The Development of an Accesible Machine to Discover and Demonstrate the Possibilities of RECURF - a Promising Biocomposite

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Executive Summary

This thesis is submitted in partial fulfilment of the requirements for the master study Integrated Product Design at Delft University of Technology. In collaboration with Amsterdam University of Applied Sciences, this project researches the development of RECURF and aims to shorten the gestation period of this new innovative material.

RECURF is an innovative new biocomposite material consisting of both bioplastic as well as recycled textile and it is hoped to be a positive contribution to a more sustainable society and circular economy. The gestation period of a new material, that is the period between invention and commercial success, usually lasts around 20 years. This project aims to shorten the gestation period of RECURF and hopes to make a positive contribution to the development of RECURF.
To do this we have researched Ashby's theory on innovation acceptance (2000), Beard's theory on experiential learning (2010) and designing for material experiences by making use of the Material Driven Design method (Karana et al., 2015). Following this initial research we decided to combine these three theories into a material experience driven demonstrator exhibition in the form of a production process that shows and teaches designers and engineers about the technical qualities and possibilities of the RECURF material. By teaching designers and engineers about the qualities, possible applications and production methods of the RECURF material, we hope to inspire them to generate new ideas and to work with RECURF.
With the guidance of the Material Driven Design method we experimented, analyzed and finally designed a RECURF demonstrator exhibition in the form of a production process called the Direct Press. The Direct Press works with a flexible heating unit that you place at the location where you want to press. When in place you connect a lever to the heating unit which then allows you to press the material with high pressure. The Direct Press in combination with RECURF samples from different development stages teaches the audience about RECURF through experience by having them actively participate in the production process of RECURF. The user is enabled to heat and press tessellated origami patterns onto a large sheet of RECURF. This design was exhibited at Dutch Design Week 2018 in Eindhoven for a duration of 10 days.

Following our experiences with the Direct Press at the Dutch Design Week 2018 we concluded that our design was successful in terms of meeting our design requirements. To start, the exhibition attracted a lot of visitors and demonstrated the different development stages of RECURF well. It also displayed the duality of the material through the combination of hard- and soft-pressed areas to create the tesselation origami pattern on a large sheet. And lastly, it provided a new flexible heating and pressing method for RECURF that facilitates easier experimentation and development for future RECURF developers. Although we received many enthusiastic responses from visitors and managed to reach and teach a lot of people about the RECURF material, due to the size of the exhibition it was difficult to distinguish the generall visitors from the designers and engineers. Therefore it is hard to make draw any conclusions as to whether or not we managed to reach and inspire designers and engineers to get interested in working with RECURF.

As the gestation period of a new material takes around 20 years, until we can make the observation that RECURF has managed to go from invention to social acceptance and widespread application in less than 20 years, we cannot make any concrete conclusions as to whether this project influenced the gestation period of RECURF. Nonetheless, we conclude that the exhibition was a success even if it may not have reached as many designers and engineers as would be necessary to influence the gestation period of RECURF. The demonstrator project increased the exposure of the RECURF material to a larger public and produced a new, more flexible production method which can be of great value to future RECURF developers. In order to heighten the chance of a demonstrator project making a difference to the duration of the gestation period of RECURF, we recommend repeating this and/or similar exhibitions that teach designers and engineers about the technical

specifications, production methods and possible applications of RECURF. This should preferably occur at exhibitions that have a larger ratio of engineers and designers to general visitors.

Thanks to:
My supervisory team: Elvin Karana, David Klein and Mark Lepelaar for the guidance and inspiration during this project

So many thanks to Sophia, for her help and support along the way. I could not have done it without you!

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Everybody else who helped me along the way!

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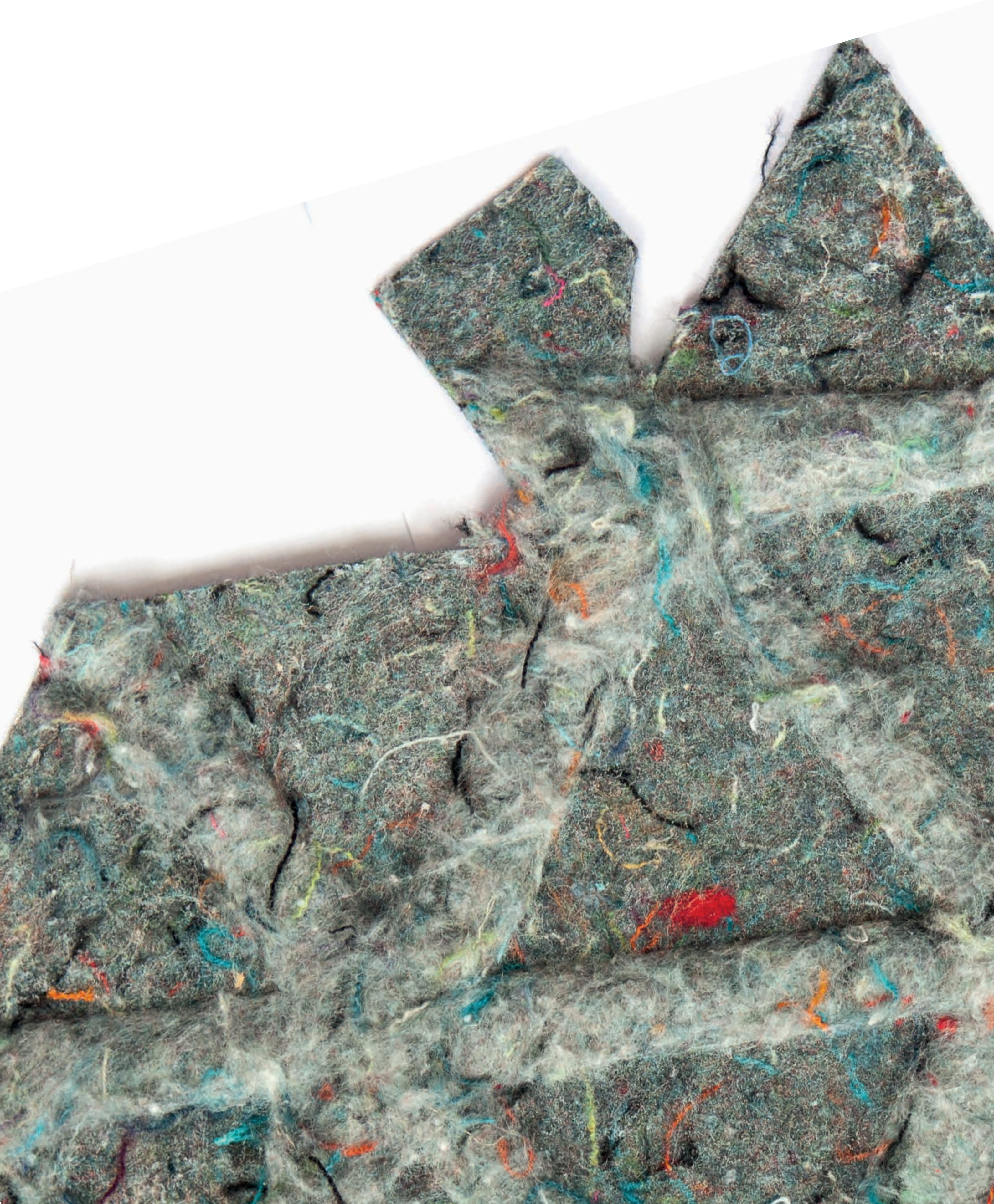


1. Introduction

In recent times, environmental problems relating to plastic and waste pollution have garnered widespread media and public attention. Decades of increased use of plastics on a global scale, and general disregard for the effect plastic use has on our environment, has led to the current reality where plastic pollution is considered one of the most harmful threats to our environment.
There are many ongoing initiatives attempting to tackle this problem. These initiatives range from trying to find a solution to the already existing plastic pollution, to finding ways to reduce the amount of plastic we discard through means such reusing, recycling, and upcycling. This includes developing plastics with alternative resources that are better for the environment.
This project is part of the development of a new innovative material, RECURF, which is being developed as an intended answer to multiple problems regarding plastic and waste pollution. By combining recycled plastic made from alternative resources with textile waste streams, this new material development endeavors to contribute to a more sustainable and circular economy.
The gestation period of an innovative new material typically takes over 20 years from invention to commercial uptake by the industry. This project aims to shorten the gestation period for the new RECURF material.

This thesis introduces the background of plastic and waste pollution that has led to the development of RECURF, followed by a specific introduction of the RECURF material. We then explain the scope of our project in the Project Description by introducing our theoretical framework, which consists of several theories and models on innovation acceptance, experiential learning and the Material Driven Design method by Karana et al. (2015). Following our discussion of these theories and models, we explain our decision to design a demonstrator project as means to shorten the gestation period of the innovative material RECURF.
As RECURF is a new material, we make use of the Material Driven Design method to give our project structure. Following the steps of this method we start off with our analysis phase, which contains the results of our benchmarks, tinkering sessions and the creation of our material experience vision. We continue with the design phase, which consists of our design brief, concepting phase, and our final demonstrator design. Our demonstrator was exhibited at Dutch Design Week 2018 in Eindhoven, and as such we then analyze our observations of the users experience during this event. We finish with our conclusions and recommendations for future research of the RECURF material.

Content

[1]

2. Background

2.1 Introduction

As the current world population of approximately 7.7 billion continues to grow, so does the amount of waste produced. Whether made of plastic, textile or other materials, the disposal of vast amounts of waste has an increasingly hazardous impact on our planet's environment. Particularly in recent years, the effects of plastic pollution on our environment have become more visible. From giant plastic soup patches appearing in the middle of the oceans to large amounts of plastic waste washing up on our shores, the realization that we must do something is undeniable.
To tackle the waste problem various initiatives are popping up all over the world that approach the issue from different angles. Such initiatives include cleaning up existing waste pollution, increasing recycling efforts, and developing materials that have the potential to act as a replacement for more conventional types of plastic.
The following chapter introduces the waste problem and further outlines a couple of initiatives to provide background as to why the RECURF material was developed. It then gives an in depth introduction and definition of the RECURF material itself.

2.2 The Plastic Problem

Petroleum-based plastics have been used for decades and worldwide the use of this type of plastic is enormous. From plastic bags in supermarkets to plastic packaging of products, and even anti-allergenic pillows and blankets made of plastic, a society without plastic seems almost unthinkable. Yet the impact of the plastic industry on our environment is harrowing. Not only is petroleum a fossil fuel and thus has a finite supply, the petroleum industry itself is harmful to our environment for various reasons, including oil spills and the emission of greenhouse gases. In addition, the disposal of plastics is cause for massive concern. When plastic is not disposed of properly and ends up in the environment, if left alone it can take hundreds of years to decay. In marine environments in particular, this is already causing numerous problems for marine life. Every year almost 8 million metric tons of plastic are the Ocean", 2018). At this rate, by 2050 there will be more plastic in the oceans in terms of weight than there will be fish ("Circular Economy System Diagram", 2018).

The use of plastic is so ingrained in our societies that it is virtually impossible to ban the use of plastic. Instead, we must find solutions for the environmental problems caused by the plastic industry. There are already various projects in existence that either try to clean up plastic pollution (such as the Ocean Cleanup project) or approach the plastic problem by developing alternative types of plastics made of resources that are less harmful to the environment.

This is where bioplastics can be introduced. The term bioplastics itself can be somewhat confusing as it is an overlapping term for three types of plastics:

· Plastic that is biobased and biodegradable
· Plastic that is biobased but non-biodegradable
· Plastic that is non-biobased but biodegradable

These types are shown in figure 1.

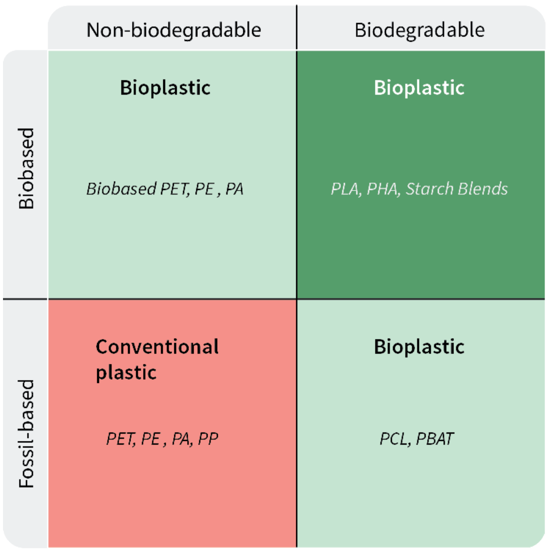


Figure 1. Bioplastics can be fossil-based or biobased and biodegradable or non-biodegradable.

Biobased plastics

Biobased plastics are types of plastics that are not made from a fossil fuel source such as petroleum, but instead are made from renewable materials such as cellulose, sugar, starch, protein, lactic acid, and even microorganisms. What makes these types of plastics better than petroleum-based plastics is that they are not reliant on a fossil fuel and its fluctuating price, and they can be made from easily producible resources such as sugarcane, corn, beets, potatoes and more (Chen, G., Patel, M.K., 2011). However, there are downsides to the production of biobased plastics. The production of their resources requires a lot of agricultural land that could otherwise be used for the production of food. This means that new agricultural lands will have to be claimed by means of deforestation, which also negatively impacts the environment.

Nevertheless, according to a study by Van den Oever et al. (2017) at Wageningen Food & Biobased Research, if we replaced all petroleum-based plastics with biobased plastics, this would require only around 5% of all the agricultural land in the world. Their prediction is, however, that this will most likely not happen. It is estimated that only 0.02% of all agricultural land will be used for the production of biobased plastics by 2022.

Another factor that hinders bioplastics from fully replacing all petroleum-based plastics is the fact that bioplastics are often more expensive than petroleum-based plastics. For example, both PHA as well as PLA, which are both bioplastics, are more expensive to produce than other petroleum-based plastics. This is shown in figure 2 where the production prices of PLA and PHA are compared to the most produced petroleum-based plastics worldwide. It can be seen that conventional plastics not only cost a lot less than PLA and PHA, but that they are also produced in much higher quantities. As long as petroleum-based plastics remain significantly cheaper than bioplastics, it is unlikely they will get replaced by them.

Plastic	Price/kg	Production x 1,000 ton / year	
PLA	€ 2.6 [1]	200 [4]	Bioplastic
PHA	€ 5 [2]	50 [4]	Bioplastic
PP	€ 1.4 [3]	68 000 [5]	
LDPE	€ 1.4 [3]	64 000 [5]	
HDPE	€ 1.4 [3]	52 000 [5]	
PVC	€ 2.6 [3]	38 000 [5]	
PET	€ 1.2-2.1 [3]	33 000 [5]	

Figure 2. An overview of two types of bioplastics and five of the most produced petroleum based plastics, with their prices per kilo and amount produced per year
[1] (“Polylactic Acid Production, Price and Market”, 2018)
[2] van den Oever, M et al. (2017) p.25
[3] (David Platt, 2018)
[4] (“materials”,european-bioplastics.org, 2018)
[5] (Geyer, Jambeck & Law, 2018)

Biodegradable plastics

Biodegradable plastics are types of plastic that are able to break down biologically by way of microorganisms. It is important to note that biodegradable plastics do not have to be biobased, as some types of petroleum-based plastics are also biodegradable, but these are more the exception than the rule.

As biodegradable plastics only degrade in certain conditions, the type of plastic, temperature, exposure to oxygen, water immersion, and whether covered in soil or not, are all variables that influence whether or not, and how quickly, a biodegradable plastic is able to break down. If the optimal conditions for the biodegradation process are not met, these plastics can still ‘survive’ for years. On the one hand, this makes them durable and useful for production and use, but on the other hand, it also makes them a potential environmental hazard if not disposed of properly.

Some biodegradable plastics are also compostable. According to the European standard EN 13432 for compostable plastics, a plastic can be called compostable when it breaks down by 90% within 6 months by microbial action, into CO2, H2O and minerals. It may not release any toxins or have any negative effect on the surrounding compost (“What Are Biodegradable Plastics? The Need For A Clarified Terminology”, 2018).

Two illustrative examples of compostable biodegradable plastics and their biodegradation conditions are PHA and PLA. PHA breaks down in soil in about two months without releasing any toxins, and PLA breaks down in soil in around twelve months. However, when placed in water both of these plastics break down much slower. When placed in water, PHA will have decomposed by only about 50% after six months, and PLA hardly decomposes at all.
Furthermore, when placed in conventional garbage landfills, PLA can even become an environmental hazard, as a lack of exposure to oxygen will cause it to emit the strong greenhouse gas methane due to its microbial processes.

These examples show that biodegradable plastics are effective in situations that allow them to degrade as they are supposed to, which in the case of PHA and PLA is when covered in soil, but in other conditions they can still be harmful to the environment.

Although biodegradable plastic shows a lot of potential when trying to find a solution for plastic pollution in the environment, the correct disposal of biodegradable plastics still seems to be a serious problem. Some types of biodegradable plastics require special compositing sites where the optimal biodegradation conditions are met. Though industries that regulate biodegradation conditions do exist, the reality is that due to a lack of widespread bio-waste separation collectors, most of these bioplastics end up in landfills or incinerators instead of being processed in an environmentally-friendly manner (“Bioplastics in a Circular Economy”, 2017).

Other waste streams

Plastic waste is not the only type of waste we produce. According to the waste package agreement of the european union, which is part of the European action plan for a circular economy, we must produce 65% less waste by 2035 (European council, 2018). One of the ways the amount of waste we produce can be reduced is by recycling and reusing as much material as possible.

An example of a waste stream, other than plastic, that can greatly be reduced through means of recycling is the textile waste stream. However, to efficiently reuse and recycle textiles, they need to be collected separately from other garbage. This already happens in Europe with about 25% of all used textiles (Zacune, 2013), but to reach the goal of 65% of the European agreement, the collection, reuse and recycling of textiles needs to grow significantly.

An opportunity emerges where we combine the bioplastic industry with the recycling of textile waste streams by combining them into biocomposites. This can create new materials that are not only be bigger in mass than bioplastic alone, but that also have new material qualities, providing new opportunities. The next step is to explore and research these composites so they can and will be used in society.

Figure 3. Denim is being collected for reuse, recycling or upcycling. [2]

2.3 A Solution: RECURF

The RECURF (I. Oskam et al., 2017) project addresses the problems surrounding biobased plastics by adding textile waste streams to biobased plastics. This leads to a larger volume of material for the same price, while simultaneously reusing a textile waste stream, which contributes to the circular economy, making it cheaper and less resource consuming. Combining the two materials into one leads to a new composite. This opens up a whole new range of possibilities, from new properties to new looks and feels.

A new kind of composite is something that needs to be adopted by designers, producers and consumers. The gestation period for a new material typically takes up to 20 years (Maine, Probert, and Ashby, 2005). This is from the start of material innovation to the widespread uptake of this material. That is why the RECURF project is a broad research program. It works together with designers, material experts, manufacturers, marketeers, circular economists and others to reduce the gestation period.

The question the RECURF (I. Oskam et al., 2017, p. 14) project tries to answer is:

“How can textile residual streams and biobased plastics be combined in circular products, leading to a mutual reinforcement?”

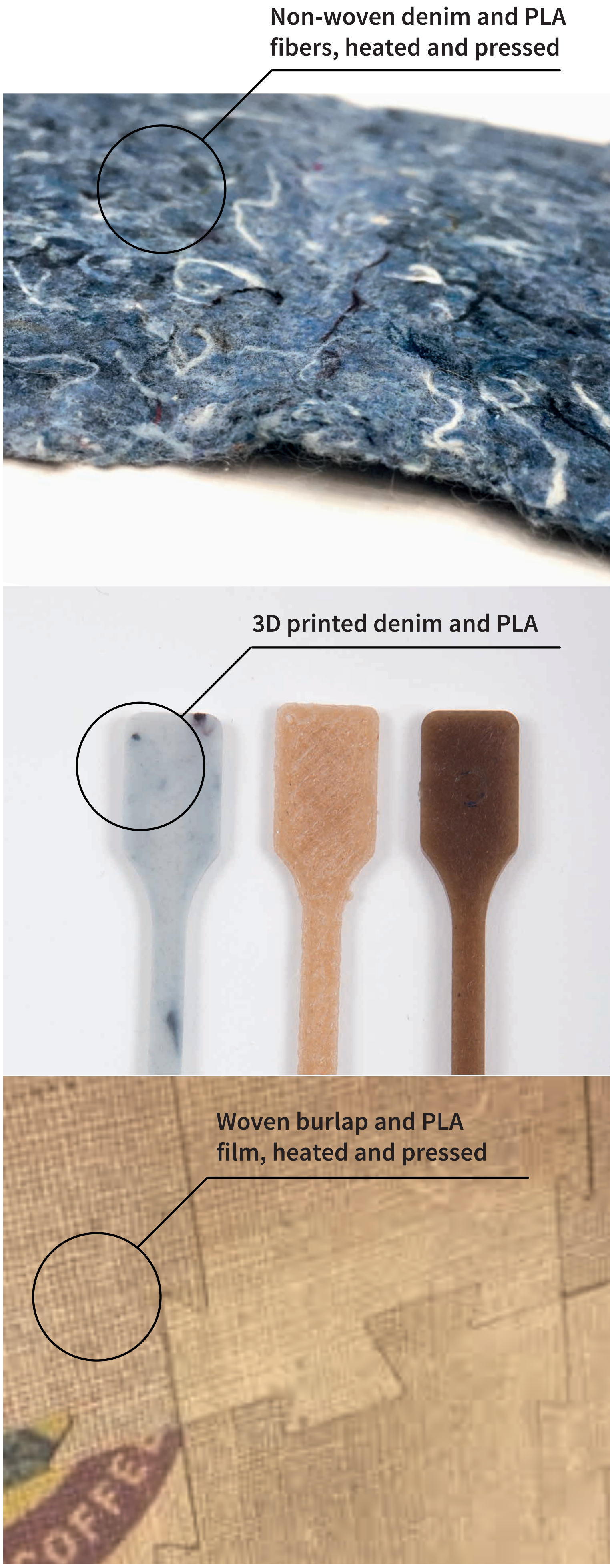


Figure 4. Three versions of RECURF. Non-woven, 3d print filament and woven with film.

Material development

The Amsterdam University of Applied Sciences (AUAS) has created three versions of the RECURF composite:

· 3D print filament mixed plastic and textile fibers
· Woven textile plus granulate or plastic film
· Mixed non-woven plastic and textile waste fibers

The first version creates a composite in the form of a filament thread for 3D printing by adding small textile fibers to the biobased plastic when molten. 3D printed objects can be made using this thread. A common problem with this method is that the fibers often get stuck in the printing nozzle. Therefore, only larger printing nozzles are have potential.

The second version uses a flat sheet of woven textiles, in which the biobased plastic is evenly added in the form of a granulate or a biobased plastic film that is laid on top of it. This layer then needs to be heated and pressed so the plastic melts all around the textile to form one hard sheet. This version depends on the amount, quality and size of recycled woven textiles. Since woven recycled textiles are often clothing or other small pieces of used cloth, they are often too small and irregular to mass produce. The quality and kind of weave can also be irregular and therefore difficult to scale up and mass produce.

The third version is also based on a textile sheet but with the textile fibers randomly pressed or needled together, just like felt. This sheet has the biobased plastic as a fiber evenly spread within the sheet, making it a composite that looks and acts like a nonwoven textile. When such a sheet of RECURF is pressed and heated above the melting point of the biobased plastic, it melts and flows around the textile. When cooled, the plastic solidifies and the whole sheet becomes rigid and hard, with the fibers visibly spread randomly through the material.

All three versions provide interesting possibilities. For an overview of qualities they measure up to, figure 5 was created.

	3D print	Woven	Non-woven
Upscale possibilities production	-	-	++
Suitable for pre- and post-manufacturing	-	+	++
Constructive qualities	+	+	+
Sound damping qualities	-	-	+

Figure 5. Comparing the three versions of RECURF, with the use of criteria.

The first two versions, however, present some limitations. The woven sheets with a PLA film are, for example, difficult to scale up in production. The plastic granulate mixed with shredded textile fibers are good for injection moulding and 3D printing, but require large 3D printers. The AUAS are researching these two versions to make them more efficient.

The most promising version is the non-woven textile. Production can be upscaled by creating large non-woven sheets and pressing and heating them. It is most suitable for pre- and post-manufacturing such as laser cutting and it has considerable sound-damping qualities.

In figure 6 the processes of the three different versions of RECURF are visualized. A burlap sack was chosen for use as the residual waste source in this example, however denim or wool can also be used as the residual waste source.

Conclusions from the RECURF research (I. Oskam et al., 2017, p. 24) project state that the follow-up research into non-woven sheets will be most promising. This research goes by the name of RECURF-UP.

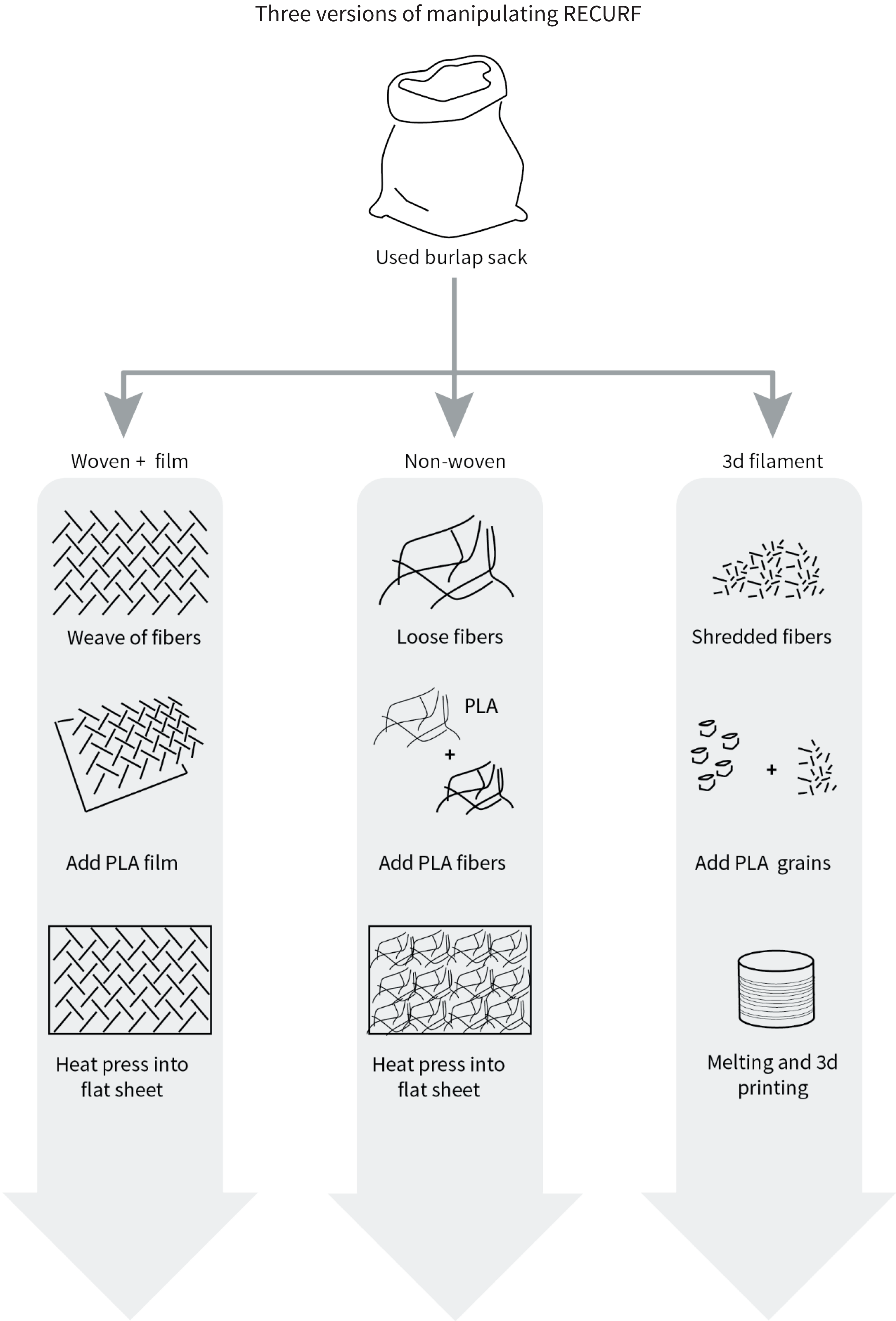


Figure 6. The processes of the three different versions of RECURF are visualised in this figure. There is chosen to use a burlap sack as residual waste source in this example, however denim or wool can also be used as the residual waste source.

Raw materials composition

At present, several Small and Medium Enterprises (SMEs) are collaborating with the RECURF project. Three companies have given a textile residual stream for use in the project. Starbucks has a residual waste stream of burlap sacks, also called jute, that is used. Ahold provides wool cutting residual streams, and Sympany has offered the use of denim residues. These three textiles are the base of the RECURF project. There are of course countless different textile waste streams, but these three are very diverse in color.

As for used plastic, the RECURF project has chosen two different types of biobased plastics, PLA (poly lactic acid) and TPS (Thermoplastic Starch). These plastics are both biobased as well as biodegradable. Since pure TPS did not have enough bonding with itself, making it very weak, it had to be mixed with a percentage of PLA. After several tests, it was concluded that pure PLA was the plastic that gave RECURF the best qualities and is to be further used in the non-woven sheets.

The non-woven sheets of RECURF can be made with three different textile waste streams. Every kind of textile brings different particular properties to the non-woven sheets. Both the type of plastic and the ratio of plastic to textile have an influence on the properties of the material.

The composition currently used at the AUAS consists of 50% PLA and 50% textile.

Figure 7. Top to bottom: A, B and C. A shows the denim fibers, B shows the PLA fibers. C shows the non-woven of the combination of denim and PLA.

Previous research

The potential of the non-woven textile and PLA fibers, in combination with the production method of using a heat press in designing flat and dish-shaped products is further researched in the follow-up study RECURF-UP. Several products have been designed with the use of this technique and researched by students of Minor New Materials AUAS and by their graduate students. During and next to this study, several characteristics of the non-woven sheets have been researched, such as:

- Noise reduction
- Strength
- Stiffness
- Sustainable colouring
- Origami
- Unique qualities of RECURF
- Experiential values
- End of life scenario and environmental impact

Material Driven Design method

The RECURF material has been researched by applying the Material Driven Design method, or MDD method (Karana, Barati, Rognoli & Zeeuw van der Laan, 2015). This is a design method that aims to design a material experience for a material. Davine Blauwhoff has applied the MDD method to RECURF (I. Oskam et al., 2017, p. 47- 48).

