING
The modern alternative to hand carving would be CNC-milling. A CNC (Computer Numerical Control) milling machine is basically a router that is controlled by a computer. CNC-routing allows accurate and effortless milling of almost anything. The machinery itself is usually quite expensive when compared to conventional machines and demands some knowledge and knowhow about 3D-modeling and manufacturing. But when everything is modelled and set up, the machine will continue milling identical patterns or components until it is told to stop. In series production CNC-milling becomes very handy and efficient when producing large quantities of complex components.

The variations and the vividity that are characteristic for hand carved surfaces are however aspects that don’t come naturally to numerically controlled machines. These qualities can although also be replicated for instance by incorporating the variations already in the 3D-models or by using algorythms that randomize the milling process.

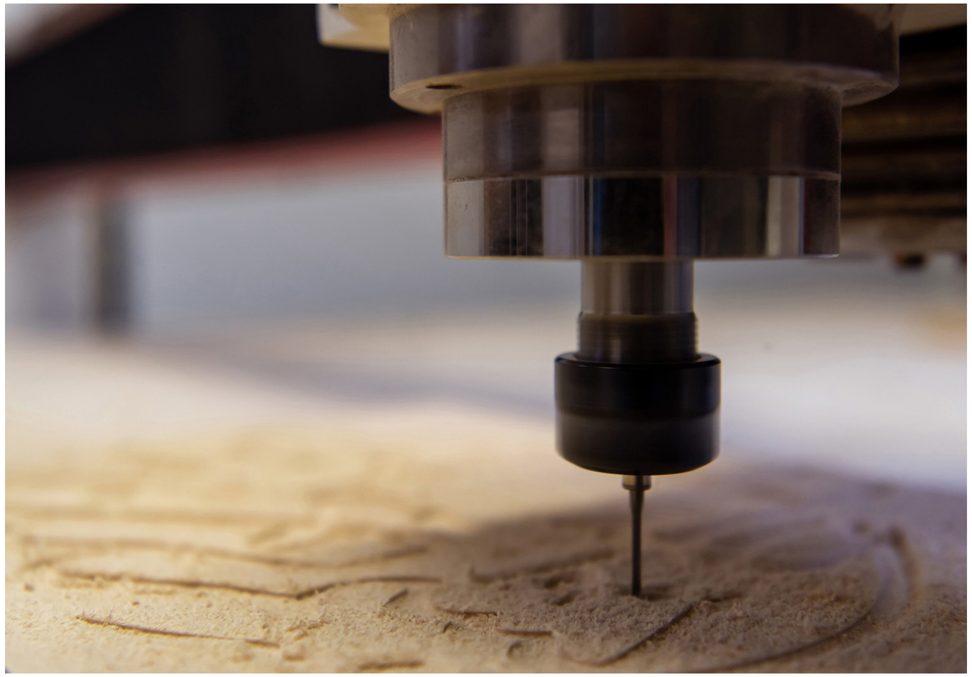


Fig.55. CNC-milling

EMBOSSING
Embossing is another more industrial method for creating textures on a wooden surface. The technique works by pressing either a raised or recessed relief image in a material such as paper, leather, metal or wood. The pressing can be done with different kinds of pressing tools depending on the scale. In the industry big cylindrical presses are used for pressing a continuous pattern on long boards or sheets. This method is used for instance in the interior industry in China to make a cheaper material such as pine wood or MDF-board to appear as something more expensive such as ash wood by pressing the distinctive grain pattern of ash on to the boards and then painting them.

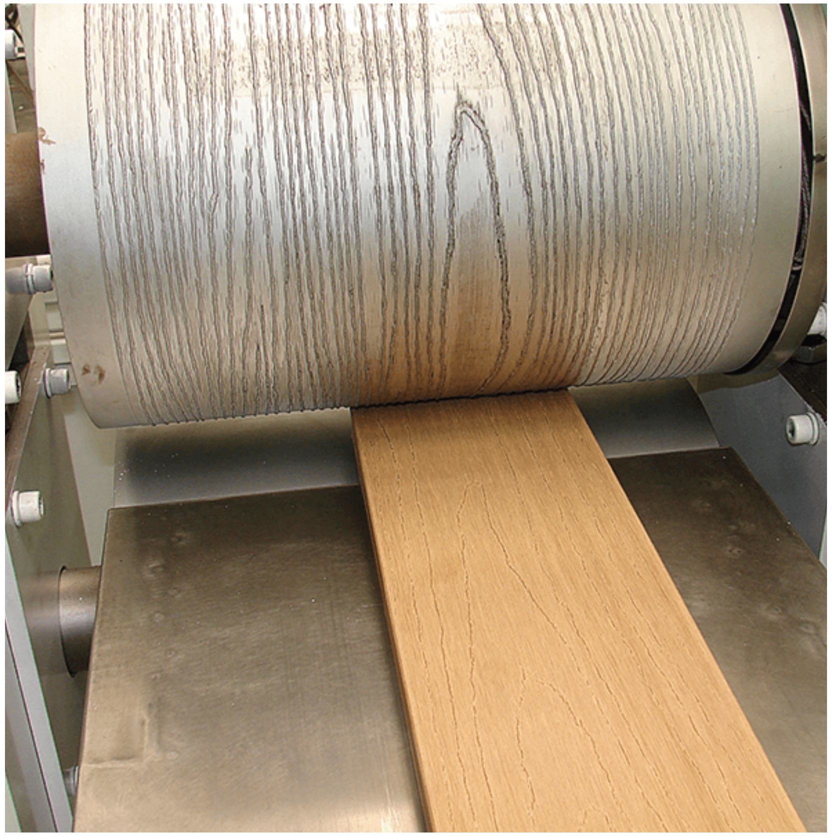


Fig.56. Wood grain pattern embossing machine

Fig.57. Embossing on paper

SHAPE EXPERIMENTS

To get started with exploring the possibilities of the surface textures I conducted a series of random shape experiments. The goal with the experiments was to find out what kind of shapes and patterns are possible to do and furthermore, what kind of shapes give the best results, which in the context of these experiments would mean clean and high embossments without any cracks or other flaws. To do this I utilized a hydraulic press and a variety of different sized and shaped metal profiles, spheres, cylinders, squares, etc. Even though beech and maple won the initial tests these random experiments were also conducted on other promising species such as alder, aspen and linden just to make sure we do not miss anything.

Fig.58. Metal profiles used to test different shapes for the embossments

Fig.59. Results of the shape experiments

Despite of the random and not so scientific nature of the experiments the results pretty soon showed which direction to go to. The radius of the shapes seemed to have a significant effect on the cleanliness of the embossment. The tighter the radius, the more fibers are going to brake. That means that the shapes need to be somewhat modest and subtle, tight curves and sharp edges are not possible to do.

3D-PRINTING

The random shape experiments laid a good foundation to continue exploring the different possibilities. The results helped narrow down the range of possibilities a bit and gave an idea of what types of shapes might work. In order to speed things up and explore shapes and textures more freely I took advantage of the 3D print lab. Utilizing 3D-printing for manufacturing the pressing tools opened up a whole new world of possibilities. Not only did 3D-printing make the manufacturing of the pressing tools faster but it also made it possible to produce basically any shape or form that can be drawn in 3D with no effort.

The numerous tests conducted with 3D-printed patterns helped me to further understand what kinds of patterns give the best results. The experiments showed that the shapes need to be large and shallow enough. Small shapes with tight radiuses tend to crack the fibers and do not give that nice results. The intensity of the pattern also seems to have a limit, if the compressed surface area is too big it will result in the whole piece of wood to compress instead of just the peaks of the pattern. Same goes for the depth of the indents, pressing the indents too deep will result in an increased amount of cracks and ultimately compressing the piece of wood over its limits.

However, with the right parameters the embossments started to turn out quite nicely. When the depth, intensity and shape are in the right balance the results are quite promising.

Fig.60. 3D-printed pressing tools

Fig.61. Embossed patterns made with 3D-printed pressing tools

The results of the 3D-printed pattern experiments also show that there is probably not a pattern or shape that would be superior to all others. Instead, there are certain boundaries set by the parameters mentioned earlier that define what can be done. Since the main functions of these surfaces are mainly aesthetics and tactility, in the end it comes down to personal preference to decide which pattern does the job best.

The exploration of different patterns and shapes could be continued for years and could be a whole project on its own. In the context of this thesis project however I have decided to choose one pattern that in my opinion performs best and continue the journey with that. The pattern that has given the most promising results so far in my opinion is the oblong seed shape pattern depicted to the right.

Finding the right parameters for the pattern also increased the quality of the embossments on other species than the ones that performed best in the initial tests. Previous experiments gave best results on beech and maple but now with the right parameters the results on alder and linden are almost equal to maple and beech.

Fig.62. Embossed pattern made with 3D-printed pressing tool

CYLINDRICAL PRESS

From the very beginning of this project I have had an ambition to utilize a cylindrical press for pressing the patterns on wood. A cylindrical press would allow fast, continuous and efficient pressing of the pattern which would open up new possibilities for the application of the technique. If the pattern can be pressed efficiently and effortlessly on long boards, that would allow larger surfaces such as walls, floors or even facades to be covered with the embossed pattern. Cylindrical pressing would take the technique to an industrial level.

1. A continuous pattern is pressed on a board with a cylindircal pressing tool

2. The surface of the board is planed until the indented pattern disappears

3. Moisture and heat is applied on the patterned surface

4. The indented fibers retain their original shape creating an embossed pattern

Fig.63.

Luckily, the Aalto ARTS jewelry workshop had an old cylindrical press that they let me use for this project. Re-building the cylindrical press to meet my needs was an interesting but time consuming process. A crash course in machine building through the method of trial and error. With some help of the masters at the metal shop we finally managed to modify the press to a point where it performed as planned. In simple terms the idea was to replace the top roll of the cylindrical press with a patterned one. Fairly simple in theory but surprisingly laborious in reality. 3D-printing also played a central role in developing and prototyping the cylindrical pressing tool but the final version was however manufactured in polyacetal (POM) since the 3D-printed tools could not withstand the pressure and ended up cracking. After a bunch of tests and re-modifications the press started to roll out clean, nice, straight boards with the indented pattern on them.

Fig.64. Cylindrical press

Fig.65. The development of the patterned pressing tool for the cylindircal press. From left to right, 1.-4. 3D-printed PLA, 5. CNC-milled nylon(PA), 6. CNC-milled POM.

DEMON- STRATION

Fig.66.