Blauwhoff's research concluded that the unique qualities lie in the contrast of duality of RECURF. These qualities are the foundation of the material development of RECURF and for this project, and will be treated further in the chapter 'Project Description'.

RECURF conclusions and recommendations

It can be concluded that non-woven sheets are the most promising and will be the kind of composite used in this project. This is due to the possibilities to upscale non-woven sheets in production, the possibilities for pre- and post manufacturing and its unique qualities , discovered through the use of the MDD method. In addition, most products made in the RECURF project and the RECURF-UP project have been within the size range of the available heat press of 40x40 cms. While there are collaborations with SMEs that are in the possession of larger presses and heat rolls, due to their own product production the time available with these larger presses for use on RECURF is very limited. Therefore, larger sheets of non-woven RECURF will be used in the scope of this project.

2.4 Material Specifications

Made from	Bioplastic and recycled textile
Bioplastic	50% PLA (polylactic acid)
Textile	50% Burlap, denim or wool

Non-woven RECURF

Density	0.5 g/cm3
Tensile strength	41-60 MPa*
Yield strength	4.9 GPa**
Melting temperature	180 degrees
Water resistance	No
Fire resistance	Yes, according to initial tests
Acoustic absoption	Yes

* Oskam et al, 2017. Tests were executed with different composiiton percentages: PLA + Wool(30%) = 41 MPa, PLA+ denim(30%) = 56MPa and PLA + Burlap(30%) = 60 MPa.
** Oskam et al, 2017. Yield strength is only measured for PLA + burlap(30%)

3. Project Description

3.1 Introduction

The aim of this project is to shorten the gestation period of the new material RECURF. What we mean by this is that we hope to shorten the development phase between the initial invention of the RECURF material, and the actual application and widespread use of the RECURF material.
In order to do this, we combined Blauwhoff's findings on the RECURF material with Ashby's recommendation of a demonstrator project to shorten the gestation period, together with theories on experiential learning and the Material Driven Design method. This led us to design an experience-based demonstrator project in the form of an exhibition that demonstrates and teaches people about the technical qualities and possibilities of the RECURF material in large sheets by making use of origami to illustrate the duality of the RECURF material.
In the following chapters we explain our theoretical framework and approach to this project.

3.2 Demonstrator Projects

As mentioned by Maine, Probert and Ashby (2005), with innovative materials there is almost always a long gestation period between the initial invention of the material and the actual application and widespread commercial use of the material.
Research conducted by Ashby et al. (2000) on the history of the development of new materials shows that the development and industrial uptake of new materials usually takes place in a scenario like figure 8 A. The normal process surrounding a new material usually involves a prolonged research period which then slumps, as there is initially little interest by the industry to use it. The industrial uptake of the new material usually follows much later, making the gestation period of a new material around 15-20 years. Even Polyethylene, which is the most commonly used (petroleum based) type of plastic today, took more than 20 years from its initial invention in 1933 to its widespread commercial use from the 1950s onwards (Maine, 2000).

According to Maine (2000), "this long gestation period is partly due to a mismatch between designers' and entrepreneurs' understanding of market needs and the development of new materials for various applications" (p. 6). What she means by this is that even if designers and entrepreneurs understand the needs of a specific market, as long as they remain unaware of a newly developed material that perfectly fits these needs, they will not be able to apply it. In short, there is not enough communication between the developers and researchers of new materials and the designers and entrepreneurs that can possibly use it.

Freeman (1982) compares the process of technological innovation to a pair of scissors. He explains that innovation is essentially a combination of two parts that have to work together, otherwise the innovation will not become a commercial success. On the one hand, you have the identification of a potential market where there is a demand for innovation, and on

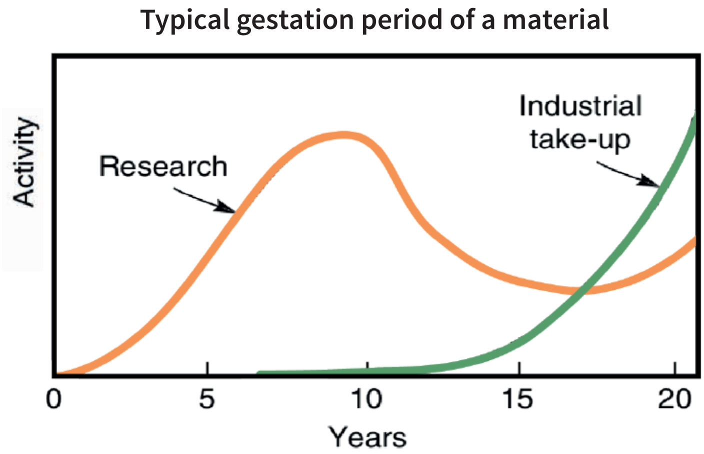


Figure 8-A. Activity of material research and take up of the related industry. Based on historic examples, by Ashby (2000)

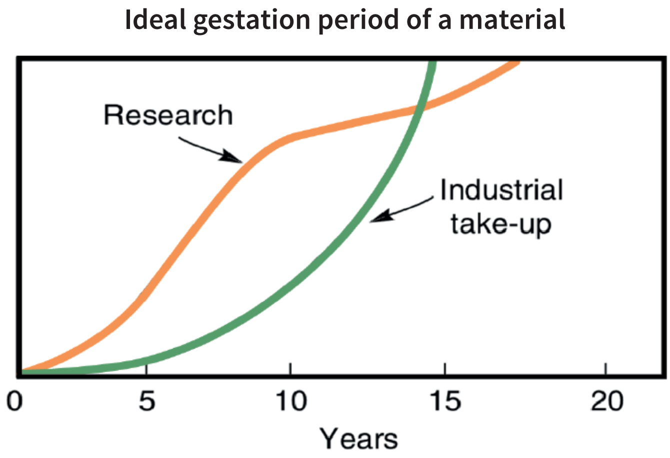


Figure 8-B. Ideal graph of activity of material research and take up of the related industry, with a shortened gestation period. The take up by industry cruve is shifted to the left, by Ashby (2000)

the other hand, you have the technological information which resulted from the developmental research of the innovation in question. According to Maine (2000), there needs to be a 'matching' methodology that brings both the market and the technological information about the material together, which will lead to a shorter gestation period between the invention of the material and its widespread commercial use.

For this Ashby et al. (2000) recommend demonstrator projects, which present the

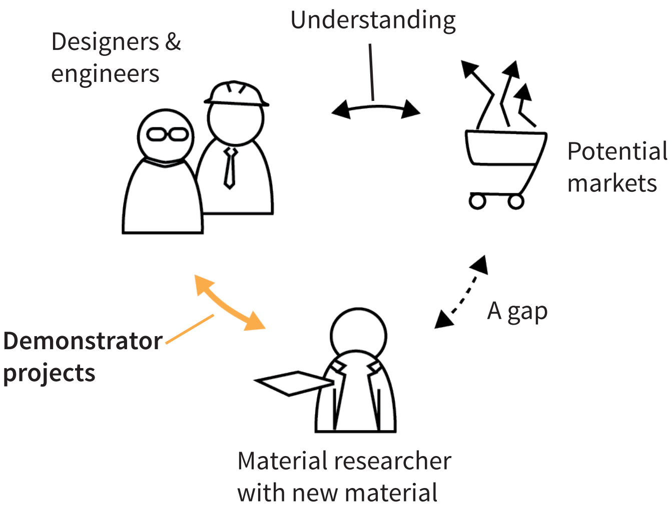


Figure 9. The mismath between the development of new materials, and the designers and engineers who have an understanding of the potential market needs. The orange arrow points out where a demonstator could increase communication. The questionmarks point out that between material researchers and potential markets lies a big gap.

properties and technological information of a new material. This facilitates easy comparison with comparable materials and demonstrates possible applications. This way a new material becomes more tangible for designers and entrepreneurs as, without any initiative on their part, they can already get a grip on the possibilities and technical specifications of the new material. Ashby's recommendation of a demonstrator project is only one part of his design guide for new materials as proposed in Metal Foams - A Design Guide (Ashby et al., 2000). According to Ashby, it is possible to speed up the uptake of a new material by the industry by applying three points: the formulation of design rules at an early stage, research aimed at characterizing the most useful properties, and the creation of demonstrator projects. By doing this, as shown in figure 8 B, we pull the industrial take up curve closer to the research curve and by doing so shorten the gestation period of the new material by many years.
These demonstrator projects do not have to be in any specific form and can be anything from a scientific research paper to an exhibition or video. However, they do have some specifications as formulated by Ashby:

- They have to present the properties (of the material) which facilitate easy comparison with other materials and structures
- They have to illustrate possible applications.

3.3 Experiential Learning

The concept of learning most effectively through experience dates as far back as Aristotle (384-322 BC) who wrote that with things that we have to learn before we can do them, we learn best by actually doing them. Confucius (552-479 BC) also famously wrote "I hear, I forget, I see, I remember, I do, I understand". Since the time of these great philosophers, many theoretical instruction and learning models have been created that are based around similar concepts of learning through experience, but to cover them all would be too big a scope for this project.

Instead we have chosen to make use of Colin Beard's model for experiential learning (figure 10). His model combines specific training and learning models and by doing so explains experiential learning from both the perspective of the teacher as well as from the perspective of the person learning.

Beard's model for experiential learning is introduced in his book "The Experiential Learning Toolkit: Blending practice with concept" (2010). He explains his model as a combination of the commonly accepted training cycle, Edgar Dale's "Cone of learning" (1969), and David Kolb's experiential learning cycle.

The training cycle is a commonly accepted model for instruction consisting of several phases, beginning with the planning/analysis phase, followed by the design phase, the implementation phase, and the evaluation phase (although not necessarily in this specific order). Beard combined the concept of the training cycle with Edgar Dale's "Cone of Learning", which suggests that people retain more information when they experience something rather than read or hear about it. He did this by redefining the implementation phase to the implementation of an experience. This way the revised training cycle teaches people something through experience rather than just reading or hearing about it.

He then combined this experience based training cycle with the experiential learning cycle as developed by David Kolb (1984). Kolb's experiential learning cycle gives a new view on the learning process that emphasizes the role of experience. The experiential learning cycle involves four phases based on learning from an experience, followed with reflection, abstraction and application.

As mentioned previously, Beard combined these models and concept into the following experiential learning model:

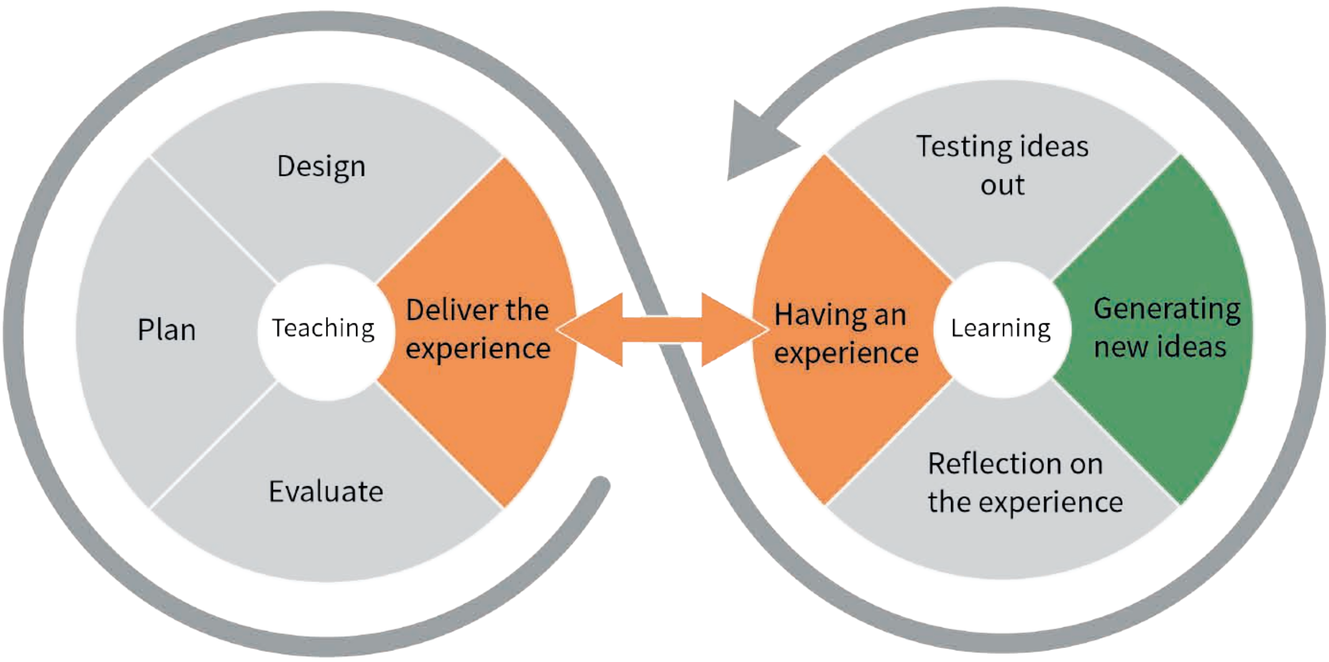


Figure 10. Collin Beard's model of experiential learning. The experience itself(orange) is the part where the teaching model and learning model meet.

This connective approach on teaching and learning through experience has the experience itself as the factor that binds the process all together as this is where the teaching model and the learning model meet. Following Edgar Dale's conclusions on the retainment of information following different means of exposure, this experiential learning model has more potential of leading to the generation of new ideas than when people are exposed to the new information by only hearing or reading about it.

3.4 Material Driven Design (MDD) Method

The Material Driven Design method is different from other design methods in the sense that it is aimed at designing a material experience with a specific material as the starting point, as opposed to designing a product where the material is secondary to the product design.
The MDD method works from the fundamental idea that to be truly able to design a good material experience you have to understand the material. The way to get a good understanding of a material is by getting hands on experience with the material to learn all of its qualities and possibilities as well as its limitations.

The MDD method works with the following steps:

- Understanding the material
- Creating material experience vision
- Manifesting materials experience patterns
- Designing material/product concepts

Understanding the material
During this step the designer discovers the technical and mechanical properties of the material by making use of tinkering techniques. This includes, for example, bending, cutting, heating, and combining the material to see how it reacts to these different conditions. As Karana et al. (2015) mention, the MDD method encourages this hands-on interaction and exploration not only to better understand a material's unique qualities and limitations, but also on the basis that physical encounters and experiences with a material can positively affect the creative process and lead to inspiration. Material benchmarking will also be done to compare the material to similar materials and give insight into possible applications that are achievable with these similar materials.
After this step the designer should be able to answer questions about the main technical properties of the material, the limitations and possibilities of the material. Furthemore, more should be known about the different kinds of production methods that are possible with the material and which ones are most convenient.

Creating material experience vision
After the designer has gained insight into the material, the designer will create a material experience vision. This means the designer has to create a vision that embodies how the designer envisions the user will experience the material. When creating this vision the designer will have to ask him/herself questions about which qualities they want to emphasize in the final design, in what kind of context the experience will take place, and how they would like people to react to their material experience.

Manifesting material experience patterns
The material experience vision represents the interaction between the user and the material. The question for the designer remains how to apply this vision concretely. This step creates patterns of how the formal qualities of the material and the material experience vision are interrelated. When the targeted material experience is elicited, the characteristics of the whole context and situation are seen as the materials experience patterns.

Designing material/product concepts
This is the final step of the MDD method where the designer combines all the findings of the previous steps into a design phase. By the end of this step the designer will choose the material with the most potential and use this material for the final product concept creation.

Designers can apply the MDD method in three scenarios. The first scenario is based on a material that is relatively well-known, such as titanium or polystyrene. The second scenario is aimed at relatively unknown materials, such as liquid wood or thermochromic materials. The third scenario is aimed at semi-developed materials, such as 3D printed textiles and food waste composites. RECURF fits best in this third scenario. In this scenario the properties are further explored, defined and evaluated in relation to a selected application area. The designer should propose meaningful applications making use of unique user experiences.

Blauwhoff's RECURF
Blauwhoff's exploration into RECURF belongs in the third scenario of the MDD method.
She has drawn several conclusions about RECURF including that, aside from the contribution the material makes to a more sustainable society, the main appeal of the RECURF material lies in the duality of its material qualities. Depending of the production process, the material can have properties that are on either side of a spectrum. These are:

- Hard - Soft
- Smooth - Textured
- Flexible - Stiff
- Two dimensional - Three dimensional

Examples of these properties can be seen in figure 11. Blauwhoff uses these properties to design unique interactions with products made of RECURF where she uses both ends of the four spectra. According to Blauwhoff, the tactility of the material plays an important role in discovering these dualities because most of these qualities can be felt better than seen. This is with the exception of the duality of two dimensional - three dimensional.
These properties will be the starting point of the material exploration in this project.

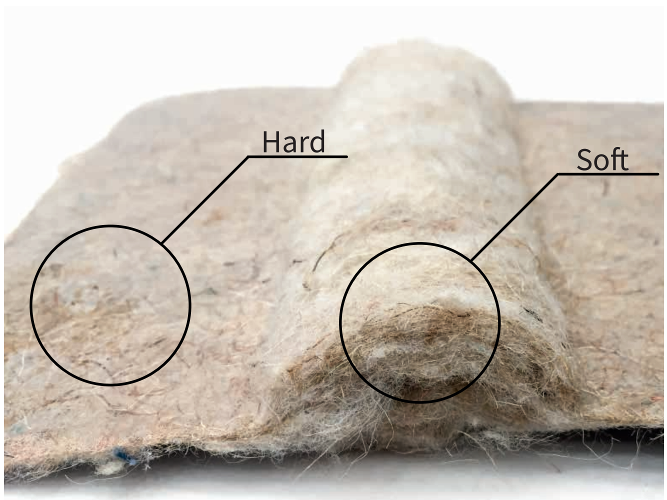
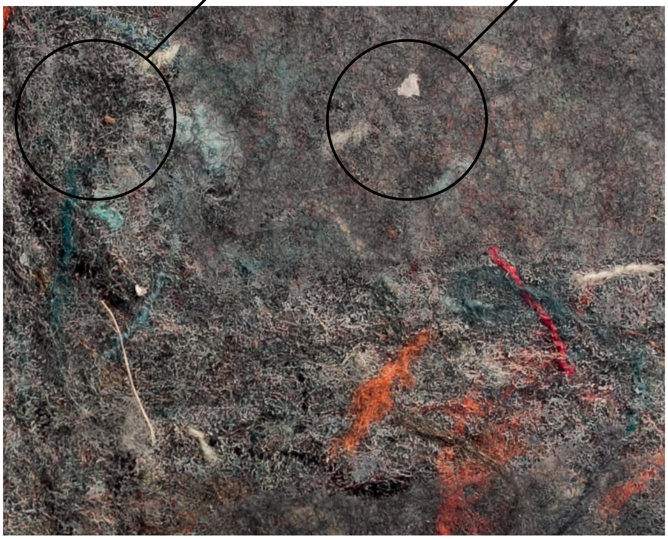
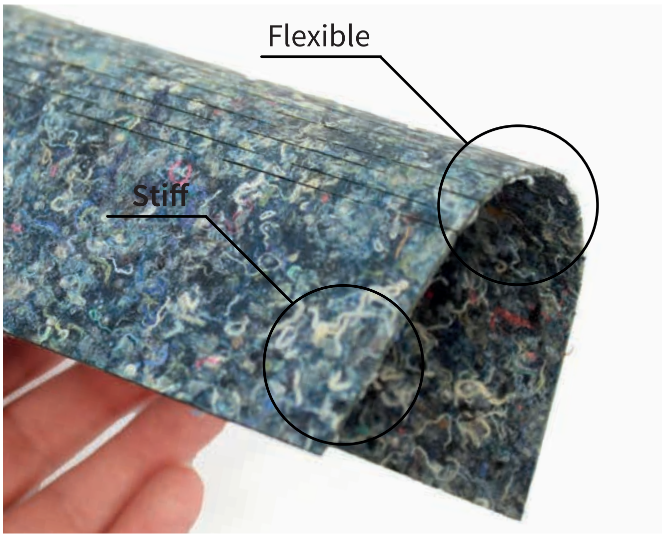
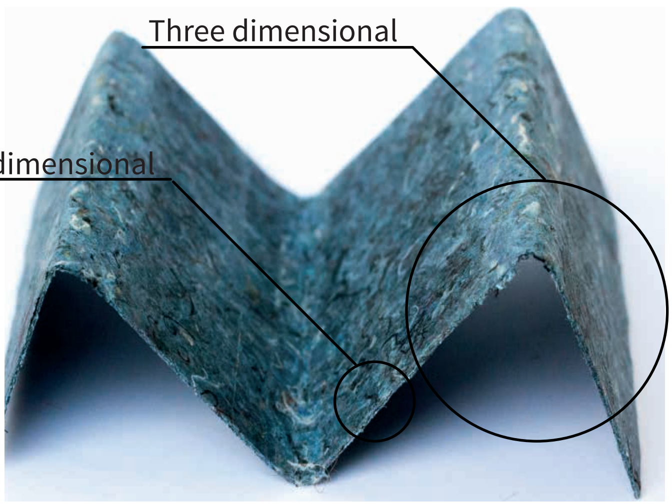


Figure 11. A, B, C and D. These four images show the contrast in duality in samples of RECURF.







3.5 Approach

Demonstrator Project Exhibition

With the aim of shortening the gestation period of the RECURF material we have followed Ashby's recommendation to design a demonstrator project.
In Ashby's design guide for Metal Foams, his demonstrator project is in the form of a scientific paper which presents his research concerning different types of metal foams, comparing them with other materials and illustrating possible applications. Instead of a scientific paper that has to be read, we combined Ashby's theory of a demonstrator project with Beard's model for experiential learning into a demonstrator project in the form of an exhibition. We aim to function as the 'matching' system that teaches possible engineers, designers and entrepreneurs about the innovative material RECURF by facilitating a material experience. This material experience exhibition essentially draws possible designers into the tinkering process of the RECURF material. As previously illustrated in Beard's model for experiential learning, by giving people a hands-on experience we hope to not only teach them about the qualities and possibilities of the RECURF material, but also to inspire them to generate new ideas and potentially work with the material.

Applying the MDD method

For this experience driven demonstration of RECURF and its unique qualities, we will be further exploring the duality of the material that was found by Blauwhoff while using the MDD method. The MDD method is used because RECURF is a new and fairly unknown material. As this project can be seen as a continuation of Blauwhoff's research into RECURF, it is valuable to continue with the same method.

Out of the steps of the MDD method, only the first two steps will be used, as our step following the creation of our material experience vision does not line up with step three from the MDD method. With the knowledge gained from these two steps and the theory of demonstrators, the next step is to answer to the question of how to engage designers in the hands-on tinkering phase by use of the ideation and design phase.

Origami

When researching the two-dimensional - three-dimensional properties of RECURF we will be making use of origami. This method of modifying a two-dimensional object to a three-dimensional object has a lot of advantages when applied to RECURF in comparison to other three-dimensional RECURF production methods.

Figure 12 shows the assessment of three different possible methods when creating three-dimensional objects with non-woven RECURF.

	3d moulds	Assemble flat parts	Origami
Versatile in creating many shapes with one production set up	--	-	+
Convenience in production of large sheets or objects	+-	+-	++
Possibility to show the duality of RECURF	-	+	++

Figure 12. Different methods of making three dimensional products are tested looking at three different criteria. Origami scores the highest.

As previous research on the RECURF material has mainly been focused on RECURF in small sheets, this project is exploring the potential of RECURF in large sheets. We have done this by examining production methods that are versatile when exploring RECURF and convenient when producing large sheets. The possibility of showing the duality of RECURF is also preferable and as shown in figure 12 origami has the most potential for this.

3.6 Research Questions

Following our aim of shortening the gestation period of RECURF and Ashby's recommendation of a demonstrator project to engage people with the new material, we propose the following main research question:

How can we engage people to interact with the RECURF material in large non-woven sheets?

As we use the Material Driven Design method during this project we also have three sets of questions that will guide us during the different phases of this method:

Material Understanding

- What are the possible RECURF production techniques?
- What are the variables and limitations of each production technique?
- What are the folding properties of RECURF?
- Which type of folds are possible with which production techniques?
- Which origami patterns are achievable using RECURF material?
- Which origami patterns evoke interesting material experience when combined with RECURF material?

Material Experience Vision

- How do we want people to experience RECURF?
- In what context do we want people to experience RECURF?
- What do we want people to do after experiencing RECURF?

Designing Material/Product concept

- What are the unique technical qualities of the material that we want people to experience in the final application?
- What type of production process has the biggest potential in terms of variation in application and approachability?

ANALYSIS

4. Benchmarking

4.1 Introduction

Part of 'material understanding' phase of the MDD method is benchmarking. Benchmarking is the process of comparing your project elements to existing similar projects. This is useful for inspiration and gaining insights and is an important step for the designer to prevent him or her from designing something that has already been done before. There are several areas that are benchmarked in this project. These are:

· Biocomposites
· RECURF projects
· Origami in design
· Production techniques

4.2 Biobased Composites

There are countless possibilities when comparing biocomposites. However, not all biocomposites are comparable or even remotely resemble RECURF. That is why we have focused on biocomposites made out of natural fiber or fiber from a waste source in combination with a plastic or resin.

Figures 13 to 21 show different types of biofiber composites, and in figure 22 these composites are compared bas on their qualities and applications.

Figure 13. Chair made of saw dust and plastic bags. By Kulla Design[3]

Figure 14. Ukalele made of flax fibers. By Ekoa [4]

Figure 15. Jute chair with PP injection. By Myung Chul Kim [5]

Figure 16. Scooter panel made of hemp fibers and bio resin. Be.e by Waarmakers [6]

Figure 17. Denimx® . Range of plastics with fibers from recycled jeans. mmd.nl [7]

Figure 18. Dashboard from keanaf composite. made by BMW [8]

Figure 19. Chair made of Cocolok®. By Jorrit Taekema [9]

Figure 20.
Bamboo fiber.
Created by
University of
Kansas and
HERObike [10]

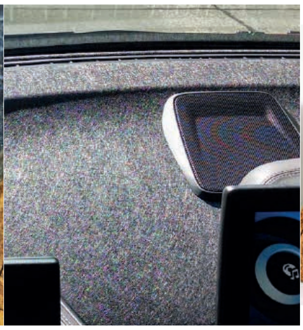
Figure 21.
Paper fiber.
Made by studio
JENS PRAET.
Picture by Theo
van Pinxteren/
Industry
Gallery [11]

Bio fiber composites




	Sawdust Kulla Design. Made Only out of plastic bags and sawdust.	Flax fibers Ekoa® by Blackbird and Lingrove	Jute chair Myung Chul Kim made of jute and flax with a PP injection	Hemp fibers Be.e scooter by waarmakers.nl. made of hemp, flax and bio resin
	Lamps and chairs are made with the use of molds	Ukalele with outstanding acoustic qualities	Jute chair. made in a mold	Body panels of a scooter
Applications				
structural	yes	yes	yes	yes
decorative	yes	yes	yes	yes
Use of contrast in duality				
Flexible / stiff	low	low	low	low
Hard / soft	medium	low	low	low
2d / 3d	medium	medium	medium	medium
Smooth / textured	high	low	low	low
Production process	3d mould	flat mould	3d mould	3d mould

Figure 22. Comparison of biofiber composite made products and their qualities and applications

				
Cotton Denimx® . Range of plastics with fibers from recycled jeans. mmd.nl	Kenaf fibers Dashboard from keanaf composite. made by BMW, for BMW i3	Coconut fibers Chair made of Cocolok®. By Jorrit Taekema	Bamboo fiber Created by University of Kansas and HERObike	Paper fibers Made by studio JENS PRAET
Different items such as juwelery	Parts of the dashboard of the bmw i3	Chair made of coconut fibers.	Skateboard part layers are bamboo composite	Bench made out of shredded magazines with clear resin
yes	yes	depends	yes	yes
yes	yes	yes	yes	yes
low	low	medium	low	low
low	low	medium	low	low
medium	medium	medium	low	medium
low	low	low	low	medium
3d mould	3d mould	3d mould	flat mould	3d mould

The overview of figure 22 gives insight into several aspects. First we looked at the applications of biofiber composites. Most of these applications are interior objects, they have simultaneously a decorative and a structural function. Structural means that the composite can bear the loads that are applied to it by having a strong and stiff structure. This is mostly applicable for chairs and benches that need to carry the weight of a person. This direction of interior objects has potential for RECURF.
The second observation is that the contrast in duality found in RECURF is hardly found in any of the other biocomposites. Most of the composites made use of one kind of quality in the whole product. There is an opportunity for RECURF to exploit this advantage.

DenimX is a composite that is very similar to the RECURF material. It also consists of a combination of both textile fibers as well as plastic, and looks very similar to the denim RECURF material. The difference between DenimX and RECURF is that the DenimX project uses different types of plastics based on the application of the composite. Whereas RECURF only makes use of the biobased PLA, DenimX also uses petroleum-based plastics. In addition, DenimX does not use any contrast in duality in its products.

The production process of DenimX products and the other composites is mostly done with the use of three-dimensional moulds. This method can create three-dimensional products, which are also strong and stiff. It is an efficient method but leaves little room for exploration, since altering the shape of the mould is very limited.

Conclusion

It can be concluded that biofiber composites are often used in interior design and are structural at the same time.
The duality in these composites is hardly made of use. This is also the case for DenimX, which is comparable to RECURF. Using the contrast in duality for RECURF is a unique possibility. It was apparent in the benchmarking process that all the products were produced in a heat press, using three-dimensional moulds.

Figure 23. A sample of DenimX. [12]

4.3 Zooming In: Past RECURF Projects

Three past RECURF projects were particularly interesting to examine in light of the current project.

Shielding at office desk
Dennis de Vries, post-graduate at the AUAS designed an acoustic and visual shielding to be used at the flex desks at the office. RECURF has great acoustic damping qualities in its soft state. Therefore he used the material to create a form of privacy in the modern office.