The goal set for this thesis project was to come up with a recipe for the technique and find an application for it in the furniture or interior industry. Now with the cylindrical press rolling out embossed boards with a quality that I feel satisfied with, I think it is time for the next step. The technique could surely be developed and improved much further but within the context of this thesis project I think the results are on such a level that we can start looking for applications for it. As mentioned earlier the embossed surface has two main functions, its visual appeal and tactility. In addition to the functions and the properties of the patterned surface what makes it interesting is the way it is produced. The conventional way to produce similar patterns on a solid wood surface would be to mill it with a CNC router. What makes this technique interesting is the ease of creating these patterns opposed to milling. In small scale it does not make a huge difference but on a larger industrial scale it might. Routing one board on the CNC is not a big deal but routing all the claddings for a whole interior sounds time consuming and expensive. With a production line set up for rolling, planing and steaming the embossed patterns would increase the production efficiency of such boards significantly.

In order to demonstrate the potential of the technique my aim is to create a selection of objects that demonstrate the different qualities and functions of the surface. To do that I'm planing to do objects of different scale and with different functions. The two main functions that the embossed surface has are its visual appeal and its tactile qualities. The visual properties are best exhibited applied on a surface such as a cabinet door or a wall. Even though the function stays more or less the same when applied on a cabinet door or a wall they communicate different messages. A cabinet door covered with the embossed pattern exhibits the delicate and decorative qualities of the surface treatment while the larger scale application on a wall speaks of its potential on an industrial scale. Hence I think examples of different scale play an important role in presenting the scalability of the treatment.

The tactile qualities of the embossed surface demands another kind of application in order to demonstrate its potential. The tactile qualities are obviously also there in the wall panels and cabinet doors but such surfaces are rarely physically interacted with. Almost all furniture involve some sort of physical human interaction, be it a cabinet door, a table top or a chair. In a seating furniture this interaction is however probably most intimate and dominant. Hence I believe some sort of a seat would bring forth the tactile qualities of the surface most efficiently.

The material has some restrictions to it due to the way it is produced. The machinery I have access to allows me to press the pattern on 90x25mm boards. The boards can later on be joined together though to create larger uniformed surfaces. The production method also demands the boards to be flat and straight throughout the process due to the pressing and planing which means that only planar surfaces are doable.

FINAL OBJECTS

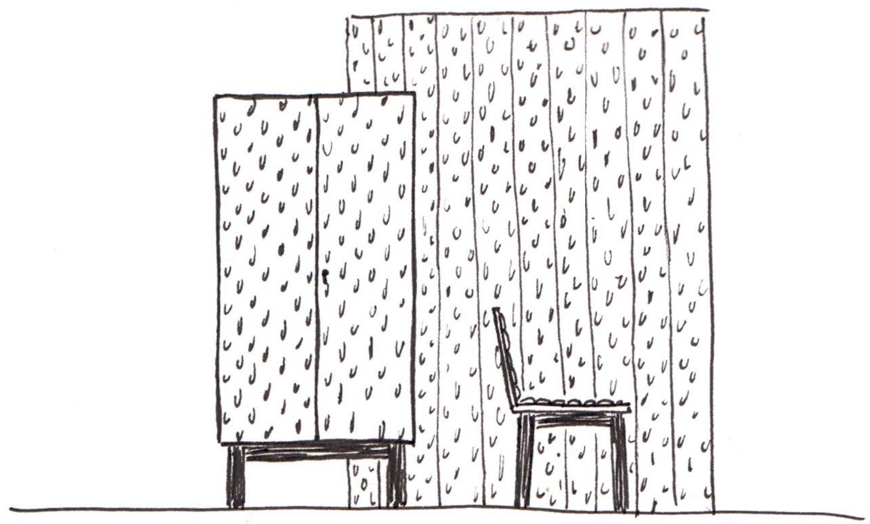


Fig.67. Sketch of the final objects demonstrating different qualities of the surface

Since the surface treatment is the main thing in this project I think the design of the pieces should be rather simple and calm in order to leave the stage for the bumps. The objects being designed now do not necessarily need to be realistic commercial products but rather demonstrational pieces showcasing the capabilities of the surface treatment.

The collection will consist of three pieces, all presenting certain qualities of the surface. The chair, being a piece of furniture that you interact physically with, will present the tactile qualities. The cabinet, also a piece that is being physically interacted with but in another manner than chairs, will present both tactile and visual properties. The larger surfaces of the cabinet also shows the pattern on a larger uniform surface. And finally the wall, consisting of several patterned boards next to each other, will present the larger scale industrial application and the architectural potential.

THE CHAIR

As previously mentioned all the pieces should be quite modest and strict in their design in order to leave the stage for the bumps. In addition to that all the patterned surfaces need to be flat. Bigger surfaces such as seats and backrests can be constructed out of several individual boards or they can be glued up to create unified surfaces. With this framework in mind I started sketching on simple, modest, archetypical chairs.

Starting with the seat and backrest felt natural since that was the thing with this chair. I made different variations on seat and backrest combinations constructed of both individual boards and glued up surfaces. Seat and backrest angles were also tested as well as different heights and types of chairs. After a long dialogue with myself on wether the chair should have comforts and qualities such as seat and backrest angles I decided to stick with the initial ideology of keeping the pieces as strict and simple as possible. The result, a strict and plain chair with a square profile frame and a separated seat and backrest.