Origami
Ties Westerhuis, student at the AUAS, created a method of making small origami pieces using laser cutting and thin sheets of RECURF. The laser cuts a dotted line in an origami pattern, after which the sheet needs to be folded in that shape, just like a piece of paper. The dotted lines help bending at the right position and give the fold a bit more flexibility. During other experiments Westerhuis added a woven textile behind the RECURF for better flexibility.

Micro moulding
The machine in figure 24C was designed by independent designer Bas Froon. It is made to inspire local production. It can press and heat all kinds of patterns in a soft sheet of RECURF. It can create a soft non-woven material with a hard pattern on it, which does not tear when a force is exerted on it. The pattern can be sent in digitally. The machine uses CNC to manoeuvre the material using two axes.
Bas Froon's work shows that, in addition to products, designers can also design machines to create new methods of producing.

Conclusion
These three projects are all inspirational for this project. The shielding product shows hard and soft RECURF to some degree, creating more duality, while the origami project gives an example of how origami can be applied. The machine by Bas Froon is in essence a demonstrational machine. It is made to inspire.

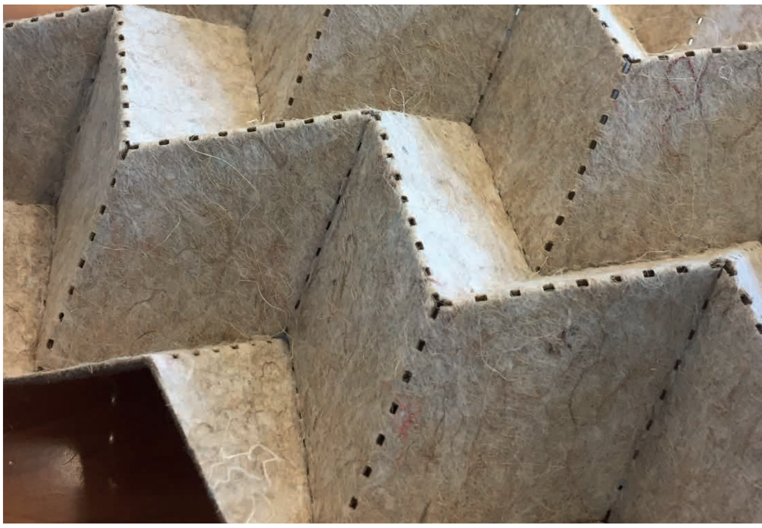


Figure 24. A, B and C. Top image(A), the shielding at office desk by Dennis de Vries, middle (B) image presents the origami by Ties Westerhuis and the lowest image(C) shows Bas Froom with his machine. [13]

4.4 Benchmark Origami

Given that we apply origami to the RECURF material, a benchmark has been conducted exploring origami. Origami is a widely used folding art originating from Japan. With this benchmark, we focused mainly on origami used in user products and interior design.

Figure 25. Studio Confused Direction made : Poissonmobile [14]

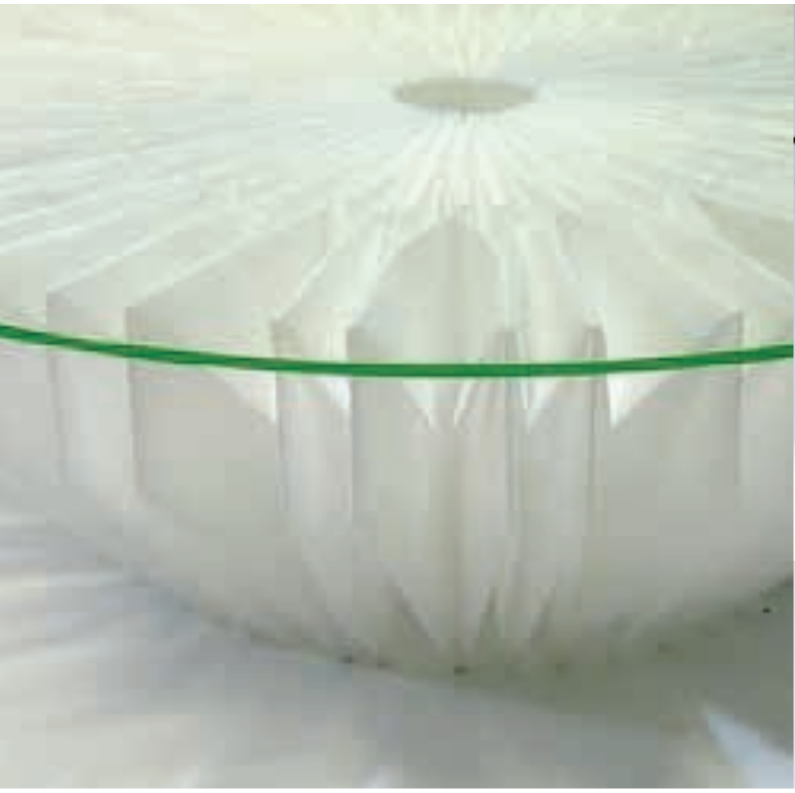


Figure 28. La table Lotus by Tian Zhen [15]

Figure 29. 4 fold low table by British designer George Rice for Formtank [16]

Figure 26. Clouds by Ronan and Erwan Bouroullec [17]

Figure 27. Florian Kräutli magnetic curtain [18]

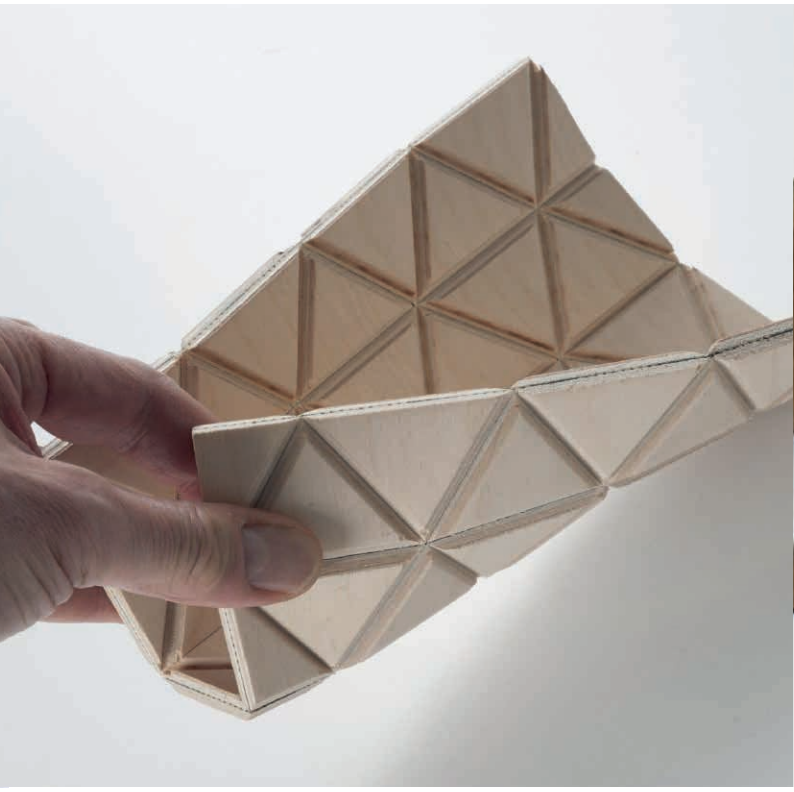


Figure 30. Wood Skin wall element [19]

Figure 31. Adjustable packaging by Patrick Sung [20]

Figure 32. beanbag made by Mathieu Lehanneur [21]

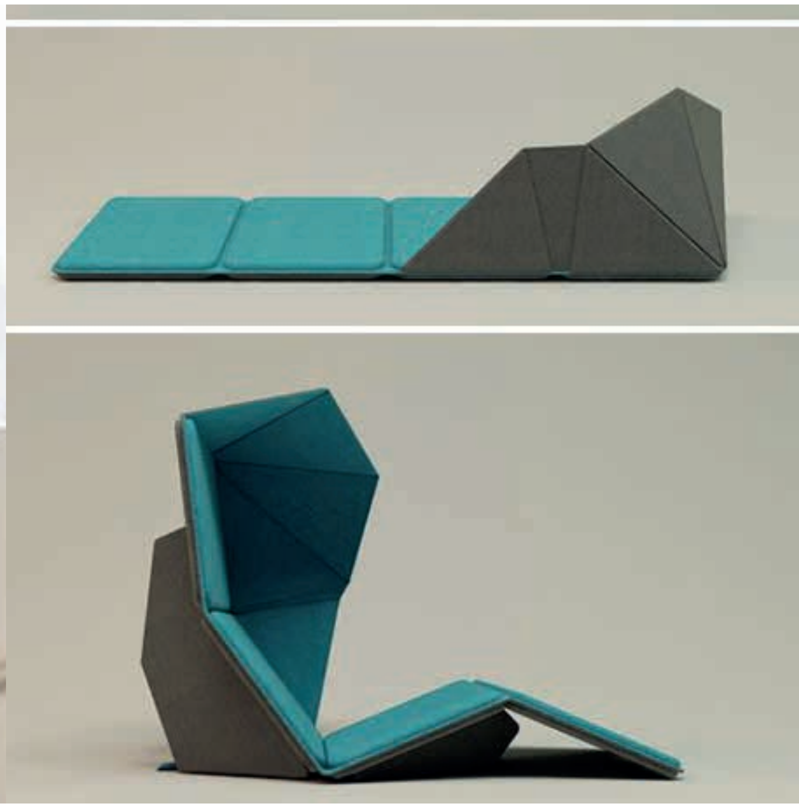


Figure 33. The RESMO by Chien-Hui Ko [22]

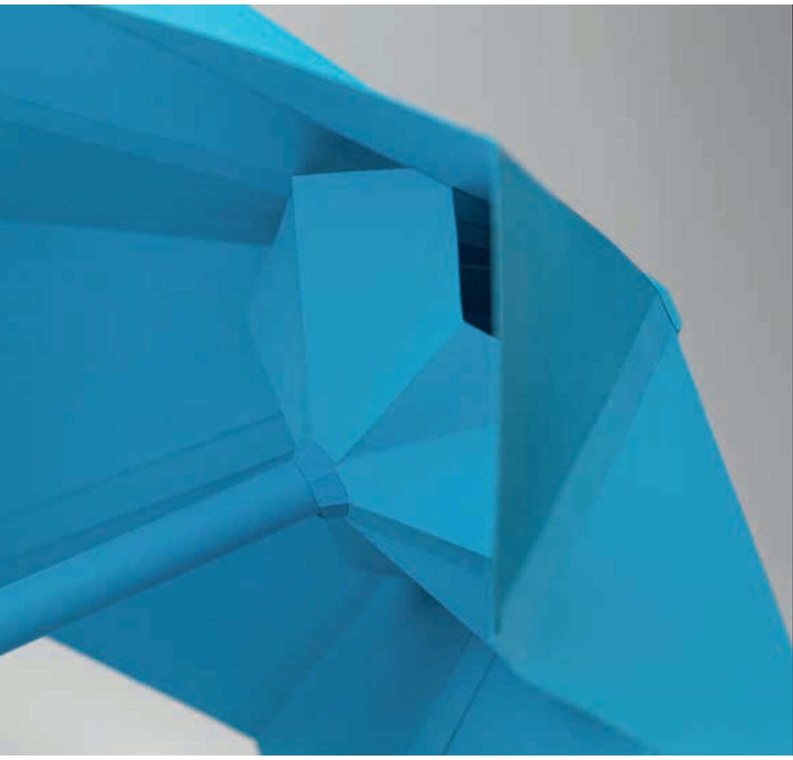


Figure 34. Umbrella By Matthew Waldman of Nooka fame and Justin Nagelberg [23]

Figure 35. Folding Chair by Gregg Fleishman [24]

Many products with origami use a material other than paper. These products are often in need of more strength or stiffness, or in some cases even more flexibility (for example the beanbag in figure 32). Paper is a very fragile material and therefore not useful for products that require, for example, user interactions, strength, or water spillings.

It should be noted that these products do not use origami for the same reasons. There are three different categories these products fall into: Two-dimensional to-three dimensional products, products with origami for aesthetic purposes, and products that require the foldability of origami.
Since origami can be seen as the art of folding a flat piece of paper into a three-dimensional figure, this could be extrapolated to folding a flat sheet of a different material, steel for example, into a three-dimensional shape such as a chair or table.
Products can also use origami for its appearance. Many of the products that do this use the geometrical look of origami tessellations. Such a pattern can add to the performative quality of the material due to the foldability of origami. This quality could be explained by someone who looks at the origami and knows from experience that it can fold, but it is unclear how it will behave during folding. This can create curiosity and attract people to touch it and test how it behaves. Take for instance the Magnetical Curtain in figure 27. Every time someone touches and plays with the curtain, it behaves differently and unexpectedly.
The last group of products using origami are those that need the functional folding capabilities in a product to expand or retract a surface. The umbrella in figure 34 is an example of a product that needs the foldability of origami to open or close.

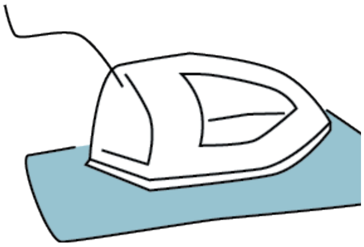
Conclusion

Origami made from different materials is often used in product design. It has three useful areas in which it is applicable. It can be used to fold two-dimensional sheets into three-dimensional products. The application of origami can also be used to change appearance. Finally, origami can be functional for the product itself when it needs folding, expanding or retracting.

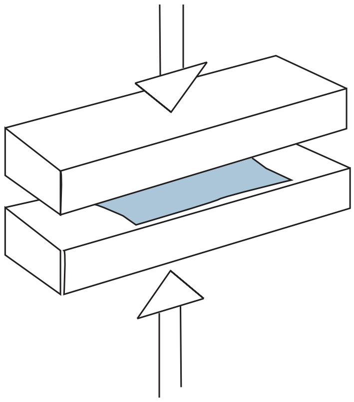
4.5 Benchmark Existing RECURF Production Processes

In figure 36, seven different production processes are compared on the basis of their functional properties and ability to produce a contrast in duality in the RECURF material. This gives new insight into what is possible when producing RECURF. All of the production processes in this benchmark are methods of heating and pressing, which are the most viable methods for creating a contrast in duality in the RECURF material. Additionally, the heating and pressing is also the most used production process applied to RECURF at the AUAS.

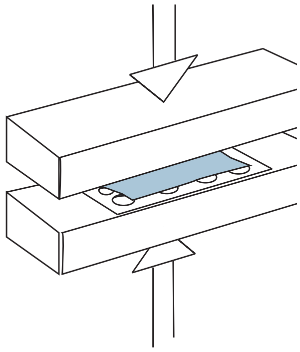
Prodution methods for heating and pressing RECURF



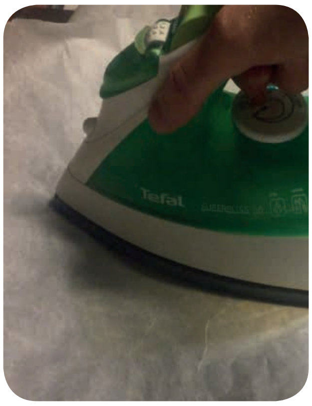
The iron



Heat press



Heat press with moulds

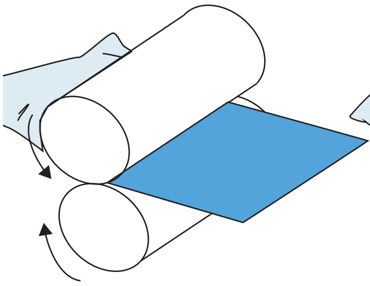


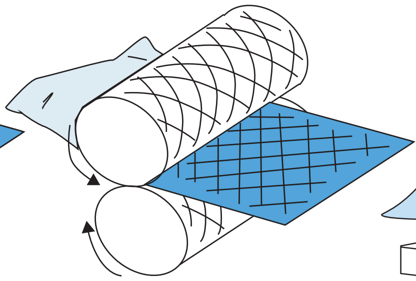
Properties	The iron	Heat press	Heat press with moulds
Heating	yes	yes	yes
Force	no	yes	yes
pressing area	medium	medium	medium
speed	low	low	low
Versitility during prototyping	high	low	medium

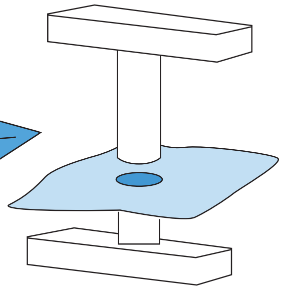
Possibility to create contrast in duality

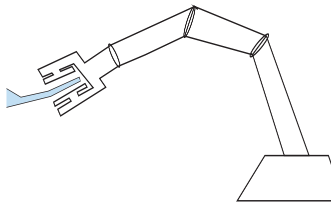
Flexible / stiff	low	medium	high
Hard / soft	high	low	medium
2d / 3d	medium	low	medium
Smooth / textured	medium	low	high

Figure 36. An overview of the production processes



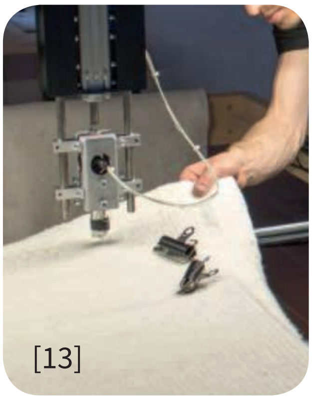


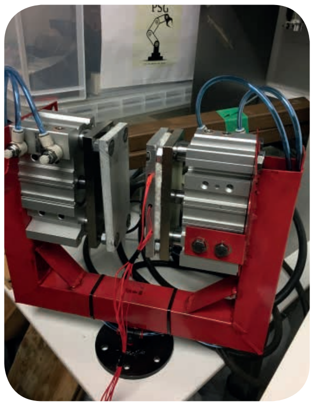




[25]


[26]


[13]



Rolling	Rolling with mould	Micro moulding	Robot arm with heating gripper
yes	yes	yes	yes
yes	yes	yes	yes
large	large	small	medium
high	high	low	low
low	low	high	high
medium	high	high	high
low	medium	high	high
low	medium	medium	high
low	medium	low	high
Not available at the AUAS	Not available at the AUAS	Not available at the AUAS	Prototype not working

Our first observation is that the production processes used on RECURF almost never simultaneously have strength as well as versatility in positioning. The iron is versatile as regards positioning but cannot press, whereas the rolling machine can create high pressure but is not versatile, as it has fixed positioning and patterns. One reason for this is that high pressure generally requires a strong and stiff frame to absorb the high amount of force. Meanwhile making it versatile means that it has to be able to move easily, which is an engineering challenge given that the press has a strong, large and heavy frame. Nonetheless, one machine did combine versatility and strength, namely the heated gripper on a robot arm. However, this machine, which is located at the AUAS, is currently not functional due to constructional problems. The machine does have some constraints, as it cannot press sheets of RECURF that are wider in size than the size of the gripper.

We also noticed during this benchmark that some contrasts in duality cannot be created with all production processes.

Flexible - stiff
When we look at the duality of flexibility and stiffness, so whether it is flexible enough to bend or so stiff that it cannot, we observed that these properties are achieved through changes in pressure and temperature. This contrast is difficult to achieve when using the iron as it does not have the high pressure capabilities necessary to create this stiffness.

Hard - soft
When using the heat press or the rolling machine, the duality of hard and soft can only be achieved with the use of moulds. This is due to the fact that without the moulds these production processes heat and press only on one level. This means that the whole surface is treated with the same amount of heat and pressure, creating a homogeneous texture without any contrast.

Conclusion

It can be concluded that the production processes used when heating and pressing large surfaces of RECURF are often not very versatile, as they tend to be restricted in terms of positioning. Nonetheless, these large surface production processes are often capable of achieving high pressure when pressing. This contrasts the production processes used when pressing and heating smaller surfaces of RECURF. These production processes for smaller surfaces tend to be versatile in terms of positioning, but lack the capabilities to apply a high amount of pressure when pressing.
Constraints in terms of versatility and strength influence whether the production processes are able to create contrasts in duality. Out of all the production processes, the heated gripper on the robot arm manages to best combine these two factors, as it has both the high pressure capability as well as the versatility to create contrasts in flexible and stiff, and hard and soft. However, the heated gripper on the robot arm cannot press and heat large surfaces, and therefore is not a viable production process for this project.

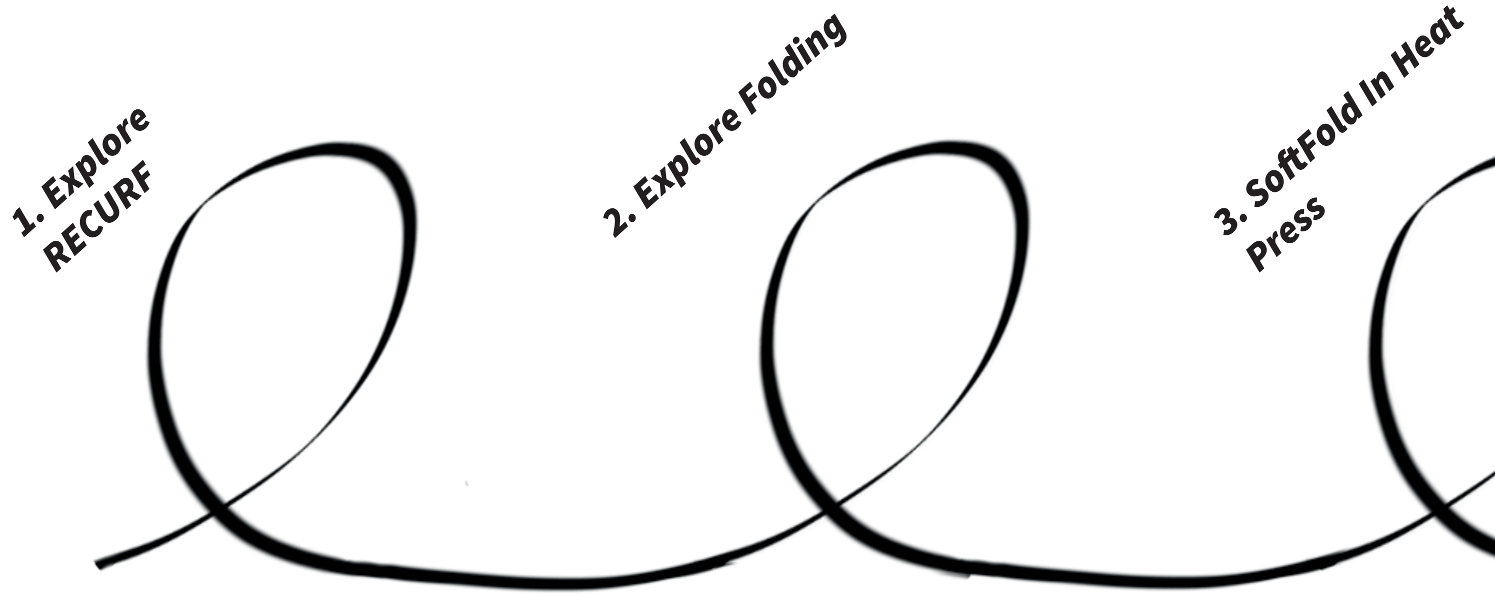
5. Tinkering: An Exploration Of Folding

5.1 Introduction

Tinkering is part of the first step of the MDD. method, which is ‘understanding the material’ (Karana et al., 2015). As we have a specific goal for our project, namely to shorten the gestation period of the RECURF material by producing a demonstrator project, we will not be tinkering aimlessly but with that direction in mind. As mentioned in the project description, we aim to combine the contrast in duality of the RECURF material, found by Blauwhoff, with origami.

This framework will first be explained,followed by an explanation of the variables, after which we detail the multiple tinkering sessions undertaken.

In figure 37 below an overview of all of the tinkering sessions is visualized. The boxes show the key samples of each tinkering session, which we then used as orientation for our next tinkering session.



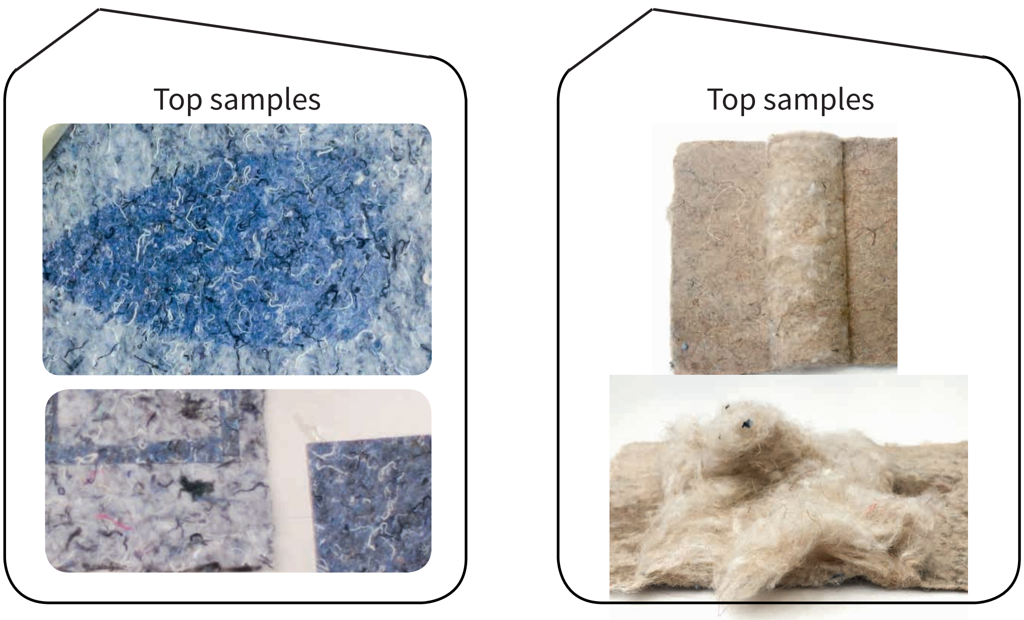


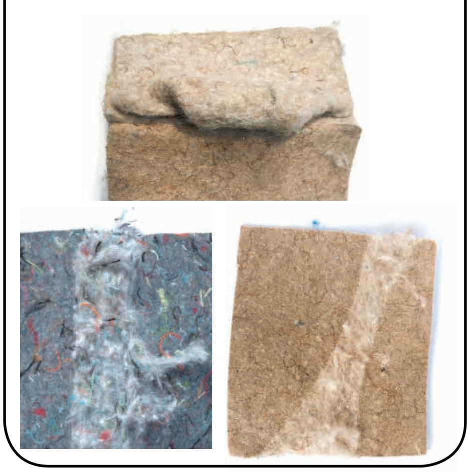
Fig. 37. all the tinkering steps and key samples. For more information about these steps ands samples, the corresponding chapters will give insight.

4. Explore Chaotic Folding

5. Folding Origami

Top samples

Top samples



Top samples

Framework

Blauwhoff's tinkering with non-woven RECURF material revealed duality as one of its prominent unique qualities. She discovered that RECURF has several material qualities that can be on either side of a spectrum, these being:

- Hard - Soft
- Smooth - Textured
- Flexible - Stiff
- Two dimensional - Three dimensional

These material qualities were achieved through changes in the material's variables and through varied production methods during the tinkering process. Origami has the ability
to enhance the contrast in duality of two-dimensional to a three-dimensional, because with origami a flat sheet can folds to a three dimensional object. Applying origami to RECURF changes the way RECURF is perceived as it makes it three-dimensional and adds geometric patterns. Thus, the main objective of our tinkering process is to explore how to create origami by 'folding' RECURF. During the tinkering process we will concentrate on two factors when deciding whether to continue with a certain direction or not. These are:
The duality of the material
The feasibility of production processes and pre- and post-manufacturing

We will be tinkering in several successive sessions, with each session assigned its own objective. he objective and corresponding background information and context of the session will be explained before each tinkering session.
After the tinkering sessions, we should have better insight into the technical properties of the material, the constraints and opportunities of the material, and the possible production processes, including which is most convenient.

Variables

The AUAS provided the area, equipment and materials for all tinkering sessions. This means that this iterative process is constrained by a framework of variables. These variables can be divided into three groups: material features, production processes, and pre- and post-manufacturing. This is visible in figure 38A.

Material features
At the AUAS several different types of non-woven sheets of RECURF are available for tinkering. These different types of non-woven sheets differ from each other in composition. The variables in these non-woven RECURF material sheets are the type of PLA used and the different types of fibers. The PLA comes in two kinds, normal and Bi-Component (BiCo). The normal PLA melts at 180° C. The BiCo PLA exists out of two kinds of PLA, one that melts at 120° C and another that melts at 180℃.

The different PLA's are:
- PLA melting at 180° C
- BiCo PLA melting at 120° and 180° Celsius

The different fibers are:
- Burlap fibers
- Denim fibers
- Wool fibers

Production processes
The production processes that can (and have been successfully tested to) manipulate non-woven RECURF are shown in the Benchmark (chapter 4). Of these different kinds of production processes, a heat press, an oven, and an iron were available for use at the AUAS during the tinkering process. These machines were able to adjust temperature, pressure and time. Several flat rectangular metal plates were available to use as moulds (3 mm thick). It was also possible to create other shapes of 3 mm thick flat moulds.

Pre- and post-manufacturing
Pre-and post-manufacturing is the editing done to the RECURF before and after the production process. This consists of :

- The amount of layers stacked
- Orientation of the layers
- Size of the layers
- Cutting or ripping
- Use of baking paper
- Pre-heating and pressing
- Solidifying in a shape

In the figure below the steps in the tinkering process are visualized. The process begins with soft non-woven on rolls. The second step is the pre-manufacturing, followed by the third step, which is the main production process. The fourth step is post- manufacturing. It is always possible to take the end product, combine it with a soft sheet, and repeat several steps.

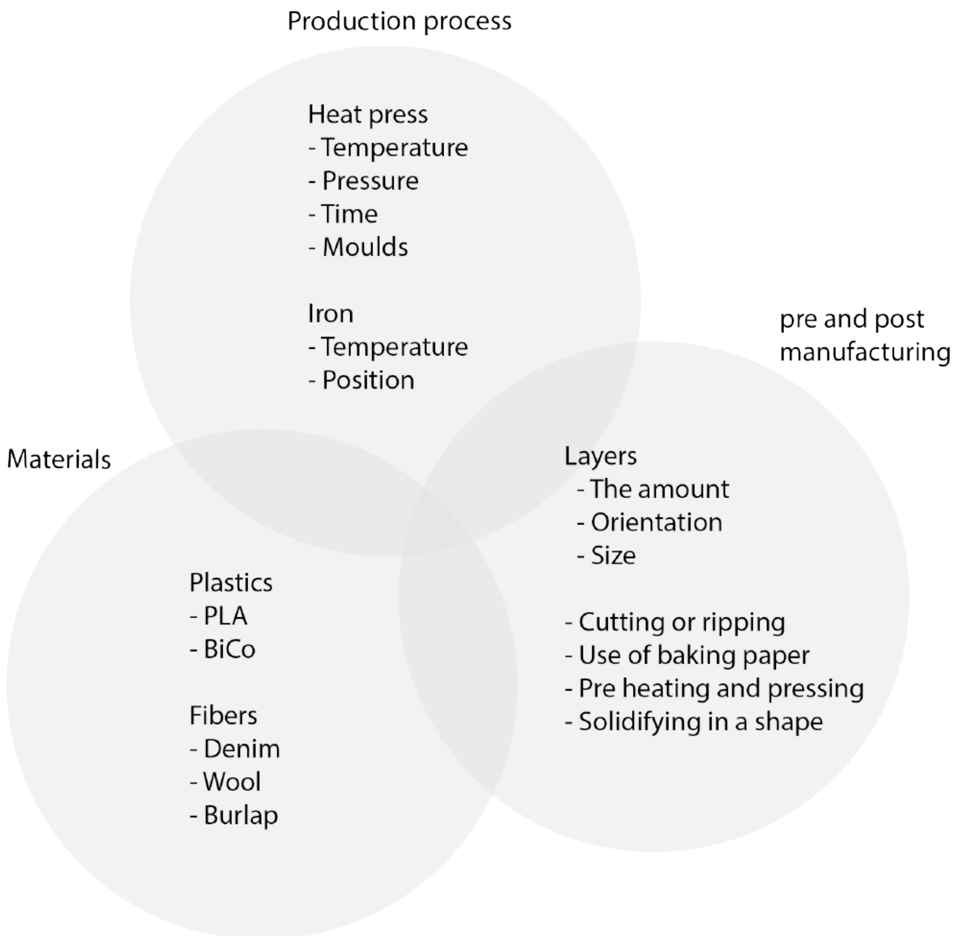


Figure 38-A. An overview of the used variables

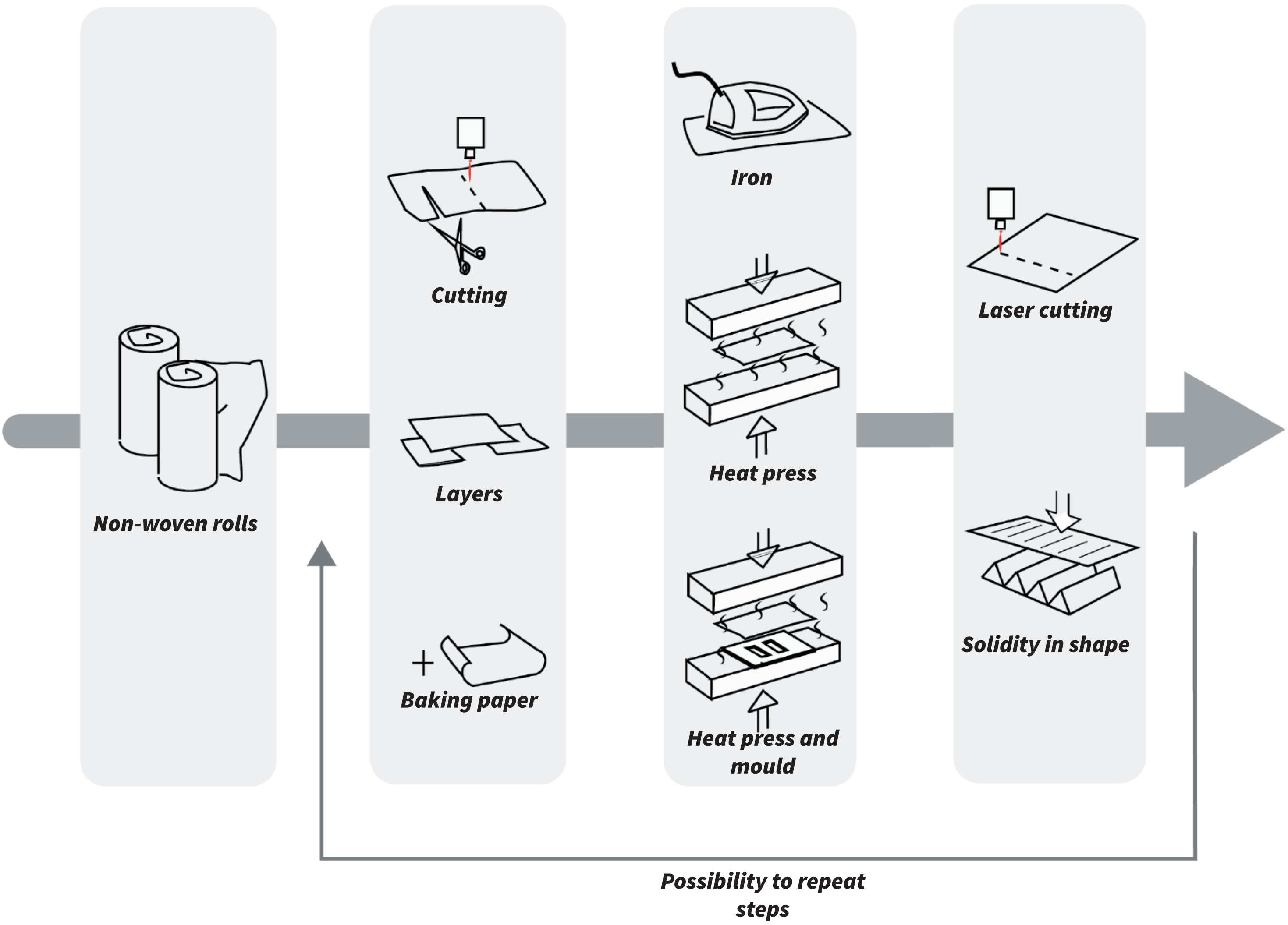


Figure 38-B. An overview of the steps taken during tinkering.

‘Folding’ definition

To create origami with RECURF the material first needs to be ‘folded’. Before we can actually get into the folding, however, we have to get a better understanding of what we define as a fold.
According to the Cambridge dictionary ‘Folding’ means “to bend something, especially paper or cloth, so that one part of it lies on the other part, or to be able to be bent in this way”. However, in this explanation the word ‘bending’ is used which makes it difficult as ‘bending’ is an accepted technical term that is not the same as the definition of a fold that we are using.
To explain what we define as a fold we will examine the differences between a fold and a bend.

‘Bending’ a material in technical terms is explained in the book ‘Industrial production’ by Kals et al. (2009) as a reshape process. When being bent, a material stretches on one side and becomes compressed on the other. This causes an angular rotation in the material. According to Lauff et al. (2014, p. 6) “A bend entails distributed curvature caused by deformation. Bending is the distributed deformation of a material along the deflected area that creates curvature. “Where a fold differs from a bend lies in the area where the curvature of the material can take place. Lauff et al. (2014, p. 6) define a fold as such:, “A fold entails localized curvature caused by deformation along a crease pattern. Folding is localized deformation of a material along crease patterns to create new shapes.”
This definition of a fold is not yet a term that is implemented industry-wide However, as it accurately describes how we are going to apply origami in our work, the term folding will be used in this project to describe localized deformation along a crease line.

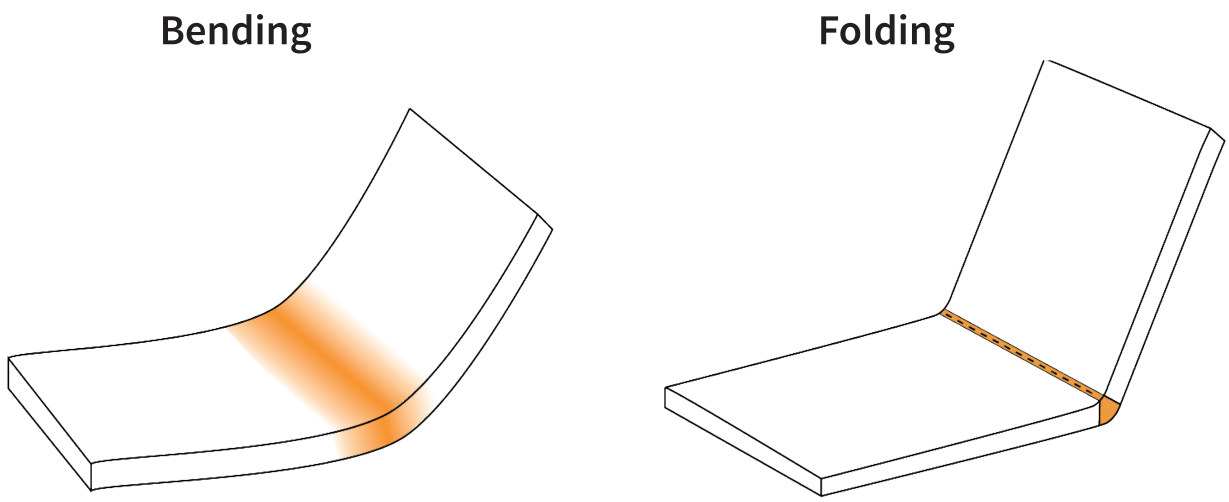


Figure 39. The difference between bending and folding. Where a fold differs from a bend lies in the area where the curvature of the material can take place. For a fold this area is localized.

Origami

Origami is often seen as the Japanese art of paper folding, but it has exceeded that definition. It is used in many fields besides art. Examples can be found in product design (Jackson, P., 2011), architecture (Liapi, 2002) and in engineering (Lauff. C., et al., 2014). Chapter #, Benchmarking, provides several examples of how origami can be applied. This project is focused on the use of origami in product design. This is evidently connected to engineering with origami as products needs to meet certain technical requirements.

The folding of a material can be seen as the foundation of origami. Applying folding techniques to another material when applied in the field of design and engineering creates many new challenges, including for instance, how to fold, changes in function, and changes in strength and appearance. Paper is so thin it can be deformed locally by folding the paper together. Materials used in design and engineering often do not share this thinness because a much larger thickness is often needed for strength, stiffness and other properties. Due to these differences in thickness, as well as inherent differences in material properties, other materials do not react the same way paper does when an attempt is made to fold them.

The kind of origami that we will be aiming for during the tinkering process is the tessellating type . As seen in the Benchmark (chapter 4), there are numerous kinds of origami for all kinds of purposes. Tessellation origami consists of repetitive patterns that can be applied to a flat material of any size, as only the amount of repetitions changes.

At this point, aiming for a larger variation of origami patterns with RECURF would be too ambitious as there is not much known yet about the folding properties of RECURF.

Figure 40. A unique piece of origami. No tessellation patternsv[27]

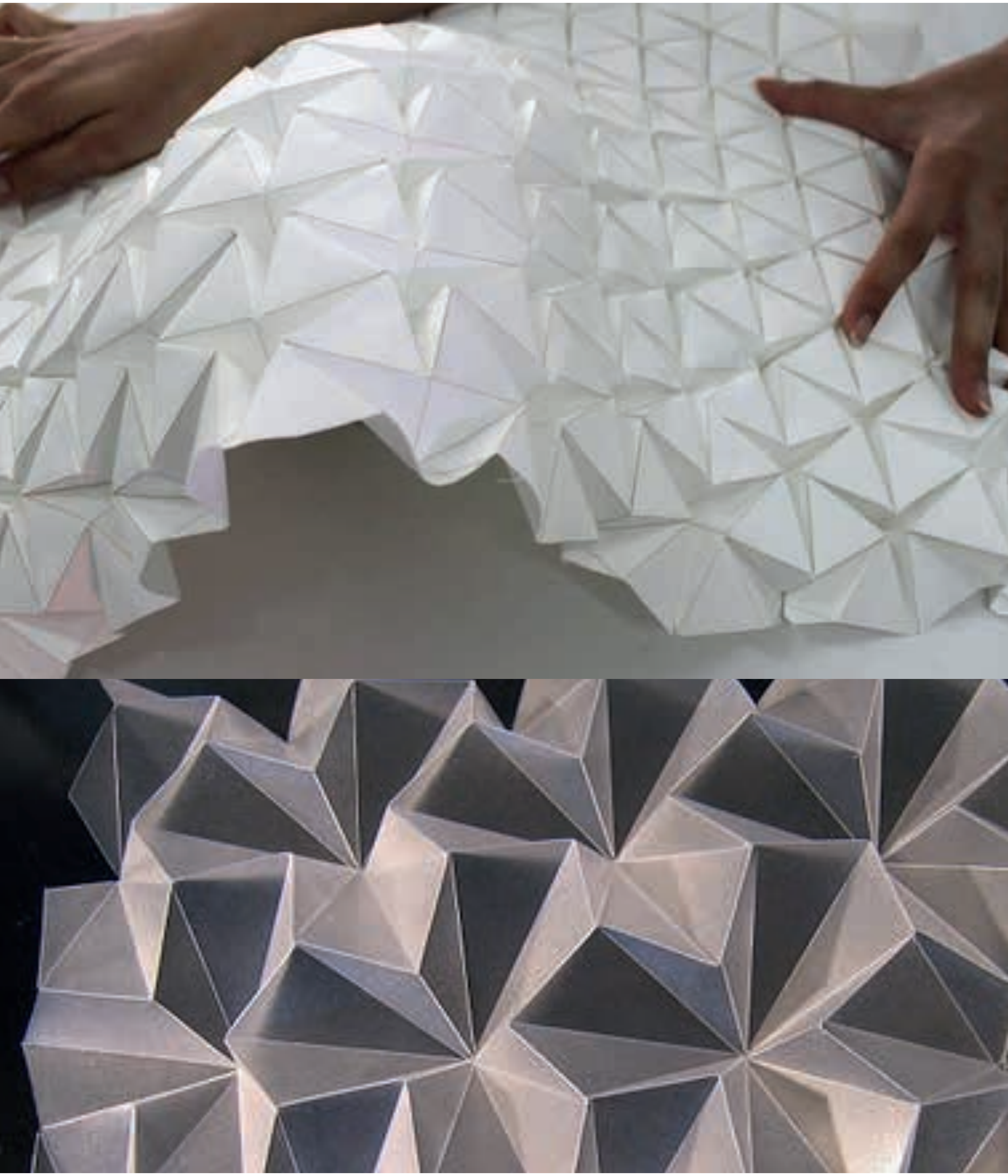


Figure 41 A and B. The top image is a tessellating sheet of origami. The lower figure shows a piece of mountain and valley origami by Rachel Pierce [28][29]

5.2 Tinkering #1: Explore RECURF

Objective

The first session is mainly to explore RECURF in general. At the AUAS, many RECURF samples belonging to other students are widely available to see and touch. The soft sheets of non-woven RECURF are available on rolls that are 2 meters wide. During this exploration, we will tinker with all available material variations and production processes to get a better understanding of the RECURF material and to see how it responds to different conditions.

Denim RECURF

Soft denim RECURF appears light blue in colour. The individual fibers are in the range of white to dark blue. This causes a blended look. The unmodified non-woven material is soft to the touch and it is clear that it is only loosely needled together. It is possible to pull areas of fibers out, or even to tear a piece of sheet in two. It handles like a textile when, for example, folding, compressing or pulling the material.

When denim RECURF is heated and pressed in the heat press or under the iron to the point that all of the PLA has melted, the average colour changes from light blue to a dark blue. The sheet becomes relatively hard and flat. The range of how hard and how flat is dependent on the production process and its variables: temperature, pressure, time and amount of layers. The white fibers in the hard sheet are suddenly the most contrasting fibers compared to the average dark blue colour. Its surface is in most samples smooth when pressed under the heat press. Pressing and heating the material with an iron causes a thicker sheet, with a rougher surface texture.

Burlap RECURF

Burlap RECURF is light brown or beige in colour. The colours of the individual fibers are more consistent because the burlap fibers are all the same color beige and the PLA fibers are all white, leading to a mix that has a light brown or beige colour. The non-woven burlap is about just as loosely needled together as the denim. A natural quality of burlap is that it feels rough. This is the same with the non-woven burlap, but to a lesser extent because the PLA fibers are much softer. The sheet of non-woven burlap also behaves like a regular textile sheet, but in comparison to the denim is less supple.

When non-woven burlap RECURF is heated and pressed it becomes hard and flat,similar to the denim. The colour changes from light beige to slightly darkish beige. The material reacts differently to heat and pressure than denim in that it appears to need less pressure or time to become completely molten. The heated burlap sheets also feel stiffer than denim. The tactile properties of the heated burlap sheet can vary a lot. Some samples have a rough, fibrous surface on top, while the bottom surface is almost smooth.

Wool RECURF

The non-woven wool samples are a mixture of light gray fibers and a small percentage of brightly coloured fibers. The non-woven wool is also loosely needled together, soft to touch, softer than the denim or burlap, and it behaves like a textile.

When heated and pressed the wool becomes hard and stiff. It changes from light gray to dark gray. The texture of the material can be smooth, but also rough. How this can be influenced is currently unclear.

The burlap and denim were both tested in Blauwhoff's research on experiential values. Wool was not tested. Therefore, burlap and denim were used more in this tinkering to allow for the possibility of a continuation of this research.

PLA / BiCo

BiCo is added to all the different textiles fibers, just like the PLA. The difference between PLA RECURF and BiCo RECURF is noticeable. The material is valued more by the students working with RECURF at the AUAS because after heating and pressing, it is lighter in colour and often softer. It is easier to work with in the heat press because it sticks less to the backing paper and is made with lower temperatures, so it cools faster. The downsides are that BiCo RECURF often warps after heating. It also feels less stiff than regular RECURF.

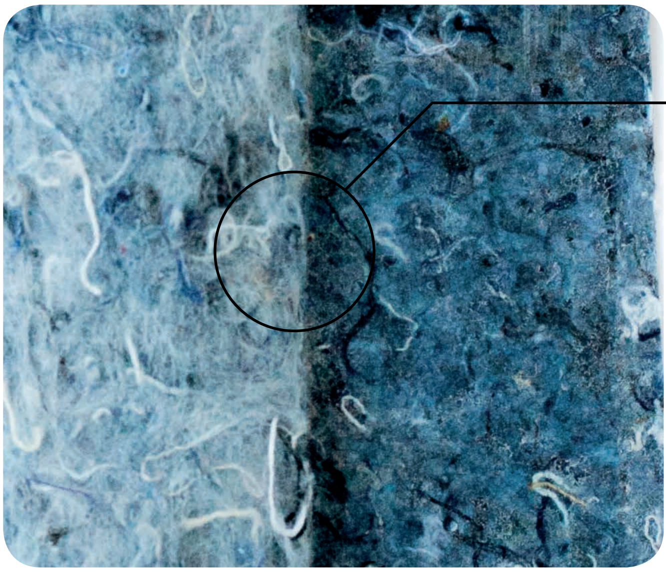


Figure 42. Soft RECURF is lighter in colour than the hard (heated) areas

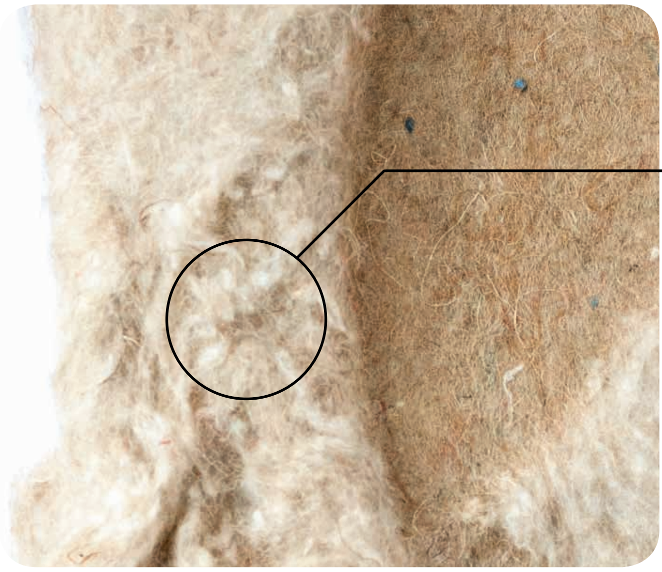


Figure 43. Visible is the loose needling in the soft areas

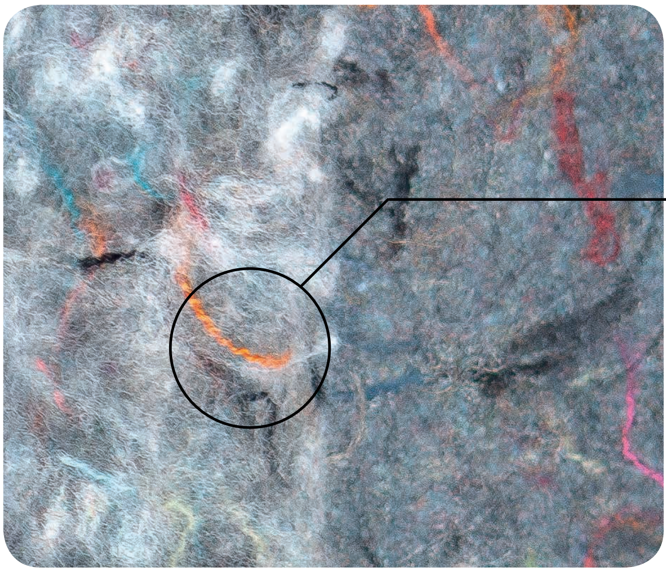


Figure 44. Clear distinction between PLA fibers (white) and textile fibers (colourful and gray)

Heat press

The heat press can press up to 300 Kilo Newton, has a surface of 40 x 40 centimeters and can heat up to far above 200 degrees. Heat is needed to melt the PLA so it encapsulates the textile fibers.
If a stiff and flat plate is the goal, the non-woven material needs to be pressed while being heated. This creates a homogeneous material, where the fibers are encapsulated by the molten plastic. The press presses all of the air out of the material, which could cause weaknesses.

Iron

The advantage of the iron is that it is very flexible and easy to use when heating local areas on a sheet. It is possible to 'draw' a path of molten RECURF on a sheet. The downside is that the iron can only apply pressure if the user leans on it. Using this method we could not create nearly as much pressure as the heat press does. The RECURF melts using the iron, but after it solidifies the sheet is not nearly as flat or stiff as the samples pressed by the heat press. The sheet still behaves as a textile, but is slightly less flexible. One of the downsides of pressing with an iron is that even though the topside of the RECURF melts well, the bottom side does not. The heat does not reach the bottom side fast enough before the top side begins to smell burned.

Pre- and post-production

Stacking multiple layers of RECURF onto each other before pressing the stack creates a much thicker and stiffer layer after heat pressing.

Conclusions

The dualities found by Blauwhoff are evidently seen in this exploration. The key to most of the four dualities is heat. When melting only a part of the RECURF sheet much of the duality becomes visible and tactile. The contrast between hard and soft was for instance directly visible after heating half a sample. The smooth and textured surface was visible in a sample that had a smooth bottom side but a rough top side. Stiff and flexible states were visible between a soft sample, ironed sample and a heat pressed sample. The contrast between two -dimensional and three-dimensional was visible using the iron, folding a soft sample together and only heating part of the sample as seen in figure #.

It can be concluded that all the soft non-woven sheets are very loosely needled together. Denim and wool are soft, while burlap feels more rough. After heating RECURF, the surface texture can be smooth, textured and/or rough (burlap) dependent on the heating and pressure methods. When heat is applied to melt the RECURF locally it causes the duality of hard and soft. Pressure in combination with heat is important for stiffness and surface texture, whether it is smooth or rough. The heat press can make stiff flat sheets, unlike the iron, but the iron is more creative in use. Enough knowledge is gathered in this session to start exploring the possibilities of folding RECURF.

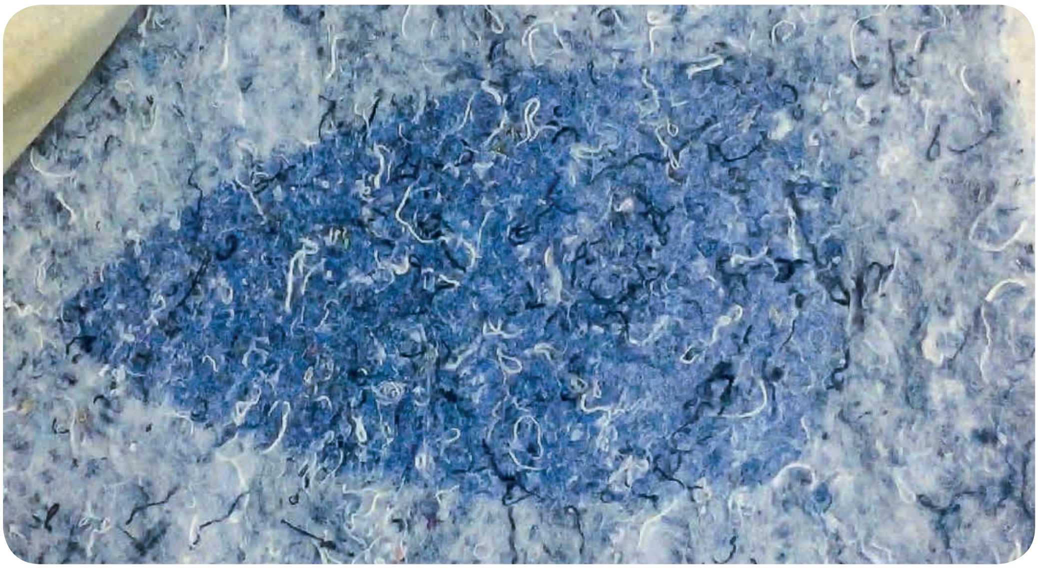


Figure 45. The imprint a iron leaves behind, after letting it stand on RECURF for 20 seconds. A clear contrast is visible between hard ans soft

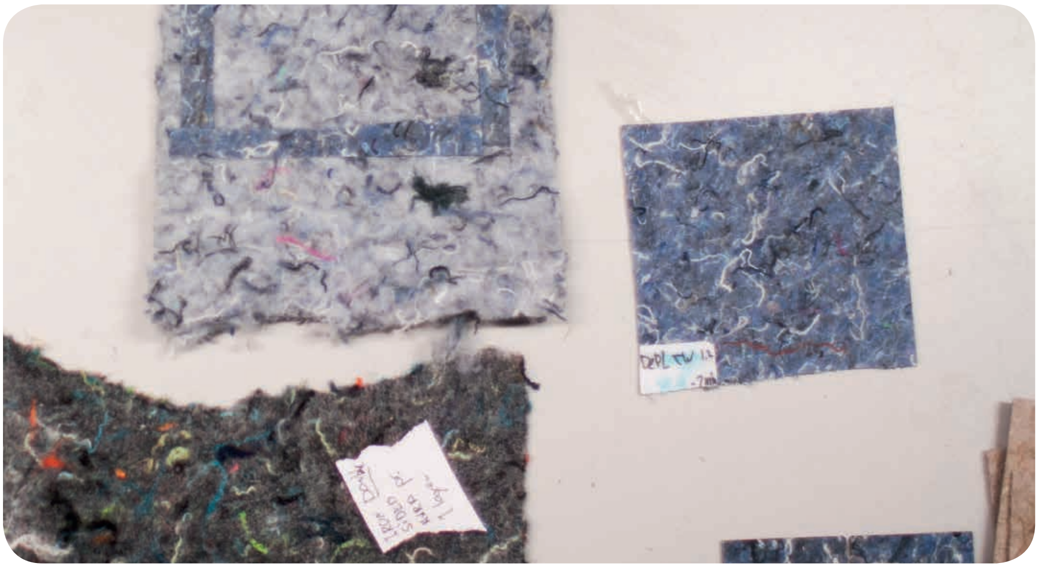


Figure 46. A overview of several samples made by students at the AUAS . The sample on the right is made with a heat press.

Figure 47. A soft sheet is Burlap RECURF can be torn in two by hand.

5.3 Tinkering #2: Explore Folding

Objective

The second tinkering session explores the folding of RECURF. One feature of a fold is that it has a crease line, fold line or hinge. The aim is to create such a feature with RECURF. In the benchmark we see that some folds have already been made with RECURF. These will be explored next to the exploration of new ways to fold. All the folds found are presented with their properties, constraints and opportunities.

Folding

There are in total six types of folds found. One of these folds were previously made with RECURF by other students of the AUAS and this sample was present at the AUAS for viewing. This can be seen in figure 48 .

There are two basic principles that are the foundation of the folds found .

The first principle is reduction of material at the fold line. When the material that is on the fold line is partly reduced, the stiffness and strength also reduce. This can cause a ‘weak’ area at the folding line. This area will fold more easily than the surrounding material and therefore it can be defined as a fold. The principle of reducing material was explored in the first and second folds.

Fold 1. Dotted fold

The first fold is made with a laser cutter. The laser cutter cuts away a dotted line, making this line weaker than the surrounding material. At this line the sheet deforms locally, creating a fold. This fold has two constraints that are similar to paper folding it folds only when forced into an angle, and after folding stays in this angle. This is caused by the deformation of the remaining material at the folding area. Since this material is thicker than paper, it is hard to fold it 180° degrees, laying the fold on top of itself. Another constraint is that this fold can only be made with BiCo RECURF because PLA RECURF behaves brittle when folding it more than once. The fold will break.

Fold 2. Engraved fold

The second fold is created by engraving a crease line with a laser cutter or knife. Engraving means the tool does not cut fully through the material, but cuts to a certain depth. The remaining material will deform when folded. This fold also stays in the angle you fold it in. The fold can be folded with the least resistance in one direction, away from the carved folding line. This fold can only be made with the BiCo RECURF because the PLA RECURF is too brittle. Engraving requires precise setting of the laser cutter, so it does not cut accidently through the RECURF, but engraves just deep enough. Creating corners is also quite difficult because when the laser slows down it cuts deeper into the material.

Fold 1. Dotted fold
figure 48. Sample made by Ties Westerhuis. Example of a laser cut fold on BiCo material. One of the 6 kinds of folds explored during this session.

Material: *Burlap BiCo*
Method: *Rolling*
Temp: *140°C*
Layers: *1*
Time: *unknown*
Force: *unknown*

Fold 2. Engraved fold
figure 49. An engraved fold. By cutting the upper half of a fold line, a fold is made.