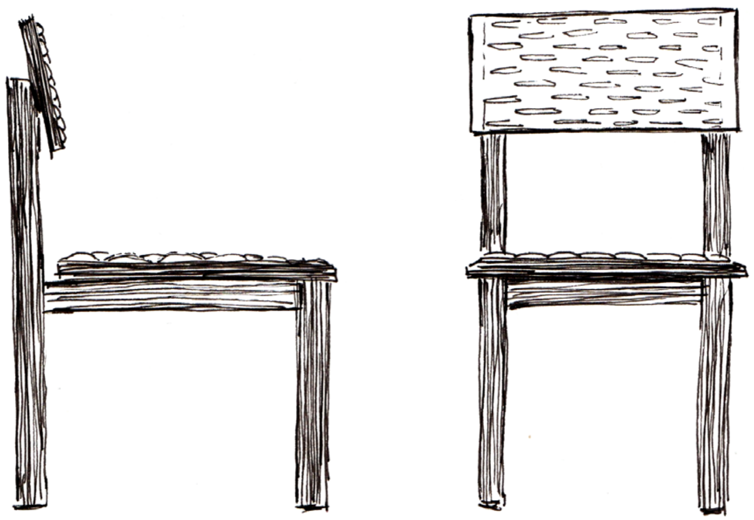


Fig.68. Sketch of the final chair prototype

Fig.69. Sketching process that eventually led to the final prototype of the chair

THE CABINET

I had a quite clear vision of the cabinet all the way from the beginning of the process. It would follow the same strict framework as the chair being a quite basic stereotypical cabinet with double doors and four or five shelves inside. It should be man-sized or a bit bigger and be all covered in the patterned surface giving a monolithic feel. The size of the cabinet was to some extent dictated by the dimensions of the raw material i.e. the 90x25mm boards. Length was obviously easily adjusted but the width of the sides and doors was determined by the width of the boards. Constructing the doors and sides out of four boards would make them 360mm wide while 5 boards would add up to 450mm. I decided to go for the narrower alternative to make the cabinet a bit more easily manageable.

In such large solid wood constructions moisture expansion starts to have significant effects and needs to be taken into consideration. The initial plan was to cover all the sides of the cabinet with a unified patterned surface including the back but due to constructional challenges I decided to cover the back with a flat back board in the end. Glueing and steaming of the large surfaces such as the sides and the doors was also somewhat challenging and made me consider wether the surfaces should be constructed out of individual boards instead. However, the impressive expression of the glued up surfaces made me stick with the unified surfaces which ended up working nicely despite the extra hassle.

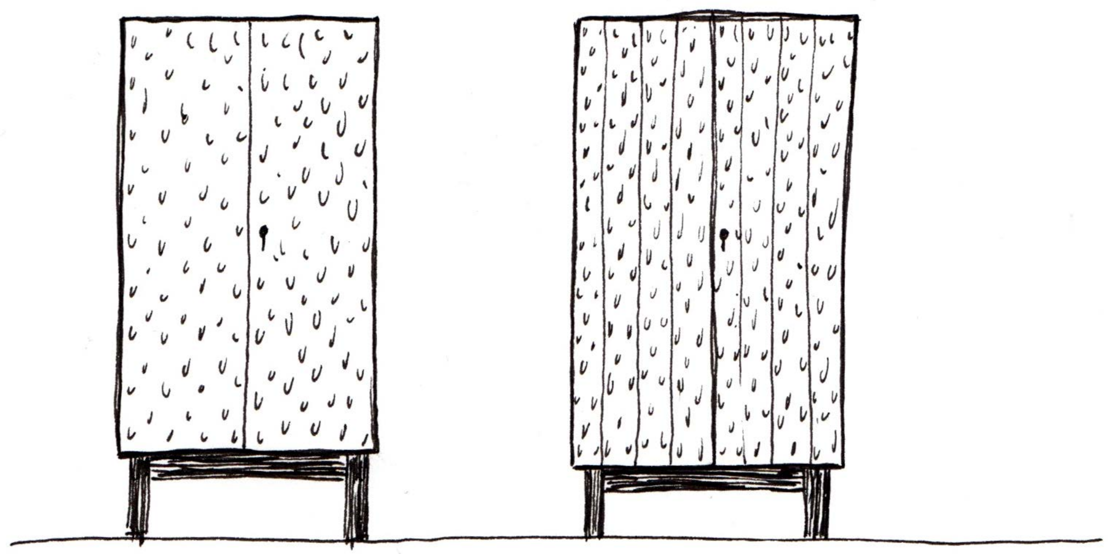


Fig.70. Sketches of the cabinet. On thte left, cabinet with solid doors. On the right, cabinet constructed out of individual boards.

THE WALL

The idea with the wall was to create a larger surface with the embossment to see how it works on a larger surface and to demonstrate the industrial potential and efficiency of the method. The wall would just be a bunch of patterned boards placed next to each other to create a large sample surface, plain and simple.

Although the embossments work quite nicely on the furniture pieces the true potential of the method lies in the larger scale architectural applications. The treatment could be used for creating embossed wall claddings or floors for instance. Instead of developing a fully functioning prototype of a wall panel system the sample wall will function as a visual prototype showing what such surfaces could look like. To further demonstrate the potential and the versatility of the method I decided to apply another pattern on the wall than on the furniture. The pattern I chose for the wall was a wave pattern that had been part of the earlier pattern tests. The wave is a bit less intense than the one on the furniture and would hence work maybe better on a larger surface viewed at from a distance.