Material: *Burlap PLA*
Method: *Heat press*
Temp: *180/180°C*
Layers: *2*
Time: *90 sec.*
Force: *30 kN*

The second principle by which folds are made makes use of the flexibility of the soft RECURF material. Here we create a fold by making a 'hinge like' area made of soft RECURF, while surrounded by hard RECURF. This property is applied to folds three to six.

Fold 3. Soft fold

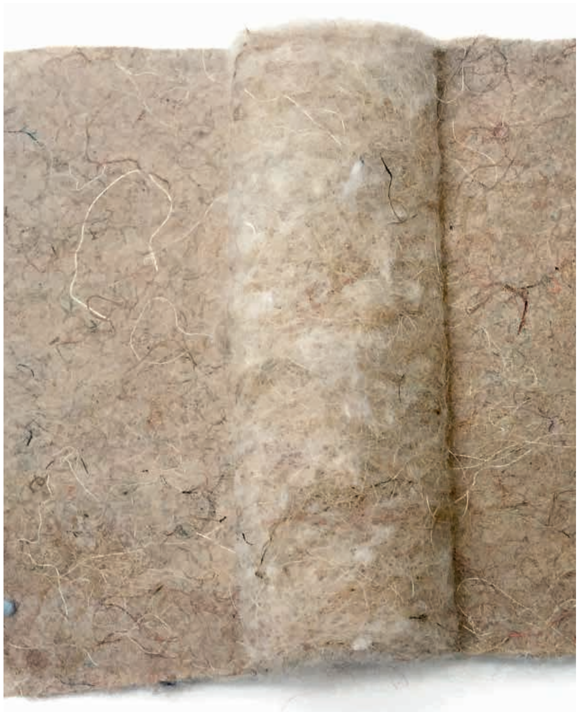
The third fold makes use of a sheet that is pressed and heated locally so the material that is part of the folding line does not get heated while the remaining area does. The soft RECURF can therefore fold. This fold behaves like a hinge, meaning it hardly needs any force to fold. This fold clearly shows the hard and soft duality of RECURF. The main constraint of this fold is that it will not stay at the angle in which you fold it. Additionally, following the results of a test on the tensile strength of the soft fold (see appendix B), we can also conclude that these soft folds are not very strong as they can withstand three to five times less force than a comparable unit of RECURF that has been uniformly heated and pressed. This fold can be achieved using a heat press in combination with a mould. The machine made by Bas Froon can also produce this fold.

Fold 4. PLA/BiCo fold

The fourth fold in figure 52 works by making use of the difference in melting temperature of PLA and BiCo. Only PLA is located at the folding line. The remaining areas have BiCo layers stacked. These BiCo layers will melt but not the PLA layer, which will stay soft. This fold behaves the same as the third fold. It is flexible, like a hinge. This also means it does not stay in the angle it is folded in. This method uses folds made of soft RECURF, enhancing the duality of hard and soft. Nevertheless, this duality is not clearly visible because all of the material is pressed together in the heat press. Therefore the soft material looks like the hard material, except for the colour which is less dark. The edges between hard and soft are also unclear. This method can be executed by a person or machine that places the different sheets at the right position on top of each other precisely, creating the right width of the fold. This needs to be placed carefully, without shifting the layers, in a heat press in order to heat and press the material.

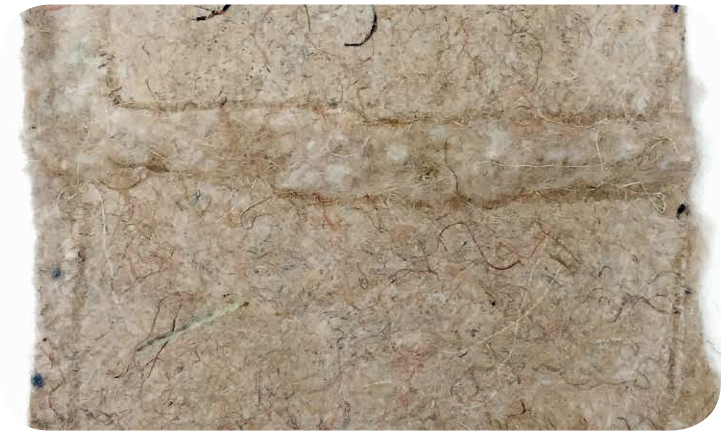
Fold 3. Soft fold
FIgure 50. Folding by using soft parts as fold. Clear contrast between hard and soft. Soft parts are orderded.

Material:	*Jute PLA*
Method:	*Heat press , sticking out*
Temp:	*180/180°C*
Layers:	*2*
Time:	*90 sec.*
Force:	*30 kN*



Fold 3
FIgure 51. Folding by using soft parts as fold. Choatic apprearence because of loose fibers. Dark spots are because of high pressure. It is too high for burlap.

Material:	*Jute PLA*
Method:	*Heat press , sticking out*
Temp:	*180/180°C*
Layers:	*2*
Time:	*90 sec.*
Force:	*150 kN*



Fold 4. PLA/BiCo fold
FIgure 52. Folding BiCo by with a middle layer PLA. The contrast between hard and soft is not clear.

Material:	*Jute PLA & BiCo*
Method:	*Heat press*
Temp:	*140/140°C*
Layers:	*3 - 1 - 3*
Time:	*90 sec.*
Force:	*30 kN*

Fold 5. Laser cut on soft fold

The fifth fold starts with a pressed and heated sheet of BiCo RECURF. The sheet needs to be (laser) cut at the folding line and its surrounding area. Then the hard part of the sheet can be placed on top of a soft part. This soft part can be a textile or a soft PLA RECURF sheet and it can be pressed and heated again to melt the hard material slightly, making it stick to the soft material. The soft material acts as a flexible hinge in the fold, and hardly needs any force to fold. This means it does not stay at the angle you bend it in. The soft material is pressed in this method, making it less visible that it is soft. The duality of hard and soft is less visible. Nevertheless, the boundary between hard and soft is distinct because the hard material is pressed and cut beforehand. This method can, similar to method 4, be executed by a person or machine that places the different sheets in the right position on top of each other. The sheets need to be placed carefully in a heat press to heat and press the material.

Fold 6. Invisible fold

This fold is called the invisible fold. This fold method makes use of the different amounts of layers. The hinging area can be made of just 1 layer of RECURF, while the remaining areas are made of 2 or more areas. These multiple layer areas are stiff, while the single layer is more flexible. Therefore the single layer can act as a folding line. The fold does not have a sharp form, like that of a paper fold. This could diminish the geometric shape found in origami.

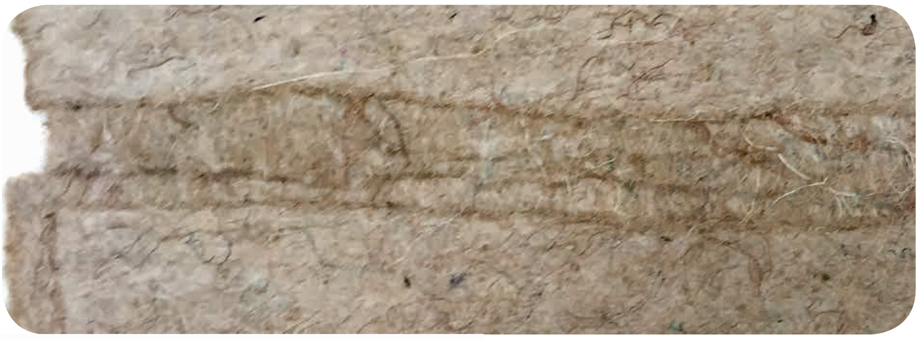
The fold behaves like a flexible hinge, which hardly requires any force to fold (after folding it a few times). It therefore, similar to folds 3 - 5, does not stay in the angle it is folded in. This fold does not contain any of the properties of the duality RECURF can possess. The fold is hardly visible in denim, while it is highly visible in burlap. This fold can only be made with the BiCo material because PLA RECURF is too brittle to be deformed and folded several times. Just like fold 4, this method can be executed by a person or machine that stacks the different sheets in the right position on top of each other precisely, creating the right fold width. These sheets needs to be placed carefully, without shifting the layers, in a heat press in order to heat and press the material.

Fold 5 Laser cut on soft fold
Figure 53. Sample made by Ties Westerhuis. Pressed RECURF is lasercut. After that the lasercut sheet is pressed again on a RECURF soft sheet made of virgin(white) cotton and PLA.

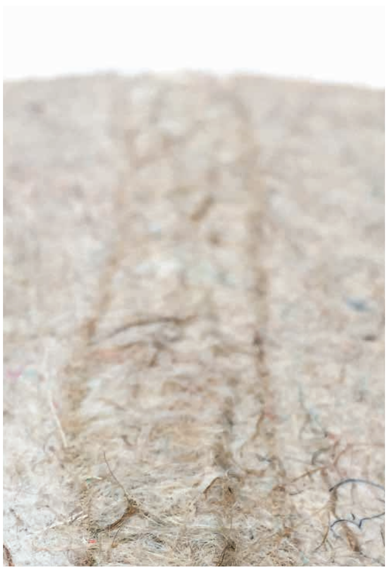
Material:	*Denim BiCo & Virgin PLA*
Method:	*Heat press 2x*
Temp:	*140/140°C*
Layers:	*1 - 1*
Time:	*90 sec.*
Force:	*150 kN*

Fold 6. Invisible fold
Figure 54. Invisible fold made of denim PLA. Folding area made with the use of the flexibility of a single layer . Surrounding area is 3 layers thick.

Material:	*Denim PLA*
Method:	*Heat press*
Temp:	*180/180°C*
Layers:	*3, fold has 1*
Time:	*90 sec.*
Force:	*150 kN*



Fold 6. Invisible fold
Figure 55. Invisible fold made of burlap PLA. Folding area made with the use of the flexibility of a single layer . Surrounding area is 3 layers thick. Not as invisible as the denim fold



Material:	*Jute BiCo*
Method:	*Heat press*
Temp:	*140/140°C*
Layers:	*3 -1 - 3*
Time:	*90 sec.*
Force:	*50 kN*

Conclusions

These six folds behave and look differently from one another.
The folds made with method 3, the soft straight fold and the chaotic fold seen in figure 56, have the most potential because they create a clear contrast between hard and soft, and also create opportunities in exploring this contrast in many different ways. The looseness of how the non-woven was needled together in combination with the width of the fold had influenced the chaotic fold. The other soft folds, folds 4 and 5, have the potential to enhance the contrast in duality with the use of moulds in the heat press, but this requires that they go through the heat press a second time. Fold number 3 can be pressed and heated in one single sheet to achieve the same result.
Folds 1, 2 and 6 do not make use of the duality of RECURF. These will not be further explored during this tinkering process. In scenarios where one of these three folds is needed, the feasibility of the production process plays a decisive role. The invisible fold can be beneficial on some occasions. However, folds 1 and 2 make use of (laser) cutters and are therefore more convenient in both production and precision because fewer manufacturing steps are needed and in addition, these folds make it possible to maintain the large structure of one single sheet of RECURF.

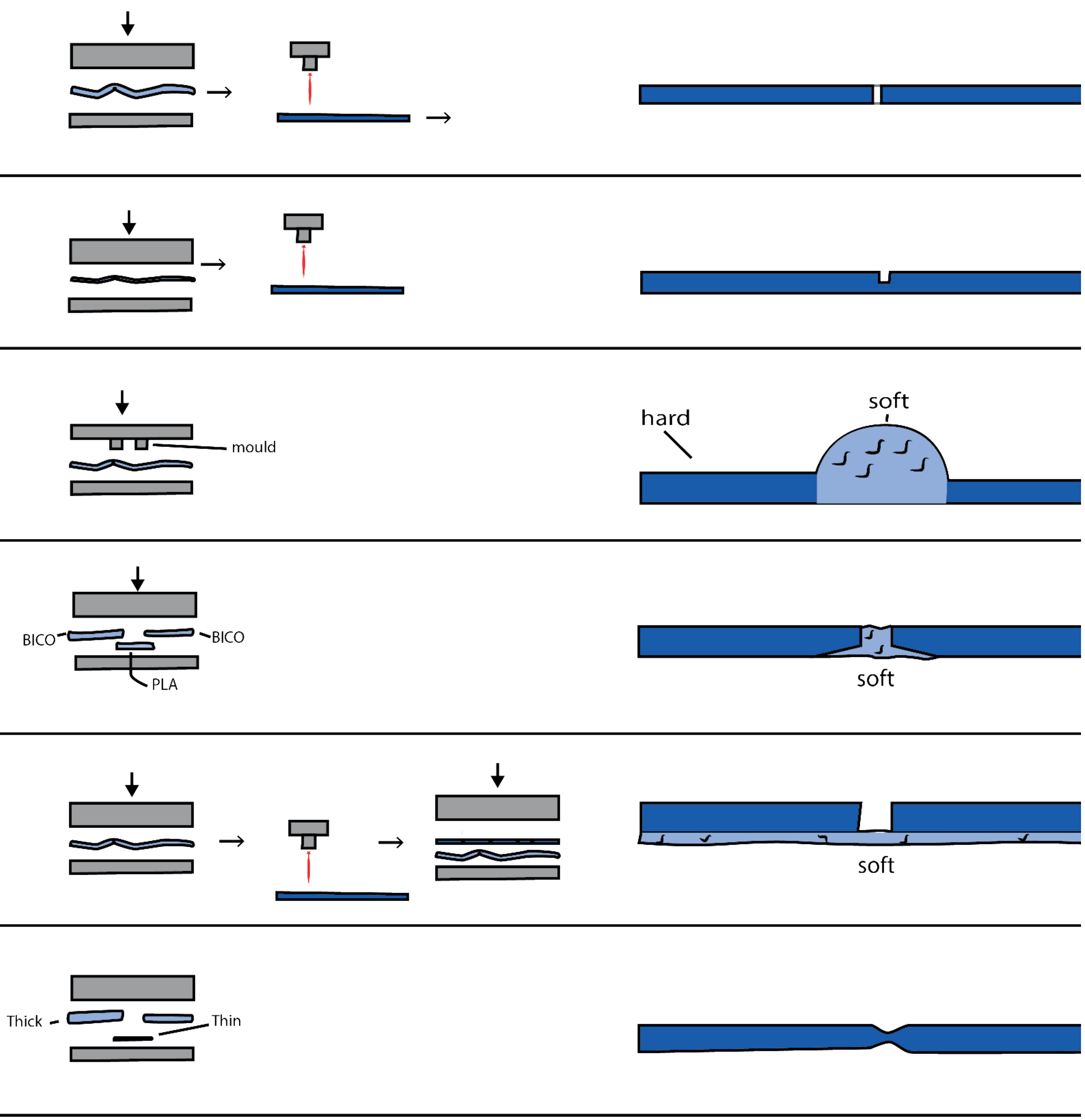
Figure 56 displays an overview of the 6 different ways to create folds in non-woven RECURF. The production steps are also shown.

Fold
Fold 1. Dotted fold
Fold 2. Engraved fold
Fold 3. Soft fold
Fold 4. PLA/ BiCo fold
Fold 5. Lasercut on soft fold
Fold 6. Invisible fold

Figure 56. An overview of the six ways RECURF can fold.

Production process

Side view of fold



5.4 Tinkering #3: Soft Fold In Heat Press

Objective

The soft folds during tinkering #2 were made while keeping the fold area outside of the press. This meant the RECURF sample needed to be pressed twice, one time for the left side of the fold, and one time for the right side.
When pressing multiple folds in patterns using one sheet of RECURF, all folds need to be pressed at one time using a large mould. The method of pressing twice is thus not possible. Therefore, we needed to explore how to create a soft fold by pressing only once. This could be done at the AUAS with use of a heat press and flat moulds.

The three different mould settings in figure 57 below were used. The height of the moulds and width of the fold were also varied.

As mentioned in the explanation of the framework, we are looking for samples with a contrast in duality. During this tinkering session #3, many samples failed to show this duality. Only the samples that came out best in terms of the contrast between hard and soft are presented. The other samples can be seen in appendix A.
During this session, the contrast in duality is explored by varying the materials (textile and kinds of PLA), the width of the fold, the amount of layers, the mould set up and thickness, and the the heat press settings.

Observations

Samples

Denim has a high contrast of hard and soft and also of light and dark blue. Burlap folds have less contrast in colour than the denim samples. Different widths create different looking folds. Folds with a smaller width needed more force to fold than folds with a larger width. This decline stops at folds that are more than 4 cm wide. Wider folds create more flexibility in other directions than the obvious folding direction. This is because the area of the fold has become so large that it starts to behave like a textile sheet.

The amount of layers influences how thick the fold becomes. The fold itself is not pressed and therefore it keeps the original thickness of the soft layers stacked on top of each other. This influences the direction the fold, since the thick fold can get in the way of itself when folding.
Using this method, the BiCo samples did not turn out well in general, and the contrast between hard and soft could not be made during this exploration. The exact reason was not clear.

Moulds in Heat press

One of the three mould set ups performed better than the others. This was the one with a single mould at the bottom side of the press, with the non-woven RECURF sheets laid on top. In the other two set ups there was a mould on top of the RECURF, which was impractical. The mould existed of two metal parts, both which were unstable when placed on the RECURF. It was not possible to adjust the RECURF, even a small amount, without shifting the moulds. Therefore, only the bottom mould was used.

The contrast of the fold was influenced by the difference in temperature of the top and bottom sides of the heat press. The temperature of the bottom side, which was close to the soft fold, was best adjusted to about 10° C below the melting temperature of the used PLA/ BiCo. The topside was, after exploration, best set at 10° C above the melting temperature. This way the parts that needed to be pressed and melted were melted, but the soft areas stayed soft. Even with the right settings the whole setup was sensitive. The temperature of the mould before was placed in in the heat press greatly influenced the time the sample needed to be pressed. Since the amount of time the mould was out of the press was never the same, many samples failed.

Conclusions

It is possible to make a soft fold under a large press using a mould. The folds have a strong contrast between hard and soft, making use of the material's duality. By altering a folds width, it is possible to influence the folding properties (i.e. amount of force needed to fold the fold, and preference direction of the fold). The soft fold can only be seen at one side of the sample because of the restraints when handling the mould in this setup.

A fold can thus be made by pressing the material in the heat press once. The main constraint is that the production process is sensitive to slight variations in temperature and time.

The next step in tinkering is to test how these folds behave in a pattern.

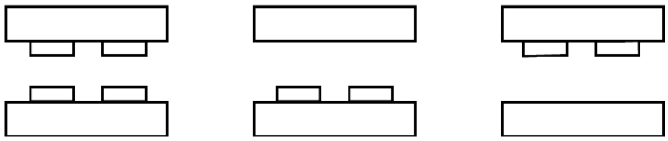


Figure 57 . Three mould set ups. The mould in the middle is the most practical to work with.

Fold 6

Figure 58. Invisible fold made of burlap PLA. Folding area made with the use of the flexibility of a single layer . Surrounding area is 3 layers thick.

Material:	*Jute PLA*
Method:	*Heat press*
Temp:	*190/170°C*
Layers:	*2*
Time:	*75 sec.*
Force:	*30 kN*
Width fold:	*3 cm*

Fold 6
Figure 59. Invisible fold made of burlap PLA. Folding area made with the use of the flexibility of a single layer . Surrounding area is 3 layers thick.

Material:	*Denim PLA*
Method:	*Heat press*
Temp:	*190/170°C*
Layers:	*2*
Time:	*90 sec.*
Force:	*150 kN*
Width fold:	*1.5 cm*

Fold 6
Figure 60. Invisible fold made of burlap PLA. Folding area made with the use of the flexibility of a single layer . Surrounding area is 3 layers thick.

Material:	*Denim PLA*
Method:	*Heat press*
Temp:	*190/170°C*
Layers:	*2*
Time:	*90 sec.*
Force:	*150 kN*
Width fold:	*6 cm*

Fold 6
Figure 61. Invisible fold made of burlap PLA. Folding area made with the use of the flexibility of a single layer . Surroun-ding area is 3 layers thick.

Material:	*Jute PLA*
Method:	*Heat press*
Temp:	*190/170°C*
Layers:	*2*
Time:	*75 sec.*
Force:	*30 kN*
Width fold:	*3 cm*

5.5 Tinkering #4: Explore Chaotic Folding

Objective

The objective of this tinkering step is the exploration of the chaotic fold. It is based on fold 3 made during tinkering session #2. During this session, we explore organic shapes, inserts, twists of layers and chaotic areas made possible by the looseness of the needled fibers. This exploration will also look at chaotic shapes that do not involve a fold. he heat press and the iron are used during this exploration.

Observations

The first exploration was done using an iron and non-woven sheets of RECURF. It is possible to apply organic shapes of hard (molten) RECURF with an iron . It was clear this created a lot of room to experiment with shard shapes and soft shapes of RECURF. The samples in figure 62 and 63 are examples of this exploration. These shapes show that more is possible with the contrast of hard and soft than shapes with straight lines. When we showed the sample in figure 63 at several students and staf from the AUAS, we observed that they found the sample in figure 63 appealing. Most said they imagined the organic line to continue into something bigger.

Some samples had chaotic areas that were overwhelming the hard parts.
Ideally, there should be a balance between the chaotic soft material with the hard material. Where this balance lies depends on the product or object used to process the material.

Since it is not possible to create functional folds with the iron, this exploration functions more as an example of what shapes could potentially be accomplished if the set up with the iron would enable it to apply more pressure. This would make the heated areas stiffer.

The method of using the heat press to press the sample at only one part of the fold, as seen in figures 64-66, creates the opportunity for another kind of exploration in chaotic folds. This method makes it possible to press and heat parts of the samples much better than an iron, and in a more creative matter than the heat press in combination with moulds. It is also possible to make three-dimensional objects with this method. These samples required a lot of physical adjustment when placed in the press. The precise angle, force and twist influenced how the sample turned out.
Furthermore, with the use of this production technique, soft (straight) folds that are more chaotic can be produced. The chaotic appearance can be seen in the looseness of the soft fibers in the fold, like in figure 64. Keeping such looseness is not possible with the heat press in combination with moulds, which was used for all the soft straight folds in tinkering session #2.

Conclusions

During this exploration we found many different shapes and forms that can be made of RECURF that present the dualities of hard and soft, two-dimensional and three-dimensional, stiff and flexible, and smooth and textured. Therefore, the exploration provides a diverse representation of how RECURF can be manipulated. However, there are inevitably many more and even better shapes and configurations to be found that show the duality of RECURF when we continuing tinkering.
For this tinkering session, the main takeaway is that even with a shape as simple as the iron, an interesting sample was made that shows the duality. The shape does not need to be complicated, an shape that is just a bit different from a straight line can create this interest. Therefore, we do not think that making a complicated shape as in figure 66 is needed to clearly show the duality of RECURF. An opportunity lies in the use of hard folds in combination with chaotic areas.

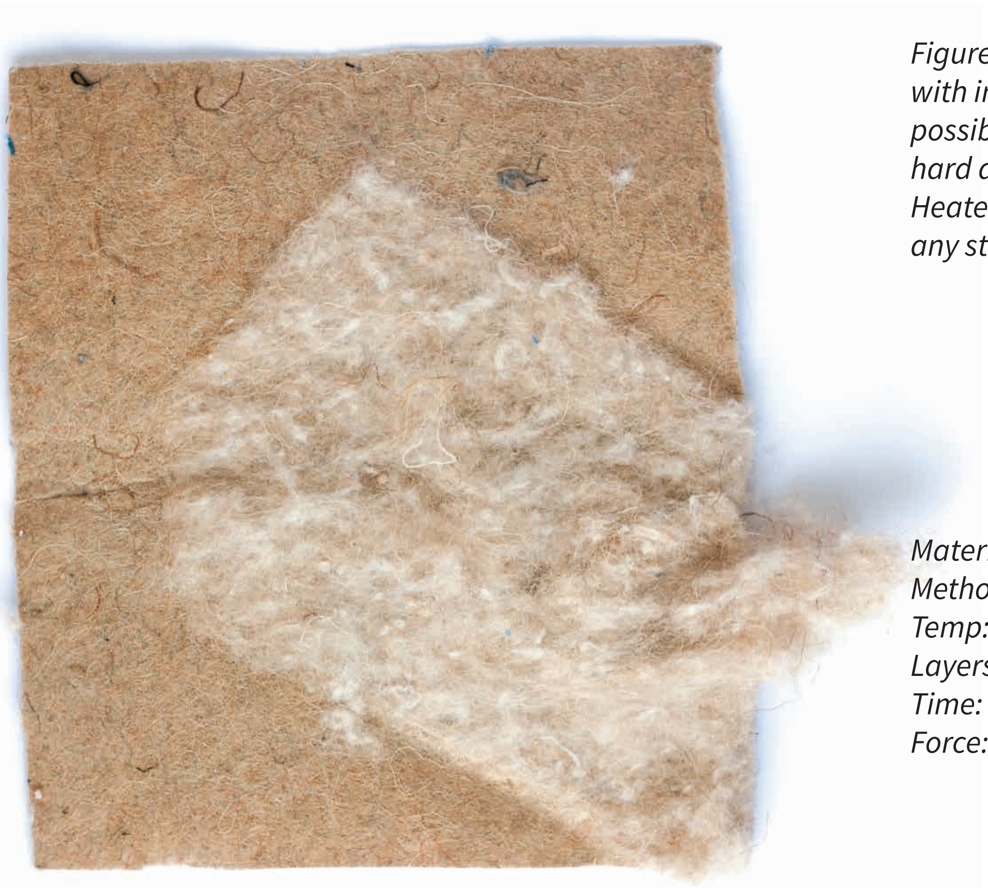


Figure 62. Sample heated with iron. This makes it possible to quickly make hard and soft areas locally. Heated areas hardly have any stiffnes

Material:	*Burlap PLA*
Method:	*Iron*
Temp:	*200°C*
Layers:	*1*
Time:	*20 sec.*
Force:	*Leaning person*

Figure 63. Sample heated with iron. This makes it possible to quickly make hard and soft areas locally. Heated areas hardly have any stiffnes. This sample has in organic shape.

Material:	*Burlap PLA*
Method:	*Iron*
Temp:	*200°C*
Layers:	*1*
Time:	*20 sec.*
Force:	*Leaning person*

Figure 64. Burlap PLA Straight fold with chaotic fold because of the loose needling of the soft non-woven sheets. This fold has properties of the soft straight fold and the chaotic fold.

Material:	*Burlap PLA*
Method:	*Heat press*
Temp:	*190°C/170°C*
Layers:	*3*
Time:	*90 sec.*
Force:	*55 kN*

Figure 65. Invisible fold made of Wool PLA. Folding area made with the use of the flexibility of a single layer . Surroun-ding area is 3 layers thick.

Material:	*Wool PLA*
Method:	*Heat press*
Temp:	*190°C/170°C*
Layers:	*2*
Time:	*90 sec.*
Force:	*30 kN*




Figure 66. These organic looking folds are made with an twist, twirl or local extra layer. Making the fold very visible. These folds took a lot of presision to make, making reproduction more complicated.

Material:	*Burlap PLA*
Method:	*Heat press , one side at a time*
Temp:	*200°C*
Layers:	*2-3*
Time:	*50-100 sec.*
Force:	*30 kN*

5.6 Tinkering #5: Folding Origami

Objective

During this tinkering session, the aim is to explore how to apply origami to RECURF with first the use of soft (straight) folds, and second, the use of hard folds with chaotic areas in between. Origami itself needs to be further explored before it can be applied to RECURF.
These two folds can be made in the heat press with a mould. This is currently the most feasible method of creating origami with soft folds.

Origami variations

Tessellation origami consists of repetitive patterns that can be applied to a flat material of any size, as only the amount of repetitions changes.
At this point, aiming for a larger variation of origami patterns with RECURF would be too ambitious as there is not much known yet about the folding properties of RECURF.
As mentioned in chapter 5.1, the kind of origami we continue with is tessellation origami. This type of origami consists of a repetitive pattern that can be applied to a flat material of any size.

Within tessellation origami, there is still a larger amount of patterns and shapes that can be made. However, they always do have to follow the basic rules of origami, explained by Robert Lang (2008). As visualized in figure 67, these rules are:

- Fill the crease pattern with two colours. Two areas of the same colour may never touch
- The amount of mountains and valleys folds always differs with two
- A sheet can never penetrate a fold
- Odd and even angles of a point where creases meet always add up to 180°

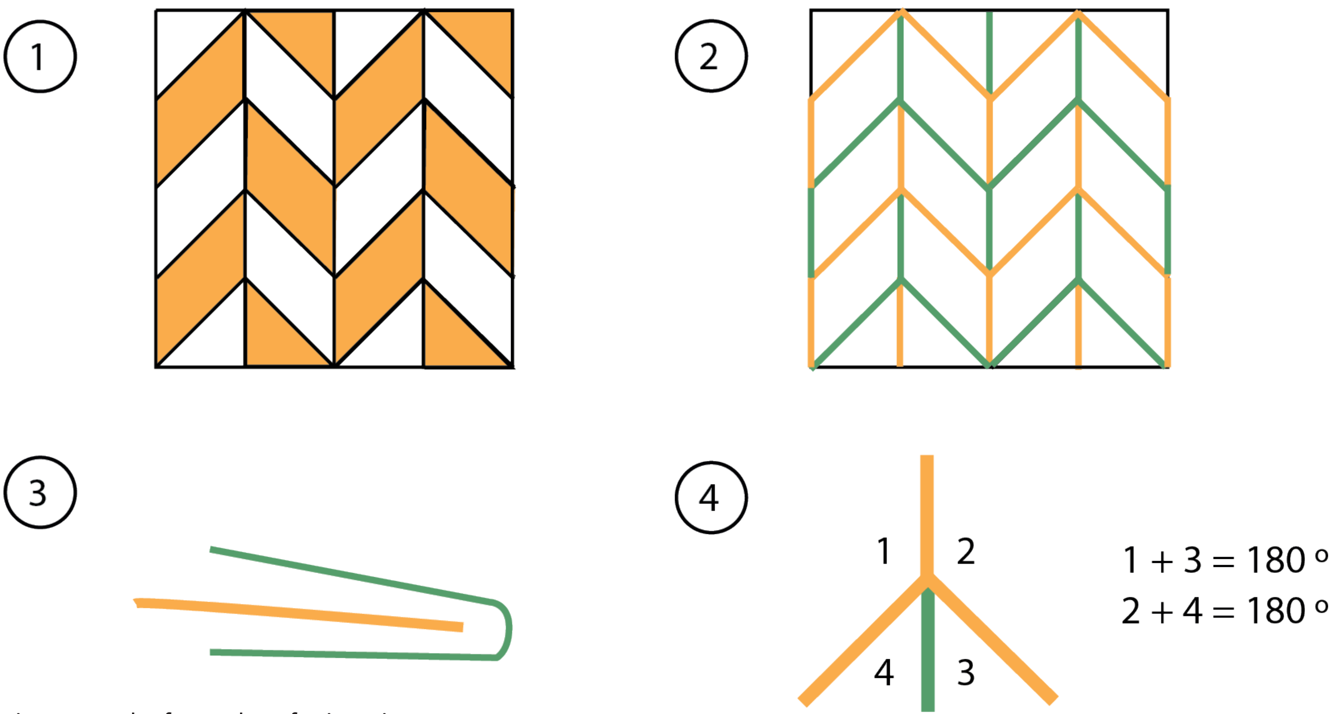


Figure 67. The four rules of origami.

From the benchmark (chapter 4.4), and from folding many different tessellation origami patterns, we noticed that there are basic groups that the origami can be divided into. These are:

- ‘Irregular’ origami
- ‘Mountain and valley’ origami
- ‘Plateau’ origami

Irregular origami
This kind of origami requires frictionless flexible folds. The folds do not remain at a certain angle. These folds do not have a built-in preferential side to fold to, and therefore when a sheet is compressed, a fold will fold in the angle that is the ‘easiest’. This can lead to irregularly folded origami.
An example of this can be seen in figure 68 A.

Mountains and valleys origami
The folds in this kind of origami are in mountains and valleys. The folds that are needed for this kind of origami need to have a preferred direction. The angle the fold will get into is often around 90°. A well known example is the herringbone origami in figure 68 B.

Plateau origami
This term refers to a kind of tessellating origami that has, when folded, a pattern of shapes that are positioned relatively flush with one another. This recurring plateau pattern can be made of one shape or many more, as long as the shape is recurring. The type of fold needed for this kind or tessellation origami is one that can fold fully on top of itself (180° in one direction). An example is the tessellations in figure 68 C.

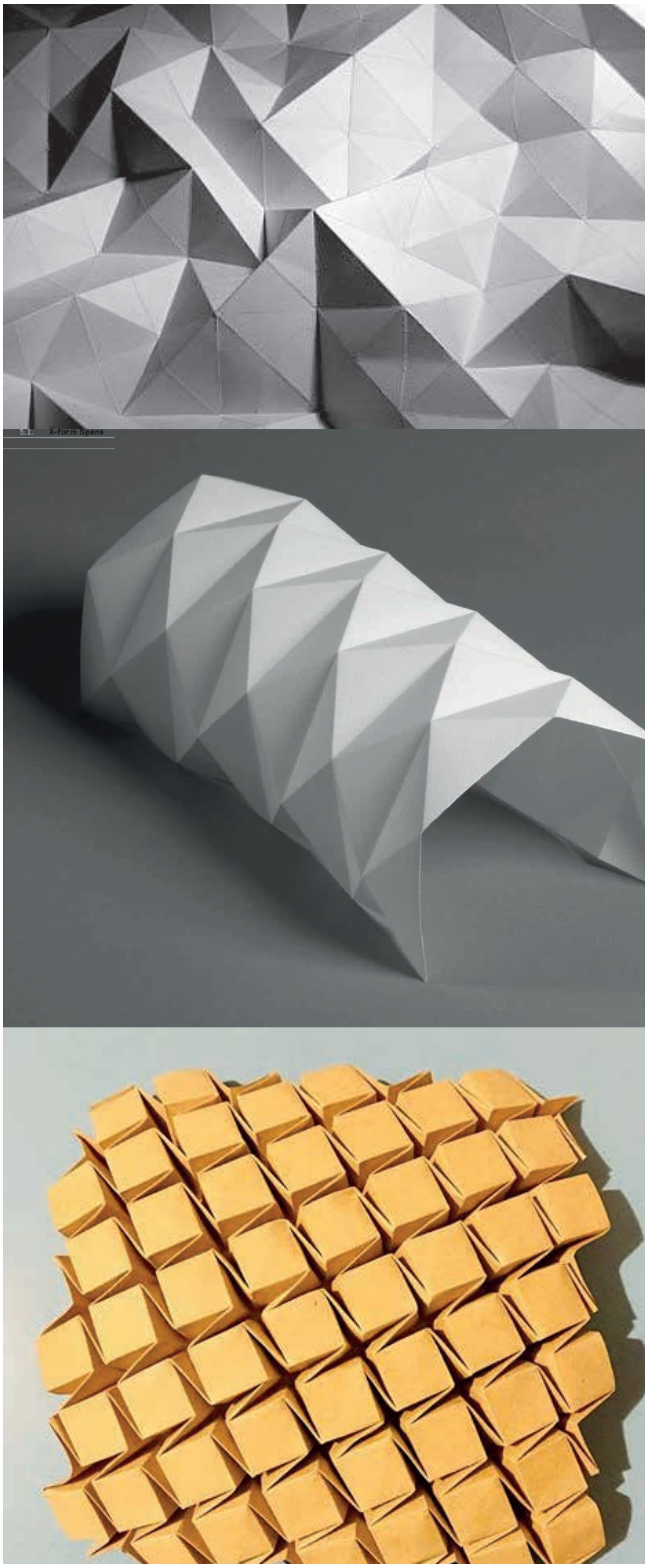


Figure 68. Three types of tessellating origami. [30][31][32]

Prototype of the soft fold origami
To get a better understanding of the behaviour of the soft fold in origami patterns, we created an origami sheet that has similarities with soft folds. This test concluded that ‘plateau’ origami does not work well with soft folds because the folds create too much resistance. The other two groups ‘mountain and valley’ and ‘irregular’, have no problems.

The setup to make this prototype was made using a velcro ‘blanket’ and triangular shapes made of hard plastic with velcro on the back. We chose three patterns that could be made with a single shape. These three patterns each fit within a basic group(irregular, mountain and valley and plateau).

The three patterns were tested on how well they folded, if they got stuck, how much resistance to folding they had and how the whole sheet behaved.

After our exploration, it can be concluded that these folds, which individually have hardly any resistance, have a lot of resistance when in a pattern. Folds of 180° cannot be reached with this method as there is too much resistance buildup in the whole pattern.

Given that the material does not fold exactly the same way the soft folds do, it is still useful to make a ‘plateau’ pattern sample to examine the differences.

As regards soft fold exploration, plateau origami could be difficult to achieve. The other two origami types are more feasible at this stage.

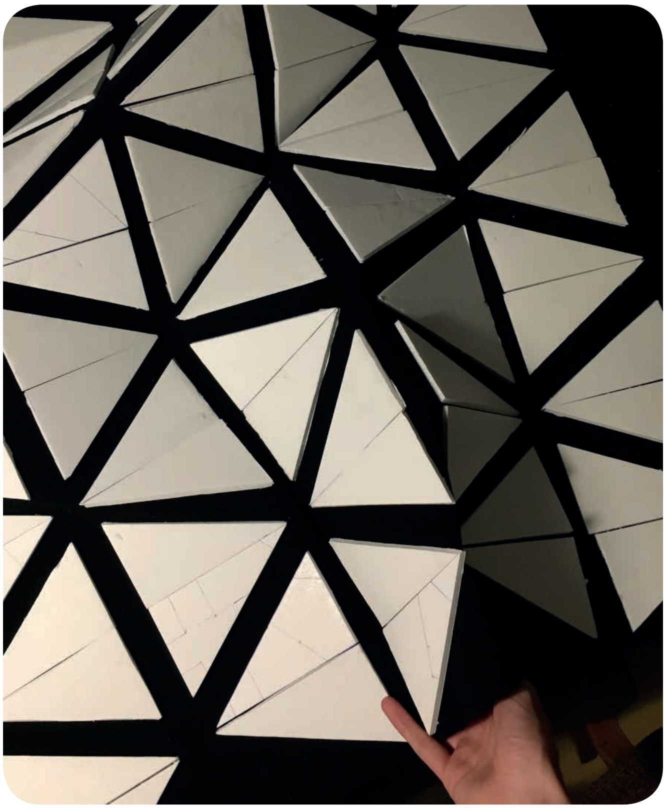


Figure 69. This is an ‘irregular’ tessellation origami sheet. It folds differently every time it is compressed.

Figure 70. This is a ‘plateau’ tessellation origami sheet. It was not possible to fold this pattern as ordened as wanted. The folds did not fold all the way up to 180°

Figure 71. This is a ‘Mountain and valley’ tessellation origami sheet. The white blocks were too unstable to fold this sheet into an three dimonsional origami pattern.

Moulds

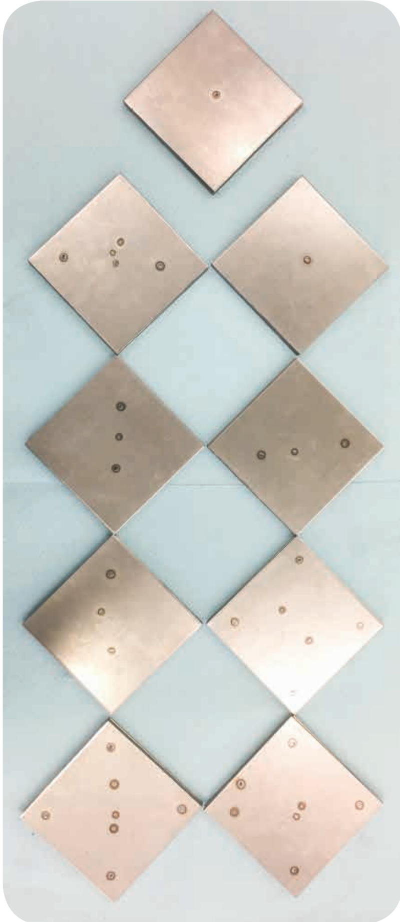
During this tinkering session the heat press is used. This method is the only method that makes the heated parts actually stiff and thereby makes the origami functional. A selection of moulds needs to be made that are suited for the heat press. These determine the type of origami that is possible to make in the heat press. It is practical to choose a few shapes for the moulds that can be used in different crease patterns. This means the moulds should exist of individual parts that can be rearranged. This way the ratio between hard and soft, and many different origami patterns, can be explored.

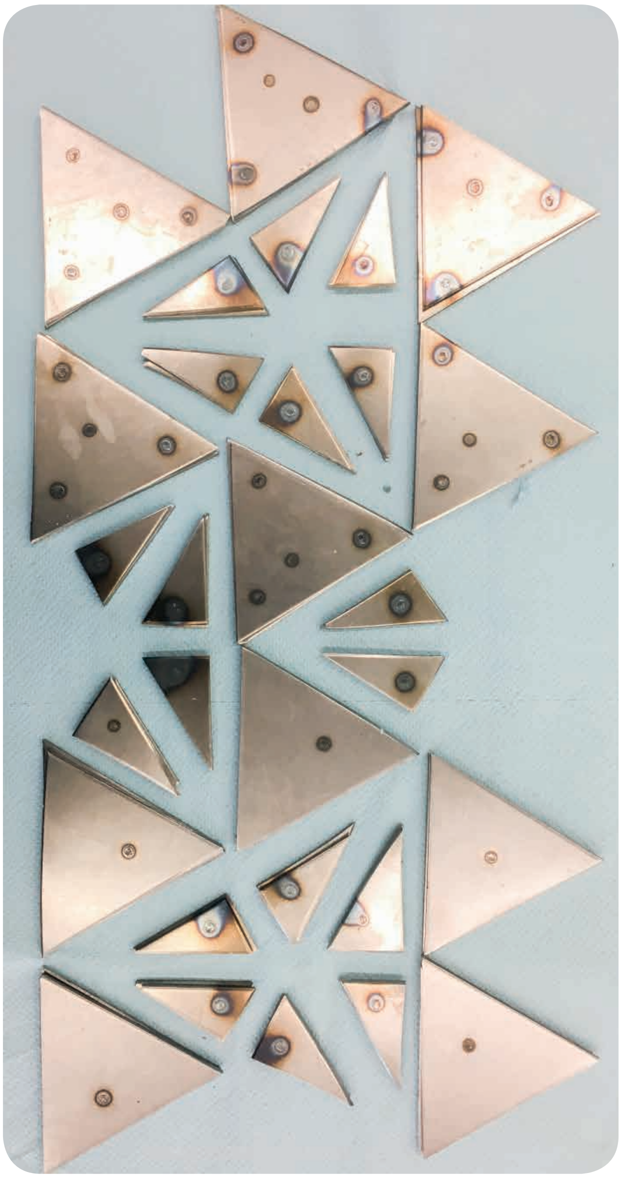
The shapes chosen for the moulds include triangles, squares and random shapes.
An necessary shape is the triangle because this can to create the same origami as the soft fold prototype. This triangle has three corners of 60 degrees (60-60-60). To make this into the three different basic origami groups, it requires one additional shape, which is half of the 60-60-60 triangle. This has the angles: 30-60-90. However, the folds of soft RECURF are in the range of 1 - 4 cms, which takes up some space. Therefore, the 30-60-90 triangle is made smaller than the original crease pattern shows.
With these triangles, a different plateau origami can also be made by the addition of squares as plateaus. These squares also function as an experiment with even simpler shapes, like a 'chess field' of hard and soft parts.
Finally, the last kind of mould is randomly shaped. These are not part of a crease pattern of origami. These shapes are made to explore how RECURF behaves when the folds get wider than 4 cms. This creates more flexibility, and therefore it can be interesting to use in an experiment.
The four different mould shapes from figure 72 were chosen. All the moulds were 6 mm thick and made out of steel. Several patterns are already made in figure 72.

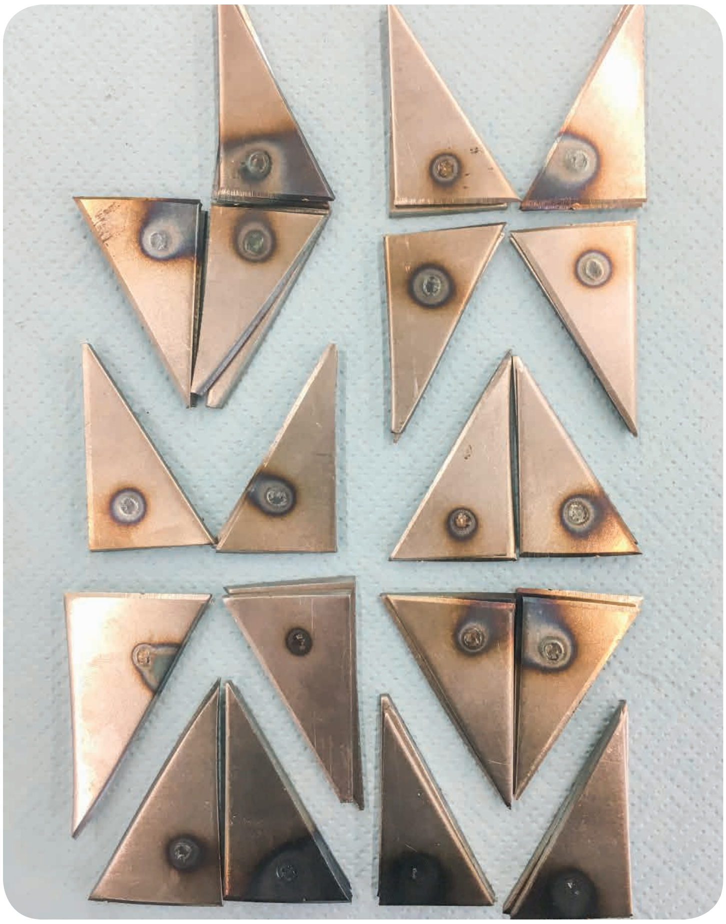
Given the conductivity of steel and aluminium, heat is transferred faster to the RECURF when using aluminium as mould. In hindsight,the moulds would have performed better when made from aluminium. In addition to the conductive qualities, is aluminium lighter in weight and therefore easier to manoeuvre, and can be edited with more production techniques than iron of the same thickness. This makes the building of the moulds more convenient, making the process of prototyping faster.

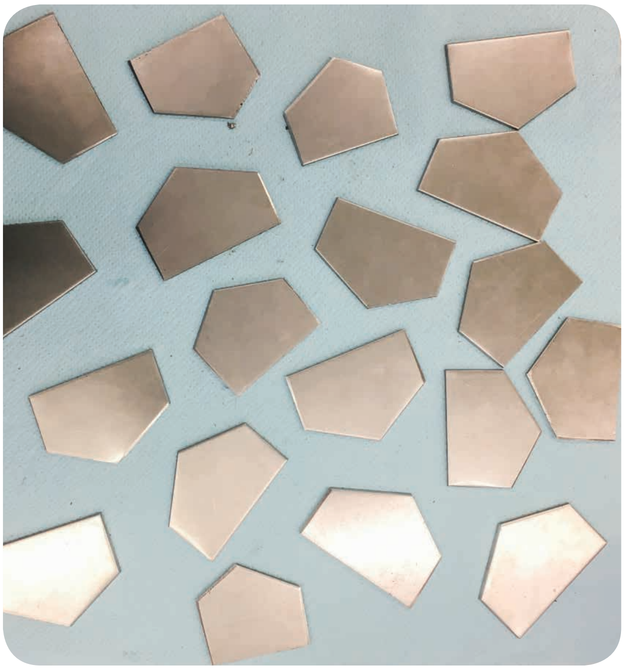
The moulds are shown in figure 72.

Figure 72. The different moulds. All made of steel. Spot welded together to get a thickness of 6 mm.









Observations

Before using the different moulds for origami with soft folds, we tested the process of making two folds in one sheet. After the first pressing, the sample from figure 74 was taken out of the press and directly put on top of two triangular blocks, so that they would take on the three-dimensional shape of the two blocks. The plastic was still molten, so they adjusted easily to the shape. After the plastic solidified, the folds kept the angle they were standing in. This is visible in figure 74. The sample from figure 73 combined two folds, the soft fold and the invisible fold. The invisible fold can only fold in a single direction because the soft 'bulge' is in the way.

The double soft fold gives us insight into how to combine movement with duality. The angle of the fold directly influences the look of the material. When the fold is pressed like a harmonica, it looks soft, but when it is pulled out, it shows mostly the hard and pressed RECURF with two lines of 'soft' in it. In this way, by movement of the origami, we see changes in the duality of hard and soft. In this set up it was easy to fold the sample together on itself, without any resistance. This was due to that fact that the standard angle this sample was set in was close to the 180 degrees angle that is needed to fold a fold on itself.

Origami

In an origami pattern, folds have much more resistance to folding. It was not possible to fold a sample without it unfolding directly back to its original position. This made it hard to create the three different tessellation origami types because they all need more flexible folds than the ones that were made. This resistance to folding probably occurred because of the bottlenecks that were created by junctions between folds and by the production process, which is explained in the next paragraph. Bottlenecks are located at the point where two folds come together. Since both folds have a soft fold, which is thick and wide, this gets in the way of itself, but at a bottleneck it also gets in the way of the other fold. This creates clusters of soft RECURF at these points, which in turn creates a lot of resistance.

The duality of the samples was clear when they were laying flat. When folding the samples, it became noticeable that the soft folds were visually dominant over the hard parts. Keeping soft areas wider than 4 cm soft in the heat press was not feasible. This limited the exploration of hard folds with soft areas in between.

After talking with three students at IDE Delft, about the samples, it became clear that this was, according to them, an interesting direction. This is because the material is sustainable and novel because of its contrast in hard and soft. However, since the samples were difficult to fold in any way, they had trouble seeing how the origami could be used.

Heat press

The individual mould parts need to be laid in the crease pattern every time it is pressed. This has to happen outside the press, on a iron plate. Then a backing paper is put over the mould, followed by the non-woven RECURF. The baking paper and the RECURF both caused the moulds to shift many times, shifting the crease pattern. The placement of the metal plate with the mould and sample into the heat press often caused everything to shift. This made the whole process of making samples sensitive and prone to fail.

The settings of the heat press are more sensitive than making just one soft fold. Because the sample was larger, it needed more time to melt, this caused the soft folds to melt very often. Only a few samples were made where this shift did not happen. In addition, the bottom of the soft fold melted more, making the folds stiffer and more resistant to bending.

Since the different mould parts all cooled down slightly differently while being out of the press, they all had a different influence on how well the material melted under the individual mould parts.

Conclusions

The soft folds in origami patterns add to the visual appearance of sheets of RECURF. The folding of the origami contributes to the duality by varying how much soft and hard RECURF is visible. It can potentially be used to create three-dimensional shapes of two-dimensional sheets, when the

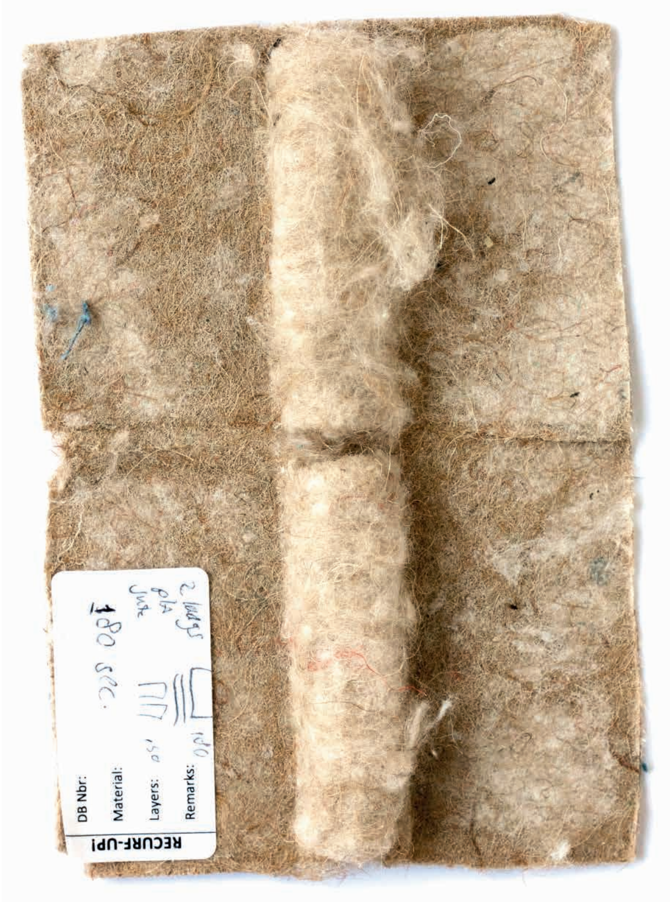


Figure 73. A soft fold made with the heat press. This soft fold also has an invisible fold going trough its middle. This kind of intersection of folds is unpractical, because only one fold can be folded at a time.

Material:	*Jute PLA*
Method:	*Heat press*
Temp:	*190°C/170°C*
Layers:	*2*
Time:	*75 sec.*
Force:	*30 kN*

Figure 74. This sample has 2 soft fold next to each other. It can be noticed that when this fold is closed, only soft material is shown. Moving the origami means changing the contrast of the duality in hard and soft.

Material:	*Denim PLA*
Method:	*Heat press*
Temp:	*190°C/170°C*
Layers:	*2*
Time:	*75 sec.*
Force:	*150 kN*

folds give less resistance when folding than they do now, especially at the junction of two folds. The use of the heat press also indirectly causes the folds to create higher resistance to folding by melting the bottom side of the fold. The use of the heat press in general to explore these origami patterns made for a sensitive production process. Most samples turned out completely molten, or had a pattern that was out of balance because the moulds shifted.
Samples of hard folds with soft areas were not created because this was not feasible in the heat press.
The use of the heat press to make these patterns was limited. It can be concluded that there is need for a different method, one that combines the flexibility of the iron with the pressure of the heat press. Such a method would keep the soft parts soft, while pressing and heating the hard parts.
The samples created can be seen as an example of what could be possible with patterns and the use of origami.

Figure 75. Invisible fold made of burlap PLA. Folding area made with the use of the flexibility of a single layer . Surrounding area is 3 layers thick.

Figure 76. 'Irregular' origami. The strong resistance to folding keeps this pattern flat. The irregularity in combination with the soft folds makes it look even more irregular.

Material:	*Burlap PLA*
Method:	*Heat press*
Temp:	*190°C/170°C*
Layers:	*2*
Time:	*120 sec.*
Force:	*30 kN*

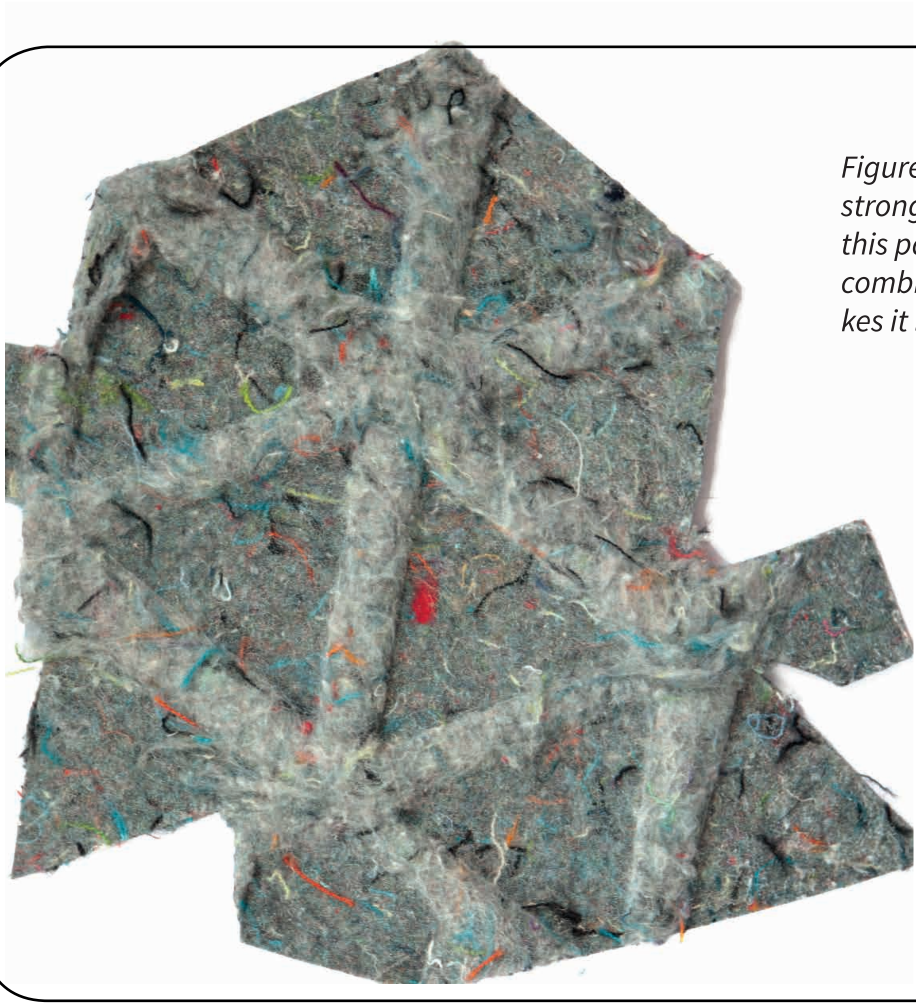


Figure 77. 'Irregular' origami. The strong resistance to folding keeps this pattern flat. The irregularity in combination with the soft folds makes it look even more irregular.

Material:	*Denim PLA*
Method:	*Heat press*
Temp:	*190°C/170°C*
Layers:	*2*
Time:	*120 sec.*
Force:	*150 kN*

Figure 78. 'Irregular' origami. The strong resistance to folding keeps this pattern flat. The irregularity in combination with the soft folds makes it look even more irregular.

Material:	*Denim PLA*
Method:	*Heat press*
Temp:	*190°C/170°C*
Layers:	*2*
Time:	*120 sec.*
Force:	*150 kN*

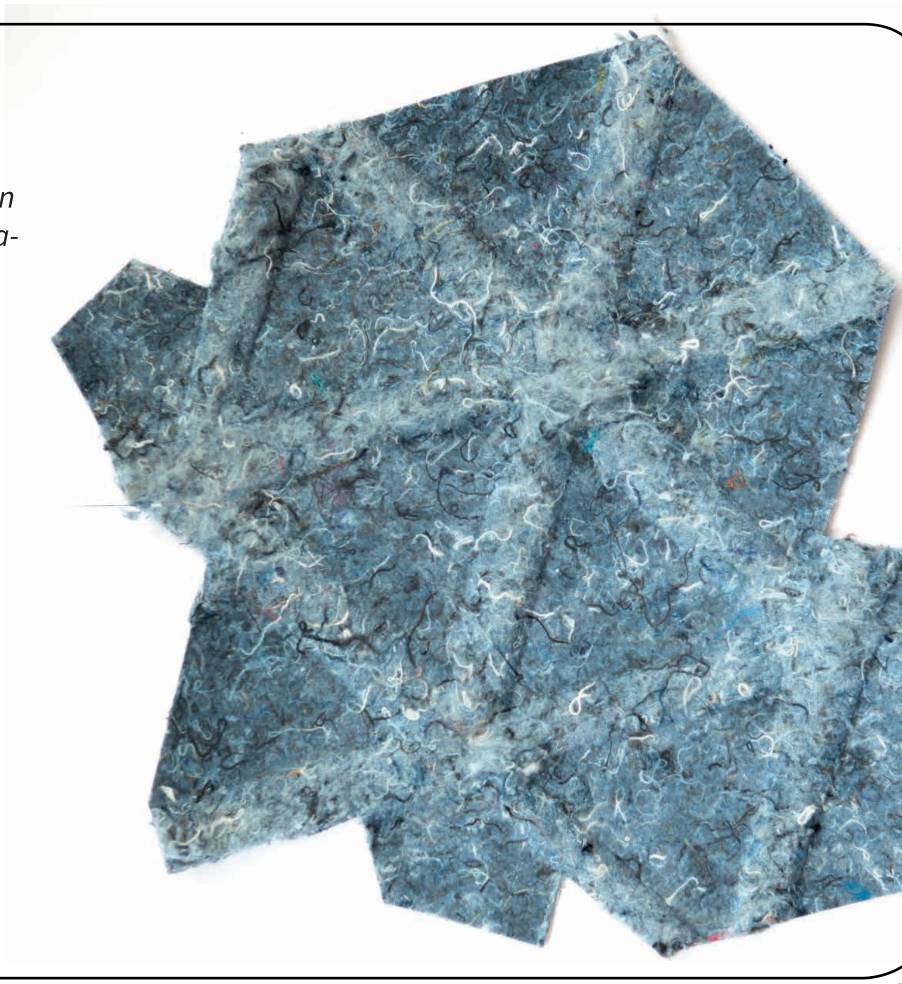






Figure 79. These origami patterns did not turn out as expected. They all had issues. Most were because of restrictions created by the use of the heat press.