Fig.71. 3D-printed pressing tools with wave pattern

Fig.72. Wave embossment samples

SURFACE TREATMENTS

Surface treatments can have a significant effect on how objects and surfaces are perceived. In wooden furniture and other everyday objects surface treatments also play an important role in protecting the wood from dirt and moisture and thus make the objects more durable. The visual appearance is one of the main properties of these embossed surfaces and hence I tested a few different surface treatment options for the pieces. I wanted to keep it simple with one natural finish and one colored. For the colored one I chose to go with black partly due to the neutral character of the color and partly due to the intriguing play between light and shadow on the black surface. The treatments I chose to test are soap and two different types of wood oils with slight differences in hue and glossiness. The black surfaces are achieved by staining the wood black with ink prior to oiling. The treatment I finally ended up going for was an oil with a semi glossy finish showed highest up on the picture. The reflections provided by the semi glossy finish seems to enhance the three dimensional texture of the surface making it more lively.

Fig.73. Surface treatment tests. From top down: 1. Danish oil, 2. Ink + Danish oil, 3. Osmocolor 3032, 4. Ink + Osmocolor 3032, 5. Osmocolor 3041 Valkotammi, 6. Ink + Soap, 7. Soap.

PROTO- TYPES

Fig.74.

Fig.75.

Fig.76.

Fig.77.

Fig.78.

Fig.79.

Fig.80.

Fig.81.

Fig.82.

Fig.83.

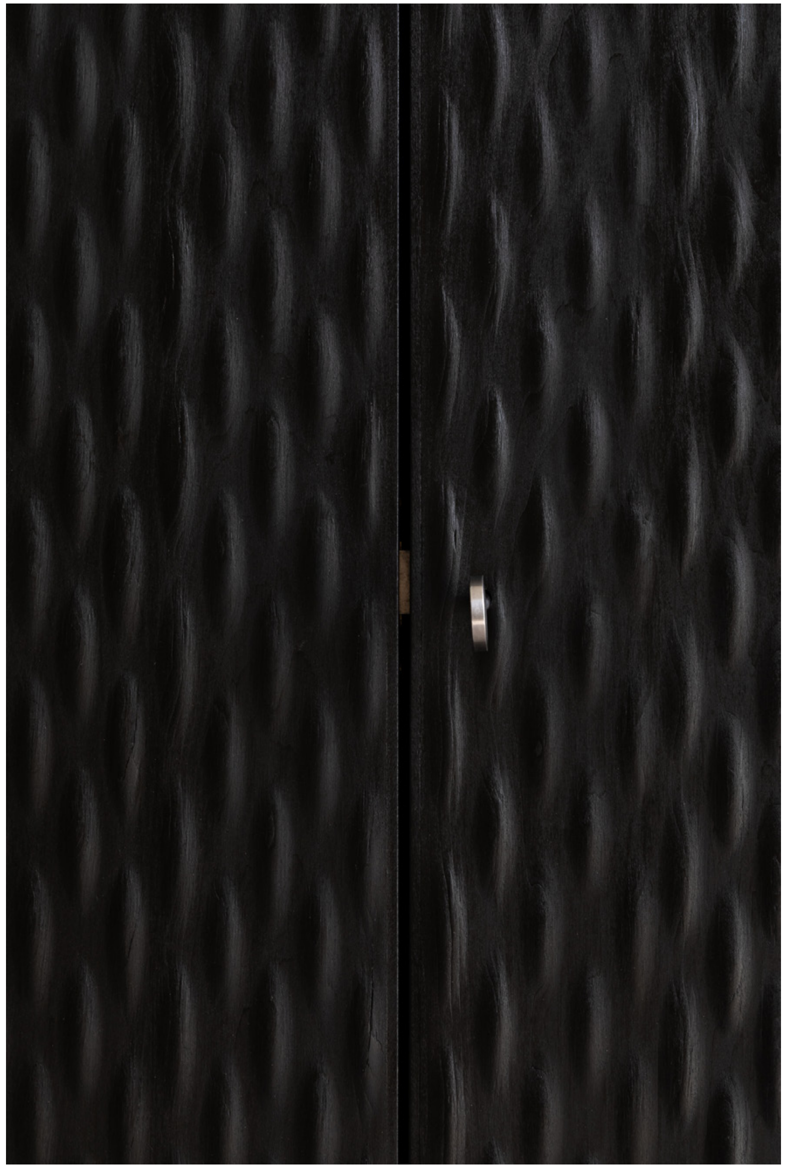


Fig.84.

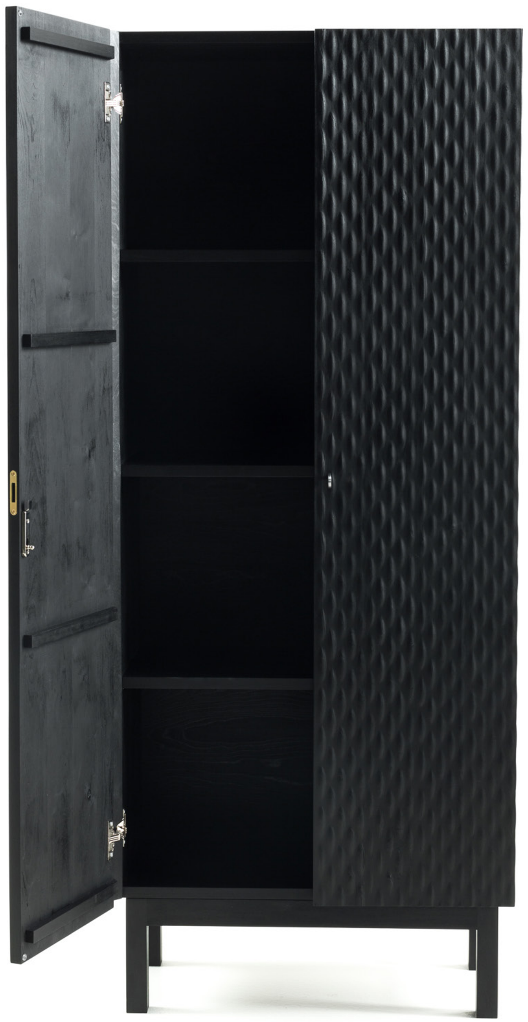


Fig.85.

Fig.86.

Fig.87.

Fig.88.

Fig.89.

Fig.90.

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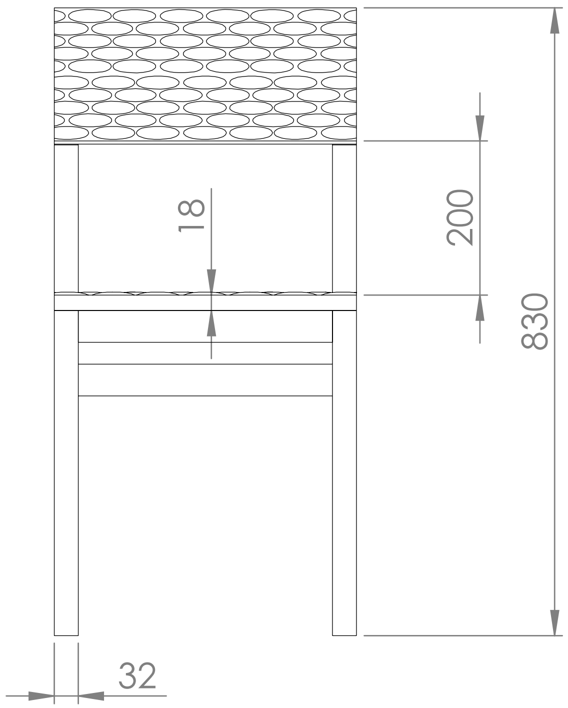
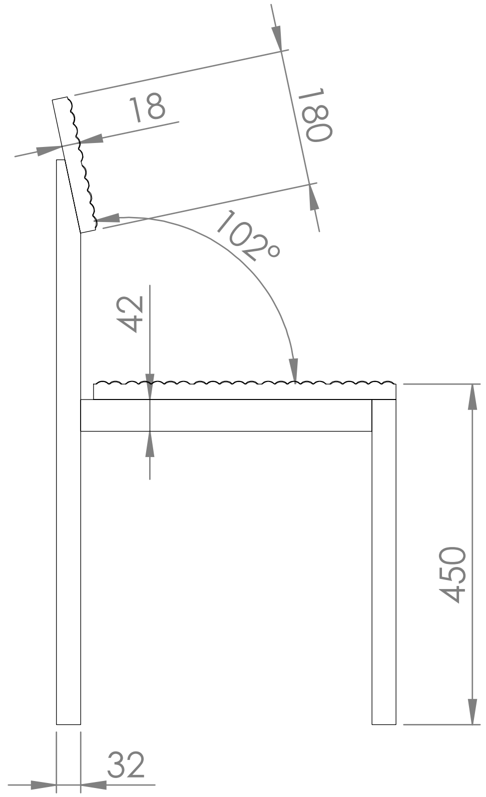
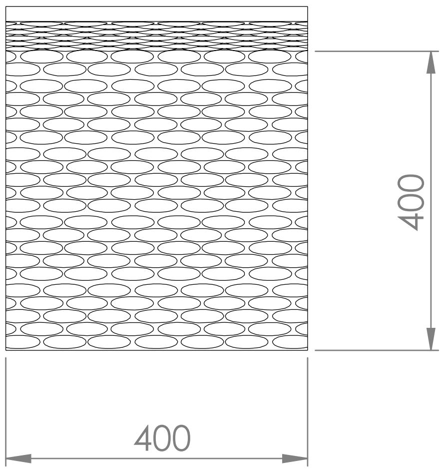