5.7 Conclusions Of Tinkering

Material

The kind of PLA used in the RECURF has an influence on both the appearance of the samples and the production process. BiCo is less brittle than PLA when it is hard, making it better suited for folding. BiCo is slightly lighter in colour than PLA when molten. This creates a lot of positive reactions among students working with RECURF. However, with BiCo it was not possible to create soft folds using the heat press.
Throughout the tinkering sessions, it appeared that the way in which the non-woven material was needled together had an impact on the soft fold. There were non-woven sheets that were very thick and had dense needling, while other pieces had a much lower density of needling. This had significant influence on the soft areas on how 'chaotic' and soft some areas looked. This was most influential during the exploration of chaotic folds. It also influenced how easy it was to pull fibers out of the soft material. This property could potentially be a large constraint for the soft parts because it is easy to pull the material out and therefore for it to wear down quickly. In other materials that are needled together, such as blankets or sheets made of felt, this is much less of a problem. Research in the needling process could potentially provide a solution for this problem in soft RECURF.

Folding

From the folding exploration during tinkering we can conclude that RECURF can be folded in many different ways which produces a large variation of results in terms of usability, duality and production processes. The results from the folds will be summarized separately in the next paragraphs.

Soft folds

Soft straight folds can be useful when expressing the duality of RECURF. They do this by creating clearly visible hard and soft patterns. The strength of a soft fold is much lower than the heated and pressed material surrounding the fold, making it the weak part of the sheet. The width of the soft fold can vary between 1 and 4 centimeters before it starts to behave like a textile instead of a fold.
Using the heat press the bottom side of the fold also gets molten, this causes more strength in the fold but also more resistance when folding. Making the sample too stiff.
When using the soft fold in origami patterns, the thickness of the soft fold is largely influential on the properties of the folding. It creates bottlenecks at areas where folds join together.
The duality of soft and hard RECURF in origami is changed by the ratio of how much hard and soft material you can see to the amount the origami pattern is folded. This could be of use in a tangible experience of products with RECURF, exploring this movement and change in duality.

Hard folds

Hard folds like the invisible fold, laser cut fold and the engraved fold are useful when a soft fold is not the desired outcome. For all three of these folds the BiCo material is better suited because the PLA is too brittle for repetitive folding. Of the three methods, the laser cut dotted line is the most practical, taking into account the production process. It is faster and more convenient to produce and has a sharper folding angle than the invisible fold, which gives a clearer view of geometric pattern of origami. It is also a more convenient production method than engraving. Looking at the materials appearance however, the engraved fold is less visible than the laser cut fold, making the fold look more constant. The invisible fold is more beneficial when looking at a clean continuation of the surface of RECURF. However, the fold does not have a sharp shape, it is curved. This does not contribute to the hard and soft duality, nor to the geometric shaped look often found in origami. The opportunity lies in combining these hard folds with more chaotic and soft areas in between the hard fold. Other opportunities lie in products that are not in the need of any soft areas at all.

Chaotic folds
Chaotic folds are interesting as they bring out the unique duality of hard and soft in RECURF. The chaotic parts are not only soft, but also very different in structure compared to the pressed hard RECURF parts. Nonetheless, it is important to have a certain balance between chaotic soft parts and hard parts. Several different areas of the chaotic folds are interesting to explore further. One of these areas is organic folds, which were of interest according to several designers. The start of this exploration was made using an iron, however because the iron does not enable enough pressure to make the RECURF stiff and it only has one shape, the created samples are for now 'inspirational' and not functional. The other exploration is chaotic areas with hard folds. This area is not explored at all up until now because of the limited heat press, but it could potentially reveal interesting new contrasts between hard and soft, and two-dimensional and three-dimensional, that have not been found yet. Chaotic folds can enhance the tactical interaction in products by the use of the soft and hard duality.

Origami
Origami with RECURF needs more research and exploration. This exploration was obstructed because of the many complications when using the heat press and moulds. However, a small amount of samples did turn out as expected. The small user test turned out several designers reacted enthusiastic after this sample was shown. Their comment was they wanted to see an application that uses this.

Examples of plateau origami often have folds that are folded up to 180 degrees, meaning the fold is folded on itself. With paper this is quite easy. Most folds with RECURF do not fold up to 180 degrees without a large increase in resistance. The other two kinds, the irregular origami and mountain and valley origami often do not have folds that come near 180 degrees. Therefore, these two kinds of tessellation origami are more feasible to explore further at this point.

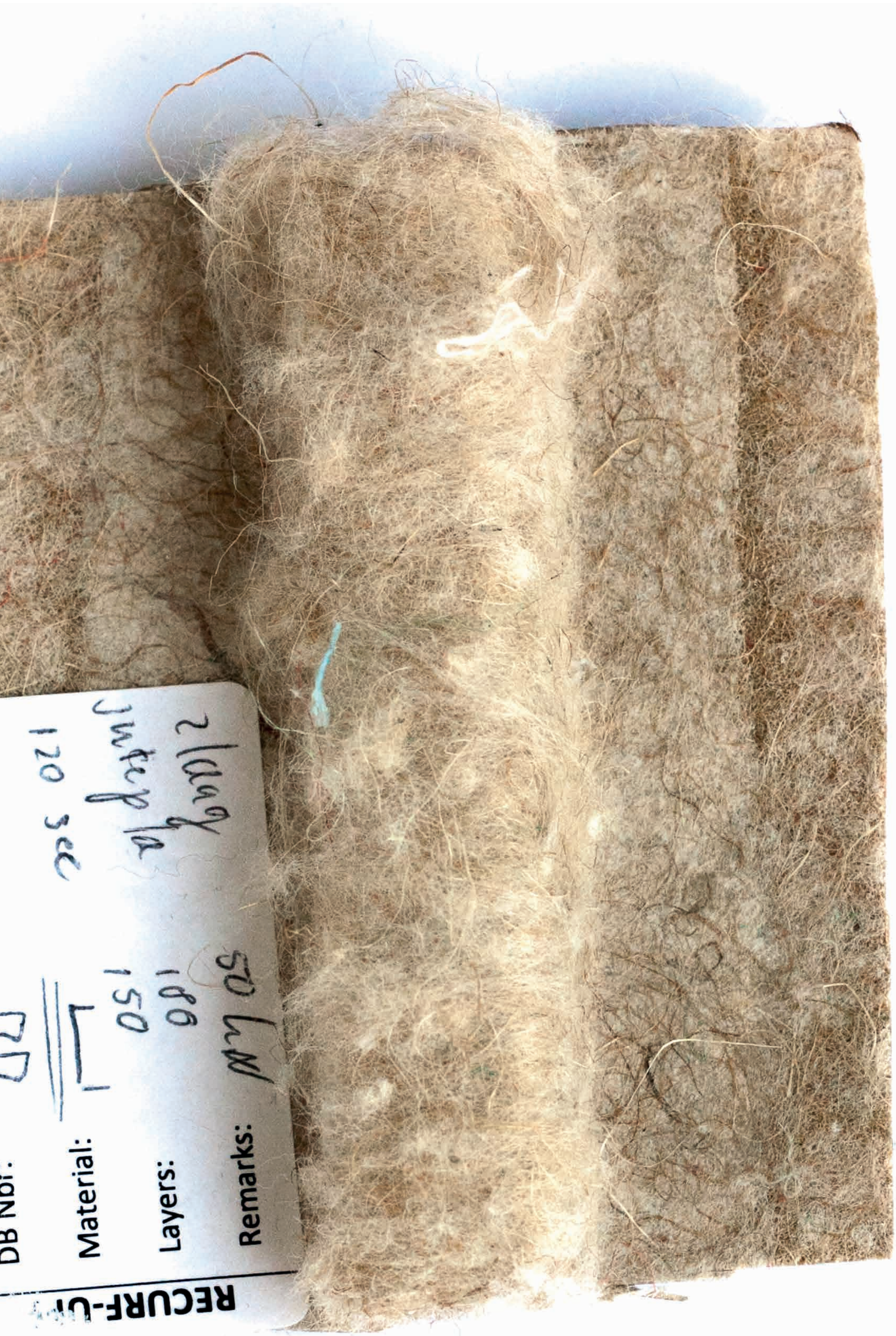
It can be concluded that origami is an interesting direction to explore. However, several questions remain:

- How does origami on RECURF look when it is bigger than 40 cm x 40 cm?
- How does origami fold with RECURF when the bottom of the fold is not molten?
- What irregular and mountain and valley origami patterns are most compatible with soft folds?
- What irregular and mountain and valley origami patterns are most compatible with hard folds and chaotic areas?
- How can we make organically shaped folds and patterns?
- Can the folds in origami all be solidified at a certain angle?

Production processes
As mentioned previously, the iron is great for the exploration of the duality in hard and soft. The soft areas stay fully soft while the adjacent hard areas melt. What is missing is the pressure to create stiff areas in order to create functional folds. The iron is also limited to one shape to heat with.
The heat press can be combined with moulds to create hard and stiff areas. The possibility to explore and prototype easily is however limited because of several complications, such as the placement of moulds relative to each other, the sensitive settings of the heat press and the heating of the bottom side of the soft folds.

Opportunities
The soft fold is at this point the fold that shows the most potential, given the contrast in duality and the feasibility of the production techniques. These folds present several opportunities in products and objects. Just as Blauwhoff noted, they can be used in three-dimensional interior objects such as room dividers, wall panels, tablecloths, etc. Fashion is also an area where these folds are useful, for instance in a hat, a purse, or a coat.

There are nevertheless many constraints that need to be addressed before these products will be designed and produced. The fibers of the soft RECURF are very easily pulled or plucked out of the non-woven material. This makes it less durable. The strength of the soft areas is also low (Appendix B). This is necessary for the design of products that require a significant amount of strength in these folds. How these folds, along with the rest of the material, behave over a longer period time is yet to be research as is the fire safety and the water resistance of the soft fold.


RECURF-U
DB Nbr.:
Material:
Layers:
Remarks:
120 sec
50 kN

6. Materials Experience Vision

6.1 Introduction

Now that we have finished our tinkering sessions and have gained more insight into the unique qualities and limitations of the material, the next step is to create our material experience vision. As explained in the project description, what we mean by this is that we have to create a vision which embodies how we want our target audience to experience this material.

To get a better idea of how our demonstrator exhibition of the RECURF material should be envisioned, we conducted interviews with product designers that have already had experience with similar demonstrator projects through installations at musea, fairs and exhibitions. By doing this we aimed to get better insight into the type of interactions you can have people experience and how to design for an exhibition or fair.

Next, we analyzed the results from our tinkering sessions and considered which qualities we want to emphasize in our material experience, which then resulted in the creation of our material experience vision.

6.2 Interviews Experts

Three interviews were conducted (Appendix C). The interviewees are Bas Froon, Jon Stam and Annelies de Leede. During these interviews it became clear that there are several factors that are important when designing for an interaction with a material. To optimize the chance of attracting people's attention the interaction should have movement, be approachable and be easy to understand and interact with. It should also look playful and be experienced like a story, with a start, a middle, and an end.

When applied to RECURF this means that the story of RECURF should be told through the exhibition design. This means showing the raw resources that make up the material, to the unmodified sheets of RECURF, to the production process and finally to the final pressed origami product. Nevertheless, it is important that the interaction that modifies the sheets of RECURF to the pressed origami product should not be so distracting that it overshadows the unique material qualities and production possibilities.

Following these interviews we have extracted the most important design criteria for our RECURF demonstrator project:

- The story of RECURF
- Inviting
- Moveability
- Understandability
- Trialability
- Complexity

These will be further explained in the design brief (chapter 7).

6.3 Material Qualities And Production Processes

Based on the results of our tinkering sessions we have drawn two main conclusions that are of influence on the creation of our material experience vision.
The first conclusion explains the configurations of RECURF we want to show during the demonstration. These are the soft folds in combination with 'mountain and valley' origami. We have chosen this type of fold and origami type as they have, at this point, the most potential for application in design. They express the duality of RECURF, are flexible and useful in the exploration of origami with RECURF, and are made with the use of feasible production processes.
Nevertheless, this type of fold requires more exploration in combination with origami, because during tinkering a functioning sample of soft fold with origami was not yet created. Other folding types (hard fold with soft areas in between) were also not yet feasible to create during the tinkering session.

The second conclusion we have drawn is that there is currently no production method that has both the flexibility of the iron as well as the high pressure capabilities of the heat press. A machine which combines these two functions would greatly improve the research possibilities to further explore origami and RECURF.

6.4 Material Experience Vision

Before we create our material experience vision in accordance with the MDD method, it is important to understand that the way we create our material experience vision is not exactly as the MDD method intended. The MDD method is based around designing an actual product with a specific material at hand which should then elicit a certain material experience. We, however, are not designing an actual physical object with a material at hand, but instead are designing an actual experience/interaction with the specific material at hand.
This means that instead of our vision embodying the specific qualities the design should elicit when interacting with it, our vision is based around the response that we want the user to have to the material from the material experience.

Following our tinkering sessions and our interviews with designers who have experience with exhibition design, we have come to an overview of the core features that we want to communicate in our design, which are as follows:

Accessible

Interaction

Inspire *Biocomposite*

Folds

Trialability

Story of RECURF

Information

Flexible production methods *Origami*

Possibilities *Duality*

Sustainable

This lead us to the following Material Experience Vision:

With the aim of informing, and by doing so inspiring designers to explore and work with RECURF, design a material experience interaction that communicates the different stages, unique qualities and possibilities of the RECURF material.

The main objective of this vision is to educate designers on the unique qualities and possibilities of RECURF and by doing so inspire them to start working with RECURF, which should lead to the shortening of the gestation period of the material.


Remarks:

DESIGN

7. Design Brief

7.1 Introduction

To execute our vision, more context is required before we can start the ideation and concepting phase. In this chapter, we explain the location, target audience, demonstrator ideation and production specifications. This design brief stems directly from our intended material experience vision:

With the aim of informing and by doing so inspiring designers to explore and work with RECURF, design a material experience interaction that communicates the different stages, unique qualities and possibilities of the RECURF material.

7.2 Location

If we simplify how a demonstrator project works, it comes down to exposing someone to something, which in this case means exposing people to the RECURF material. In essence, a demonstrator project consists of two parts, the actual demonstrator and the audience. As the audience is determined by the location, we first have to establish the location of our demonstrator project. Only when the location is established and we know more about the corresponding audience can we continue designing our actual demonstrator.

The location of our RECURF demonstrator project will be the Dutch Design Week 2018 in Eindhoven. The Dutch Design Week (DDW) is a yearly 10-day exhibition and has over 120 exhibition locations all over Eindhoven. It is the biggest design event in Northern Europe, and this year over 2.600 participants are expected to show their work to more than 350.000 visitors from all over Europe. Even though the exhibition showcases many different disciplines and aspects of design, the main focus of the DDW is innovation and the future of design. There is a broad selection of exhibits to see and to optimize the amount of stalls one can see in a single day, people often just stroll around and only look at each exhibit for a very short amount of time.

The DDW attracts a wide range of people, from people who are visiting just for pleasure as one would visit a museum, to designers and engineers looking for inspiration. For this project, we want to appeal most to the designers and engineers looking for inspiration, as we are hoping to inspire them to work with RECURF by exposing them to the material. Even so, being able to expose people who are visiting the DDW just for pleasure to RECURF would be a positive result, as this would mean that more people get to know about the RECURF material and perhaps even inform other people about it.
In short, even though our main target audience is designers and engineers visiting the DDW,

Figure 80. An image of the Dutch Design week. Image: Sjoerd Eickmans[33]

all audiences are welcome, as creating more awareness about RECURF in general is beneficial.

At the DDW this demonstrator project will be located at the AUAS RECURF research group stall in the "Klokgebouw". This building is reserved for students from a diverse range of schools and colleges, showing their latest research and design projects, and this specific stall is entirely dedicated to projects involving RECURF.

dutch design week eindhoven
20-28 Oct. 2018

7.3 Criteria

Following the establishment of the location of the demonstrator project and the interviews conducted with designers during the analysis phase, we have set the following design criteria for our RECURF demonstrator design:

· The story of RECURF
· Inviting
· Moveability
· Understandability
· Complexity
· Trialability

The consideration of these design criteria within the brief will guide the development of the demonstrator project and ensure the intended outcome for the user experience at the DDW.

The story of RECURF

The story of RECURF is about showing the whole picture of RECURF from beginning to end. Demonstrating the story of RECURF gives people a better understanding of the capabilities and limitations of the new material. This story can be divided into four stages:

· Raw materials
· Creation of non-woven
· Production process
· End product

The use of storytelling in this way invites the user to experience and understand the various stages of working with RECURF, and guides the user from an unfamiliar raw product to an end product that might have potential for application in the design of other products.

Inviting

As mentioned previously, considering the size of the DDW and the amount of exhibits to see, visitors generally tend to look at each stall for only a short amount of time in order to optimize the amount of exhibits they can see in a single day. As a result, our demonstrator needs to be inviting in the sense that it draws people's attention and has a low threshold for people to stop and take a closer look. This can be accomplished in many ways, but according to our designer interviews this is best done by making sure there is movement in the demonstration. Bas Froon, for example, experienced this during his exhibition at the DDW (Appendix C), where he noticed an increase of visitors when he included movement in his demonstration. As such we consider the moveability of the demonstrator as critical to our design.

Understandability

Understandability is essential for this design due to the location of the demonstrator. Due to the vast number of exhibits, the attention span of the average visitor is often very short. Consequently, when something looks complex at first sight, people are less inclined to stop and try and understand it as this reduces the amount of time they have left for other exhibitions. We established in the Project Description (chapter 3) that the best way to learn something is to experience it. For the user to truly learn something about the material, they should engage with that material directly in a meaningful, informative way. This usually involves a tactile experience, where the material is not only seen but felt by the user. Therefore the ability to try something, its trialability, is an important factor for our demonstrator design.

Demonstrator Ideation

When trying to narrow down our demonstrator ideation, the demonstration design possibilities are endless. We narrowed these down to the following three options that we considered as most promising:

- Samples: demonstrate RECURF samples of all four development stages
- Production process: A machine that demonstrates a production method which includes an interaction
- Final product: A fully finished product made out of RECURF. This product is made with an existing production proces

When comparing these options to our previously mentioned criteria we get the following results:

Option	Story of RECURF	Inviting	Movement	Understandability/ reducing complexity	Trailability
Samples	Yes	Yes	No	Yes	No
Production process	Partly	Yes	Yes	Yes	Yes
Final Product	No	Yes	No	Yes	No

figure 81. A comparison between three demonstrator ideas

From these results we can conclude that the production process option has the most potential as this option fits almost all of our design criteria. The only aspect that can be improved on this option is the fact that showing the production process only shows one-fourth of the story of RECURF. As we aim to teach our target audience as much as possible about the RECURF material, it would be optimal if we can combine the production process option with a presentation of the other stages of the RECURF development process.

As such we have decided that we are going to design an exhibition that tells the story of RECURF with the production process as the main focal point. This means that the majority of the exhibition space will be taken up by the designed production process in the form of a machine. Additionally, there will be samples visible of both the raw RECURF materials, as well as an origami tessellation sample of the RECURF material as created in the production process. This way, all the stages of the story of RECURF are represented except for one, which is the creation of the non-woven. However, in order to show how the creation of the non-woven RECURF works we would have to bring the machine that creates non-woven RECURF sheets to the exhibition which would be impractical.

Production specifications

Following our decision to have the production process as the main focal point of the exhibition, we now have to decide on what kind of production process. In line with our material experience vision, we want our production process to show the unique qualities and possibilities of the RECURF material. Following our tinkering sessions we concluded that these qualities and possibilities lie in the duality of the material and that heating and pressing RECURF brings out this contrast in duality at its best. From our tinkering sessions we also concluded that the pre-existing production methods that are viable with the RECURF material offer either flexibility in terms of positioning or a high pressure heat press, but never both. Therefore an opportunity emerges for a machine that combines flexible positioning with a high pressure heat press.

As established in the Project Description, we will be working with large sheets of RECURF for our exhibition. Therefore we have the following requirements for our production process design:

- Can melt and press BiCo
- Different shapes can be pressed
- Create hard and soft areas on one sheet
- Positioning of the shape of the pressing head is as flexible as an iron
- Large sheets can be pressed, at least in 2 meter x 2 meter

These requirements allow the production process of RECURF to be highlighted in line with the goals of our overall vision for the user experience and criteria for design.

In sum, we will be designing a RECURF production process to be exhibited at the Dutch Design Week 2018 (DDW) in Eindhoven. Even though the DDW has a broad audience, the main target group for our exhibition will be other designers and engineers. The exhibition will tell the story of RECURF through samples of RECURF in various states, with the main focus point on the production process in the form of a machine. This machine will have to be inviting and understandable, flexible and high pressure, and should be able to create tessellated origami patterns in large sheets of RECURF.

8. Ideation and Concepting

8.1 Introduction

In this chapter, we outline two brainstorming sessions that led to three different concepts. All the concepts contain the production process of heating and pressing RECURF. For the first brainstorming session we made use of the ‘How to’s’ brainstorm technique. For the second brainstorming session we made use of the SCAMPER ((Boeijen, 2013, p123) technique. From these three concepts we finally decided on one specific concept for our final design.

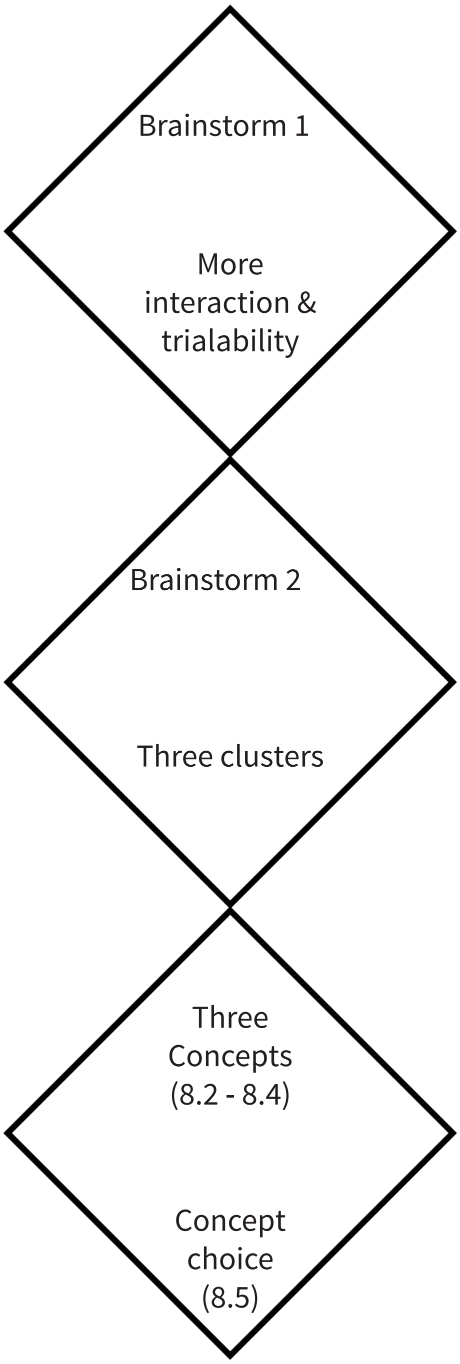


Figure 82. A diamond shape visualisation of the design process

Brainstorm session 1

The first brainstorm session was used to generate several ideas which helped us decide the design direction we wanted for our design. During this session we used a brainstorm technique that is called: ‘How to’s’ (Boeijen, 2013, p. 127). This technique divides a brainstorm into several clusters, some of these are: how to apply force, how to create heat, how to position the press, etc. An overview of all of these ideas can be seen in figure 83. We reflected on these ideas in combination with our material experience vision. The ideas that were most in line with our design criteria were the ones that required users to participate in the demonstrator. Therefore we decided on an exhibition design that involves an interaction.

We have chosen this as our design direction as an actual experience of the RECURF material, whether that be tactile or manual. In other words the trialability of the demonstrator can help a person get a better understanding RECURF material and its qualities and possibilities. The next step is to explore this interaction-based design direction further to create three feasible concepts.

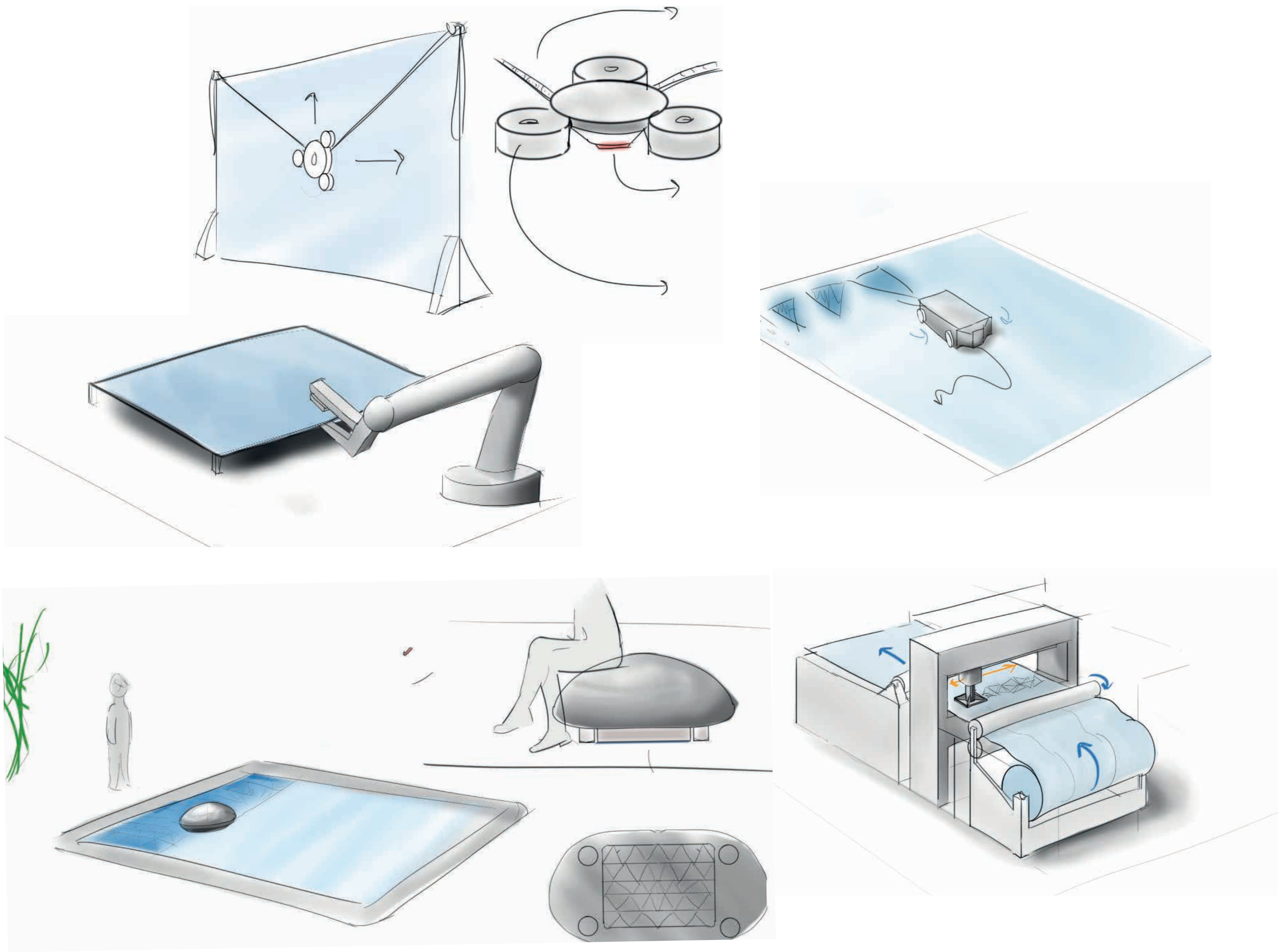


Figure 83. Drawings made during the first brainstorm

Brainstorm session 2

For this brainstorming session the SCAMPER technique (Delft Design Guide, 2013) was used. This technique needs an existing concept or idea which is then used as foundation for the second brainstorming session. In this case our existing concept was the idea of a production method that required an interaction with a person to function. This brainstorming session led to the following three options:

- Option 1: An interaction with the material after production
- Option 2: An interaction with pattern placement during production
- Option 3: An interaction where two or more people apply force to press

For every option a concept was created. Each concept, including its user path and method of interaction, is further outlined in the following section.