FRONT VIEW

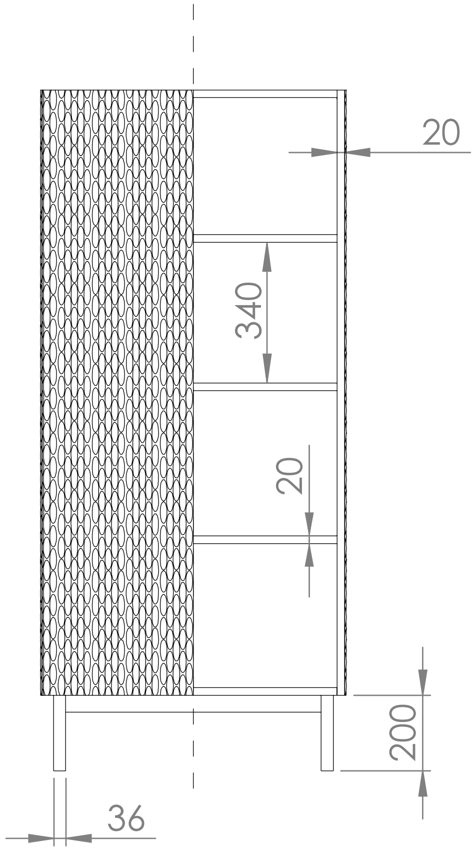


SIDE VIEW

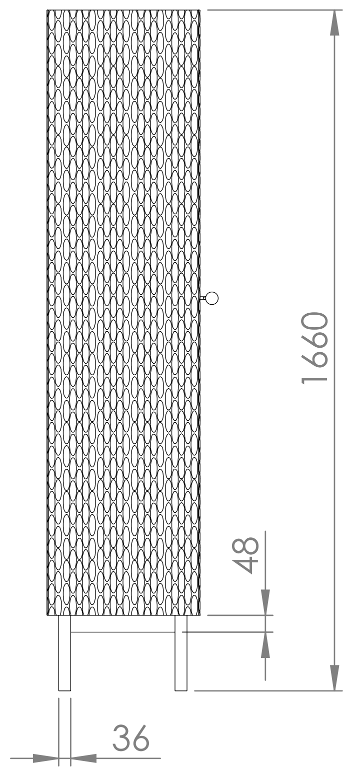


TOP VIEW

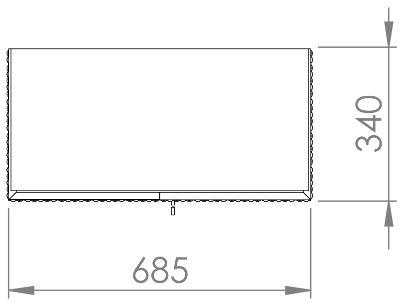
EMBOSSED CHAIR		
SCALE: 1:10	SHEET: 1 / 1	DATE: 05-05-2021
DRAWN BY: Hemmo Honkonen		



FRONT VIEW

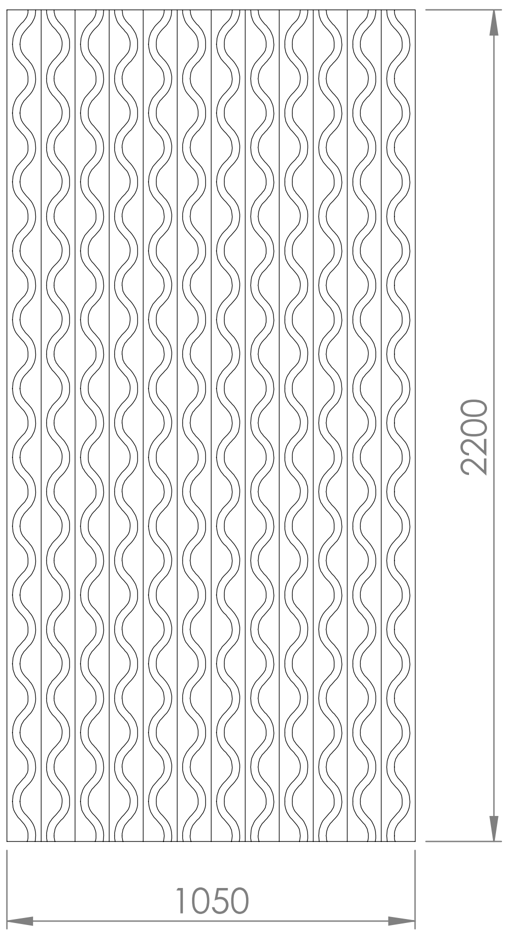


SIDE VIEW



TOP VIEW

EMBOSSED CABINET		
SCALE: 1:20	SHEET: 1 / 1	DATE: 05-05-2021
DRAWN BY: Hemmo Honkonen		



FRONT VIEW

EMBOSSED WALL		
SCALE: 1:20	SHEET: 1 / 1	DATE: 05-05-2021
DRAWN BY: Hemmo Honkonen		

REF-
LECTION

THE METHOD, THE OBJECTS

As a whole, I very happy with the project and its outcomes. I have got a lot of good feedback along the way and people s ameem to like the things they have seen which is good. In a way there are two design outcomes in this project, the method itself and the prototypes. The prototypes, the chair, the cabinet and the wall, turned out pretty much like I had thought they would. The workload was once again bigger than expected and everything took way longer than planned but apart from that everything went according to plan. The goal with the project was to explore and develop the method to a point where it could be applied on something in the furniture and interior industry. In my opinion that goal has been achieved and the three prototypes present three different applications of the technique on products for the interior industry.

Harshly put, as furniture the prototypes are not that remarkable or interesting in the end. If it was not for the bumps they would just be a couple of quite plain furniture. But that was sort of the idea with them all along. The furniture itself should just function as a platform or a canvas for the embossed surfaces. Obviously the shape, look, dimensions and details of the furniture need to be in the right balance in order to serve as that plain canvas that does not conflict nor compete with the embossments but rather elevates them. In that sense I think the design of the pieces is quite successful.

The second and maybe the more important design outcome of the project, the embossing method, also turned out rather well. When looking back and comparing the initial tests that I did with the end results the difference is quite remarkable. As stated earlier I think that the goal set for the project has been reached and the method has been developed to a point where you could start looking for industrial applications for it. It is definitely not ready for large scale industrial production but ready enough to serve as a proof of concept. A lot of improvements could still be done regarding the consistency and quality of the embossments for instance. Further experiments and developments of the process would also be in place.

The process itself could probably also be developed and improved in many ways. The machinery could be bigger and maybe customizable to allow different sized boards and different patterns to be pressed. The steaming process could probably be modified and improved, maybe it would be enough to steam only the surface instead of the whole board. Maybe steaming is not the best way at all, maybe the moisture and heat should be applied in some other manner. The moisture and temperature could be controlled throughout the process to decrease problems with twisting and cracking of the boards. Maybe the swelling of the embossments could be done with a surface treatment instead of steam, so that the board would be surfaced and ready to use after the process.

Apart from the more technical improvements another area of development would be the function and end application of these embossed surfaces. In the context of this thesis I ended up using the embossed surface mostly as a decorative element. Decoration or decorativeness is definitely a valid function among other functions. Throughout history mankind has decorated objects and buildings using various techniques. Decorations might have been added on to objects for religious reasons or to document important events, to tell a story. The motivation has however also in many cases been purely the strive for creating visually appealing surfaces or details on objects, decorations.

However, from a commercial point of view a decoration technique is maybe not the most impressive and profitable innovation. The fact that the technique allows you to create visually interesting surface patterns is probably not enough in itself to make it a commercial success. The potential of the method and the embossed surfaces could however be increased by developing additional functions or properties for the surface. In addition to its visual expression maybe the three dimensional texture of the surface could increase the friction of the surface making it applicable to solutions where increased friction is needed. Or maybe the embossed pattern on exterior wall claddings could help divert rainwater off the surface thus making the claddings more weatherproof. Recently there has been a lot of discussion about finding ecological alternatives for paint and other surface treatments that often include toxic or harmful ingredients. Maybe these embossed surface patterns could serve as an alternative to surface treatments and thus help make our buildings and surroundings more healthy. If embossed wall claddings for instance were possible to produce for a reasonable price maybe instead of painting a house with a pleasing color you would cover it with a pleasing embossment pattern instead. Furthermore, as mentioned earlier maybe the steaming of the boards could be replaced with a treatment that would serve as a surface treatment making the surface more weatherproof.

THE PROCESS

When looking back at this project the first thing that crosses my mind is the length of it. It all started with a few initial tests during my bachelors in 2017. Back then the plan was to do this as my bachelors thesis but then I eventually ended up doing something else. In the spring 2019, I picked it up again and started working on it as my masters thesis. Due to various interruptions, work, other projects, exhibitions and a stolen computer it got stretched out over a period of two years. For the past six months I have however been able to work quite intensively on the project and most of the work has been done during that period. In relation to the thesis guidelines the project has obviously exceeded all the limitations regarding time consumption and workload. However, I believe that the long time span has also been beneficial to the project by allowing thorough exploration and reflection of the method. I see a lot of potential in the method myself and hence I have also strived to explore its possibilities as thoroughly as possible. Alongside the last six months of the project I have had a very interesting dialogue with a company from the industry and the Aalto University Innovation team regarding further development of the method and the possible commercialization of it. This conversation and the work around the method is likely to continue after the thesis which I am very pleased with.

This project has taught me a lot about doing research and product development. The process has involved a fair amount of content that would maybe fit in better in the field of engineering or machine building but nevertheless it has been very educational and interesting. In addition to machine building I have learned a lot about 3D-printing, modeling and CNC-milling for which I have the workshop staff to thank for without whom this project would have ended up looking a whole lot different. Apart from the physical objects and the embossing method I have also learned a lot about commercializing innovations and patents and rights etc. which is maybe a bit off topic in regards of the thesis project but very valuable and important in regards of the industry that I am planning to work within.

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Fig.66. Morris, R., (1972), *At the office desk* [photograph], Retrieved 25.04.2021 from: <https://nymag.com/intelligencer/2020/01/frank-gehry-in-conversation.html>

Fig.67. Honkonen, H., (2021), *Final objects* [photograph]

Fig.68. Honkonen, H., (2021), *Embossed chair* [sketch]

Fig.69. Honkonen, H., (2021), *Chair sketches* [sketch]

Fig.70. Honkonen, H., (2021), *Embossed cabinet* [sketch]

Fig.71. Honkonen, H., (2021), *3D-printed pressing tools with wave pattern* [photograph]

Fig.72. Honkonen, H., (2021), *Wave embossment samples* [photograph]

Fig.73. Honkonen, H., (2021), *Surface treatment tests* [photograph]

Fig.74. Pennanen, E., (2021) Embossed c*abinet detail* [photograph]

Fig.75. Pennanen, E., (2021) *Embossed collection* [photograph]

Fig.76. Pennanen, E., (2021) *Embossed chair, black* [photograph]

Fig.77. Pennanen, E., (2021) *Embossed chair detail, blonde* [photograph]

Fig.78. Pennanen, E., (2021) *Embossed chairs, black and blonde* [photograph]

Fig.79. Pennanen, E., (2021) *Embossed chair front, black* [photograph]

Fig.80. Pennanen, E., (2021) *Embossed chair back, black* [photograph]

Fig.81. Pennanen, E., (2021) *Embossed chair seat detail, black* [photograph]

Fig.82. Pennanen, E., (2021) *Embossed chair backrest detail, black* [photograph]

Fig.83. Pennanen, E., (2021) *Embossed cabinet* [photograph]

Fig.84. Pennanen, E., (2021) *Embossed cabinet detail* [photograph]

Fig.85. Pennanen, E., (2021) *Embossed cabinet with door open* [photograph]

Fig.86. Pennanen, E., (2021) *Embossed cabinet with door open, close up* [photograph]

Fig.87. Pennanen, E., (2021) *Embossed wall* [photograph]

Fig.88. Pennanen, E., (2021) *Embossed wall close up* [photograph]

Fig.89. Pennanen, E., (2021) *Embossed wall close up* [photograph]

Fig.90. Pennanen, E., (2021) *Embossed collection* [photograph]