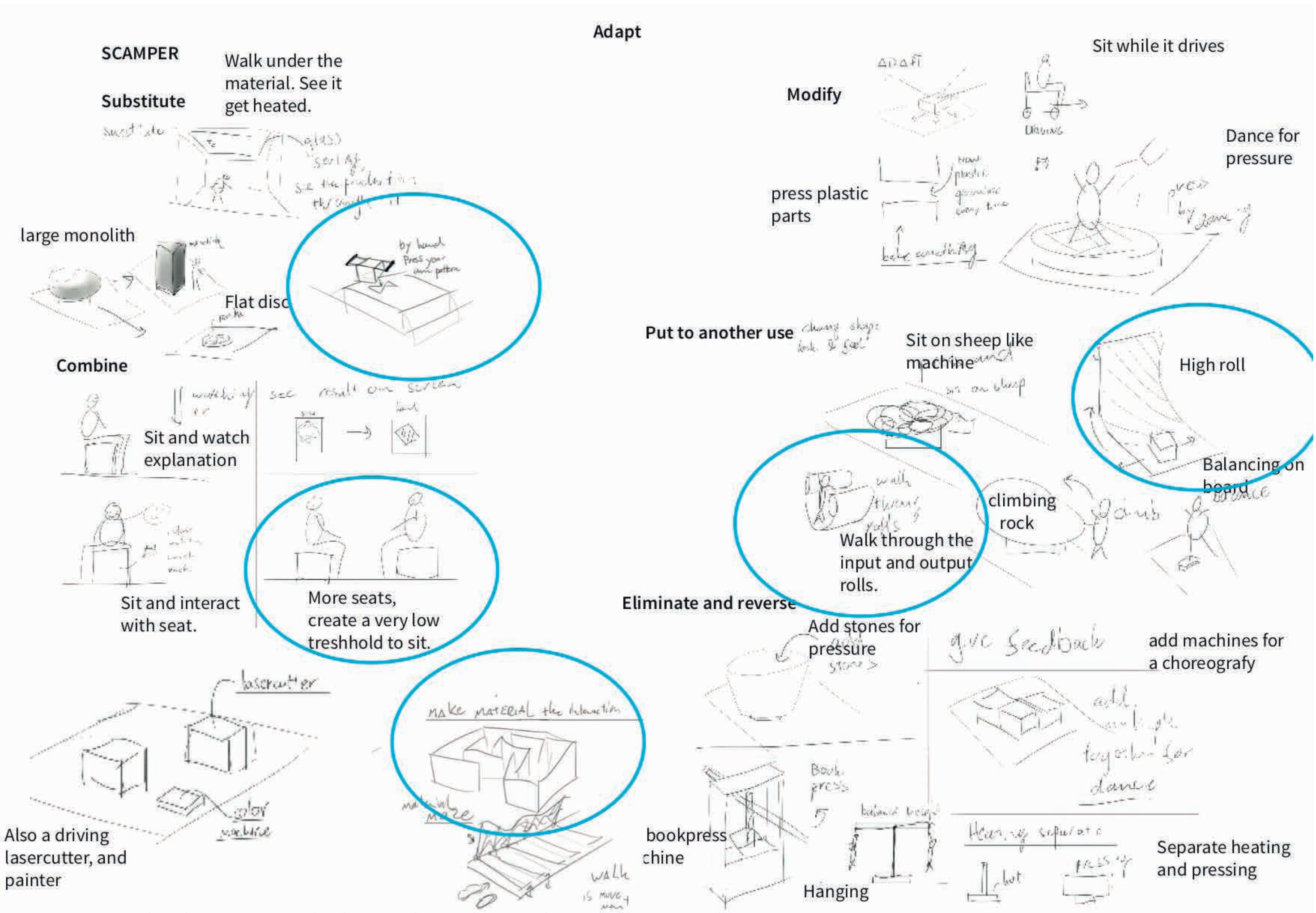


Figure 84. The drawings made during the SCAMPER brainstorm

8.2 Concept 1

The Maze

This concept uses a press that is Computer Numerical Controlled (CNC) and thereby presses and heats automatically. The press automatically produces a long pressed sheet of RECURF in a tessellated origami pattern, which as it continues to grow slowly curls around the machine but with enough space for people to walk between the sheets. This way it looks almost like a maze of tessellated origami RECURF with the press at its center. Visitors are invited to walk between the sheets to find the press and explore the material by touching it.

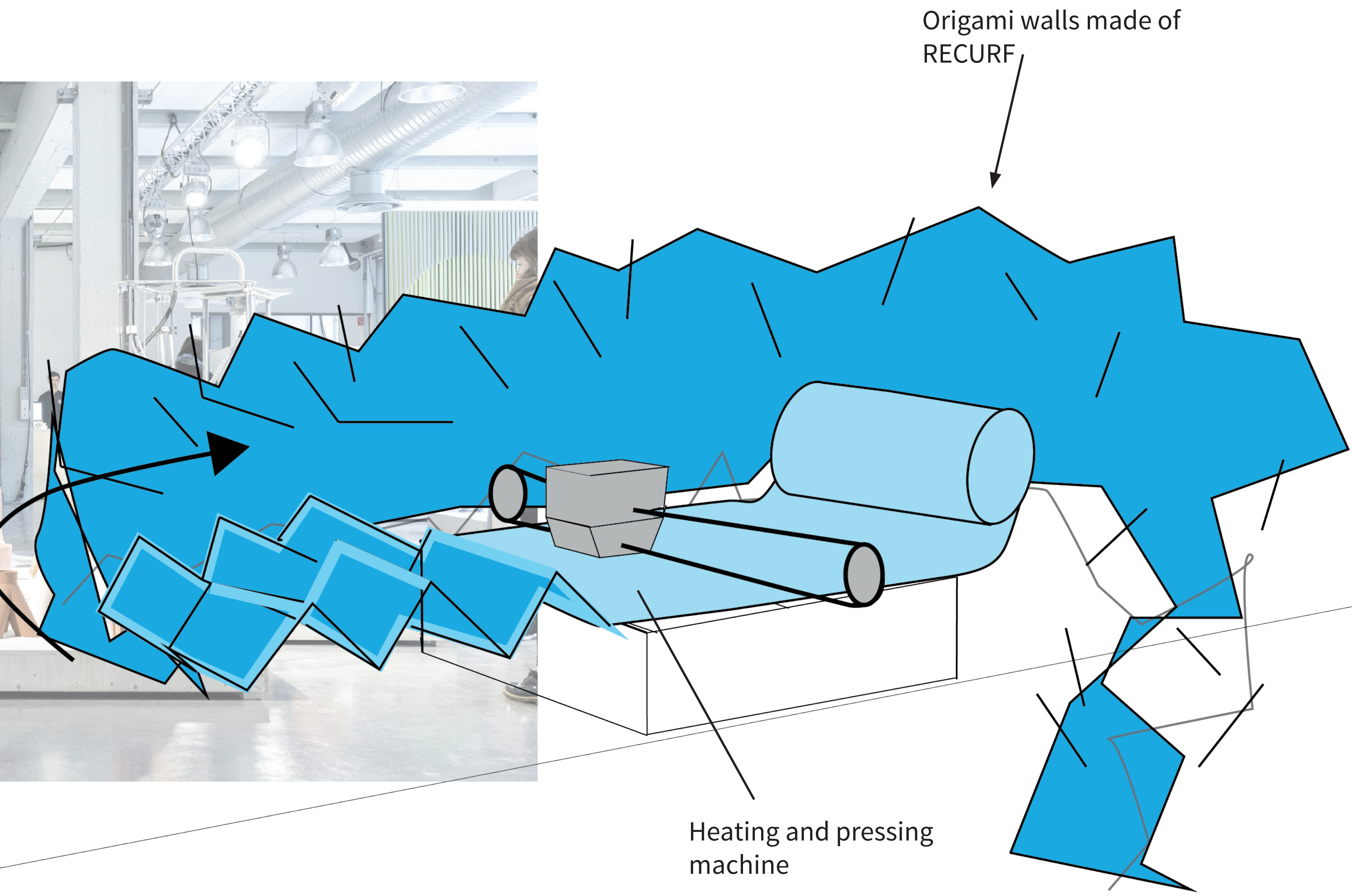
User path

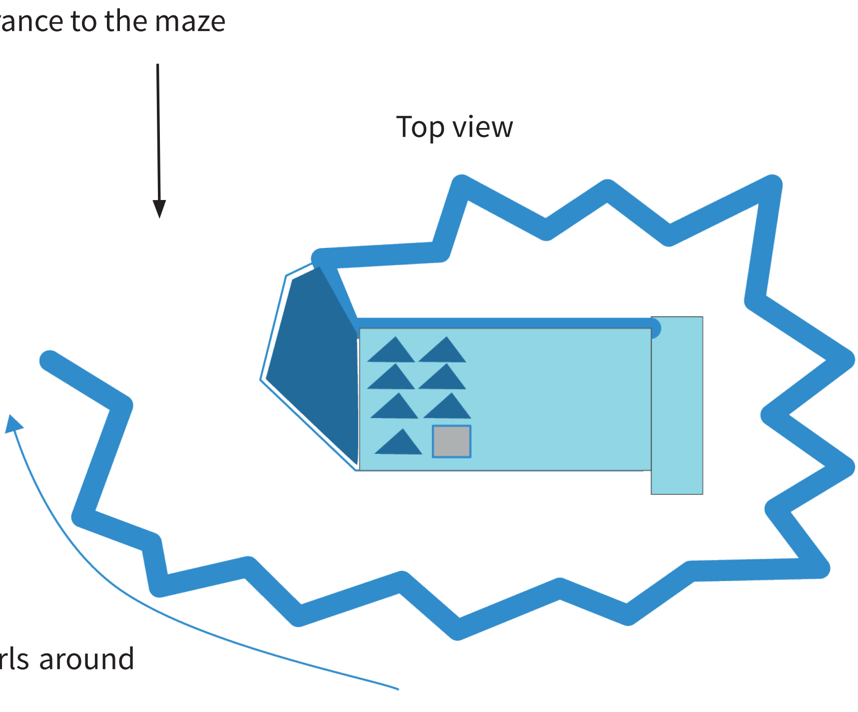
- See a maze-like shape made of one long sheet of RECURF in a tessellated origami pattern with the press at the center
- User does not know what material it is or why it is standing this way
- If curious enough to approach: user walks inside the opening, touching RECURF
- Sees machine that is pressing RECURF
- Questions arise: Why this setup? what is this material?

Interaction

- Walking into the maze
- Touching the pressed RECURF material

Figure 85. Concept 1. Image by Sjoerd Eickmans [34]


Origami walls made of RECURF
Heating and pressing machine


Visitors entrance to the maze
Top view
RECURF Slowly curls around the machine

8.3 Concept 2

Direct Press

This concept makes use of a handheld press. This press can be moved around by a single person. He or she can position this press to the location where he or she wants to press the shape. This interaction invites people to both position the press where they want to press the material, as well as press it. The use of magnets helps to achieve the required pressure on the RECURF, as the magnets are drawn to the metal plate on the table.

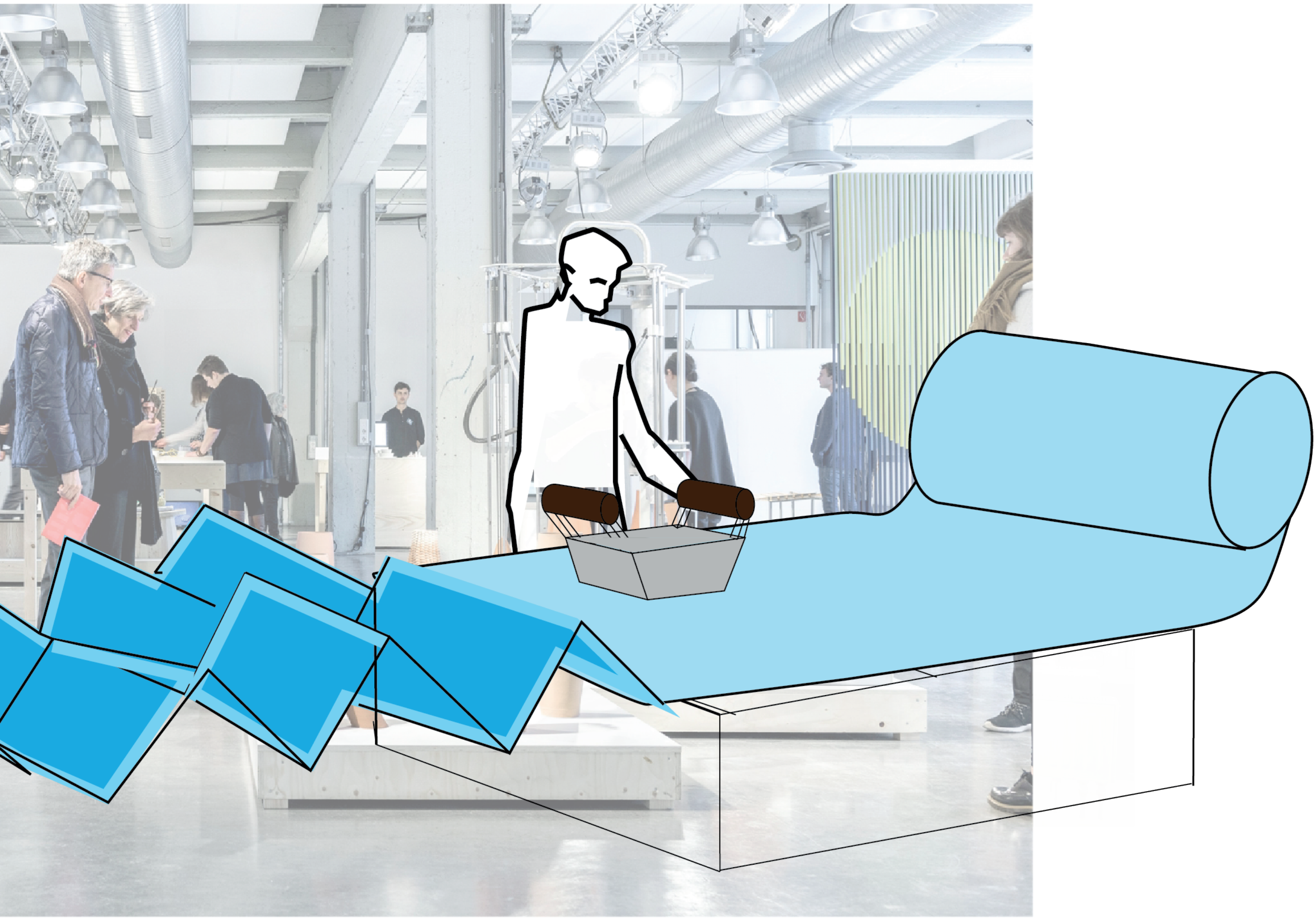
User path

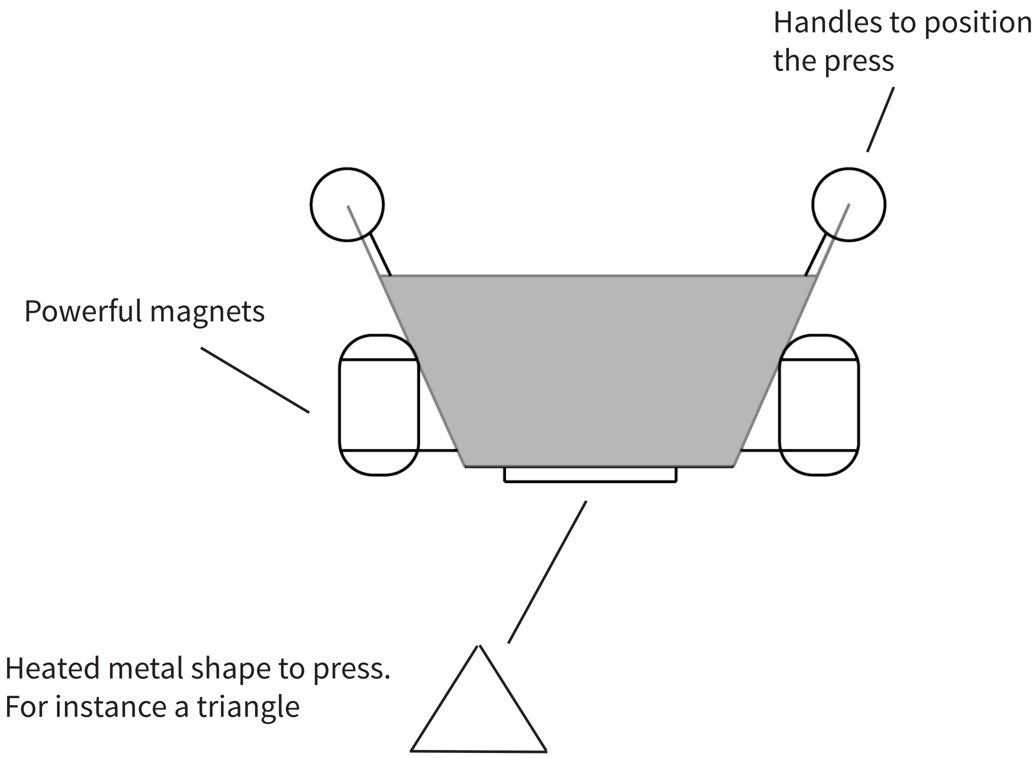
- See person standing at table with device in hand
- Can see he/she is doing something to the material
- If curious, take a closer look
- Questions arise: What is this material, what are you doing? What can you make?

Interaction

- Position the press by lifting it and moving it into place
- Pressing the RECURF material

Figure 86. Concept 2. Image by Sjoerd Eickmans [34]





Handles to position the press
Powerful magnets
Heated metal shape to press.
For instance a triangle

8.4 Concept 3

Sit WithTwo

Two people need to sit on this demonstrator to create a downwards force to assist in pressing the RECURF. This concept also asks people to work together and press a shape in the RECURF. This creates an interaction between two people and the demonstrator. When a shape has been pressed onto the RECURF, the sitting unit is rolled to a new position.

User path

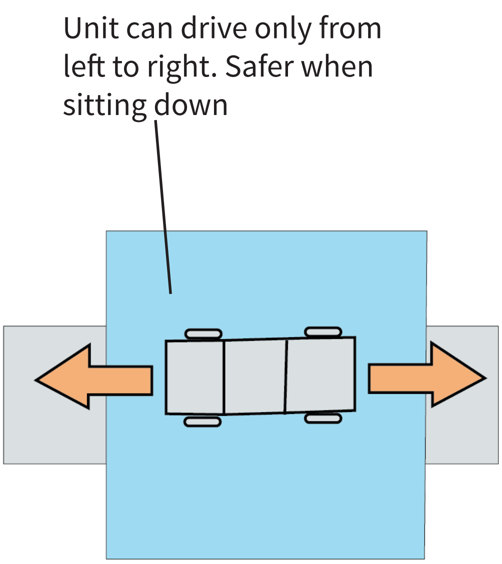
- Observe people sitting on the double seat or see two empty seats
- Curiosity: what is this for or what are they doing
- Standing in crowd, questioning if they want to sit: Why should I sit, what is the effect of sitting? What does that material have to do with it?
- Asks these questions to person that is helping the sitting people

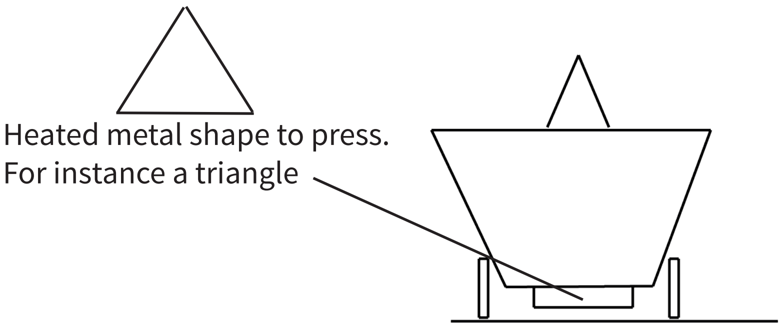
Interaction

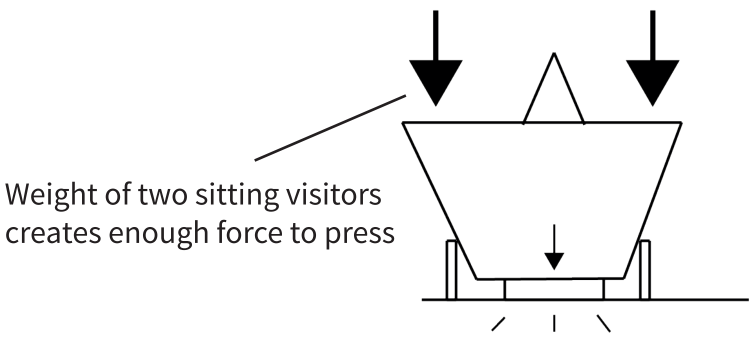
- Two people sit on the the double seat

Figure 87. Concept 3, image Sjoerd Eickmans

s [34]


Unit can drive only from
left to right. Safer when
sitting down


Heated metal shape to press.
For instance a triangle


Weight of two sitting visitors
creates enough force to press

8.5 Concept Choice

From these three concepts we now have to choose one concept for our final design. To assist us in making this decision we compared each of these concepts to the design criteria as set in the design brief. Figure 88 shows the results of this analysis which will now be further explained.

Option	Concept 1, The maze	Concept 2, Direct Press	Concept 3, Sit with two
Story of RECURF	+	++	+
Inviting	-	++	++
Movement	-	+	+
Understandability/ reducing complexity	-	++	+
Trailability	-	++	+

Figure 88. Choice for a concept. Concept 2 scores the highest

Story of RECURF
- - : Only one state of RECURF is shown inat the demonstration
++ : The focus lies on the story of RECURF, all stages are presented

Inviting
-- : There is nothing that invites people to take a closer look.
++ : The demonstration has aspects that draws the attention of people, they can touch, watch more closely, and feel invited by the look of the demonstration.

Movability
--: no movement at all
++: Continues clearly visible motion

Trialability
-- : There is nothing that can be tried out
++: People can easily try out one or more things

Complexity
-- : The demonstration is hard to understand
++: The demonstration is simplistic, all the steps are understandable

Story of RECURF

The concept that scores the highest on how well it tells the story of RECURF is concept 2, whereas concept 3 scores the lowest. Concept 2 engages the person in the story of RECURF by having them contribute to the process of pressing a pattern onto the RECURF material. This not only makes them part of the story, but also makes the person think of what is possible with the production process. Concept 3 creates an interaction that is focused on the sitting on an object, while the sitting itself is not really an integral part of the story of RECURF. It is also unclear whether the people sitting will realize that their weight is necessary to press the material, or if they just think it is fun that they can sit together, therefore this concept can be considered as distracting from the story. Concept 1 scores somewhat in the middle of Concepts 2 and 3. It has an interaction that revolves around the person exploring the exhibition and material by walking through it and touching it. Even though Concept 1 does tell the story of RECURF in the sense that you see it being produced, the focus still lies more on the maze.

Inviting / moveability

Concepts 2 and 3 are both considered as very inviting as they both invite people to participate in the production process of RECURF. Both are directly observable and can evoke curiosity as to what they are doing and what kind of effect the interaction has on the material. Another important aspect is that both Concept 2 and 3 have a lot of movement going on. This invites people take a closer look. Concept 1 scores the lowest of the three. It has an interaction that is based on exploring the maze made from RECURF. However, that means the centre of the maze is not visible, and it is therefore not clear where the maze is directing you to go. This creates less of an inviting look. Concept 1 also lacks movement.

Understandability (Trialability and Complexity)

Concept 2 scores highest in trialability, while Concept 1 scores the lowest. In Concept 2 it is clear that visitors can participate in positioning the press. Concept 1 in contrast does not let visitors do any activity that is part of the production process. Concept 3 lets visitors press by sitting on the press. Visitors are partly participating but are not fully trying out the production process.

Concepts 2 and 3 score the highest in complexity. They both show all of the steps of the production process one by one, making it less complex. Concept 1 does show the production process but the process is automated, which makes it more complex and harder to understand.

Conclusion

Following this analysis we have chosen Concept 2 for our final design, as this concept scores the highest on average on all criteria. We feel that, in comparison to Concepts 1 and 3, Concept 2 gives a more realistic view on how the production process of creating something with the RECURF material works. Whereas Concepts 1 and 3 might appear as less technical and more ‘fun’, this can also distract the audience from the information that we are trying to convey. As we are trying to teach the audience about the material itself and the possible production methods and possibilities, showing something that is more realistic appears to be the better approach and is more in line with our aim.

9. Final Design

9.1 Introduction

The final design is called the Direct Press. It tells the story of RECURF best when compared to the other concepts. It is inviting and people can try pressing the RECURF material themselves. This chapter explains the steps that were taken that led to the final design and build of this demonstrator. It starts with further designing the method of applying force, followed by the designing of the pressing shape. These two designs led to the positioning of the heating unit, and the general shape of the heating-unit and general demonstrator size. After these design iterations, the demonstrator was built and tested. After the test, a second re-design was made and the final demonstrator was built.

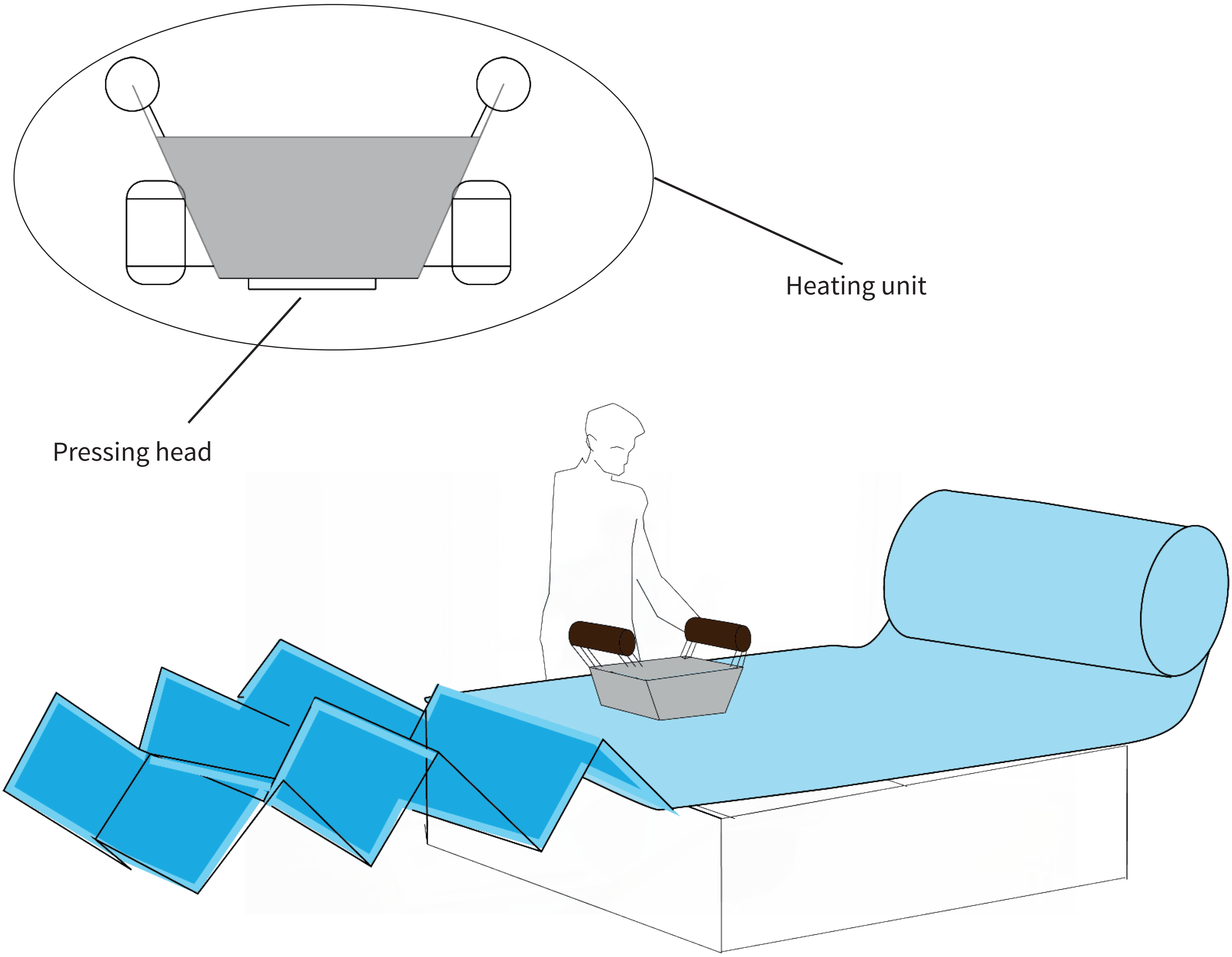


Figure 89. Overview of the final concept.

9.2 Applying Force

Introduction

In this section we explain the design of the new method for applying force. The reason for this new method is that, in the initial design, the magnets that were supposed to apply enough force could only do so when physically in touch with the steel it was attracted to. Any distance between the magnets and the steel led to a rapid decline in strength. As such we decided to develop a new method for applying force.

Problem of the magnets

The chosen electromagnet has a strength of 600 N when touching the steel it is attracted to. To reach the minimum of 800N of force we bought two of these magnets to reach 1200 N. Since the magnets are on top of the RECURF, with the steel below the RECURF, there is a distance between them. During the test, a distance of 2 mm caused the strength of 600 N to decline to less than 5 N, making the magnets not functional for this demonstrator.

Brainstorm

Changing from force applied by magnets to another kind led to an overview of four different methods of how to apply force:

- Hydraulic
- Weights and spring
- Weight of person
- Lever

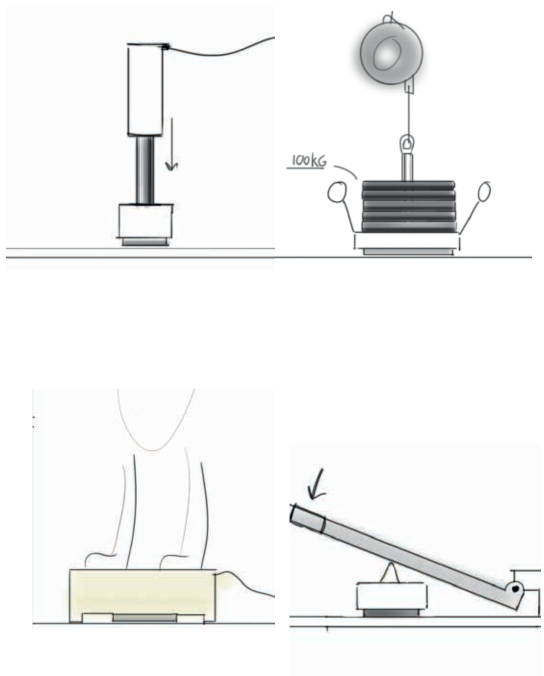


Figure 90. Four methods of applying force

Option	Pneumatic	Weights	Weight of person	Lever
Story of RECURF	+	+	+-	+
Inviting	-	-	+	+
Movement	-	+	+	++
Understandability/ reducing complexity	+-	+-	+	++
Trailability	-	-	++	++

Figure 91. Choice method with multiple criteria. The lever scores the highest

It can be concluded that the lever is most suited to apply a force. It tells the story of force because the lever is recognizable as something to create force. Since it is recognizable it is therefore easy to understand, as a lever is a commonly known method of enlarging a force. It is also inviting, because a person can try pressing.

In appendix D, the choice for a specific kind of lever is made out of four different levers. The chosen lever is shown in figure 93.

The heating unit can move along the lever, and therefore the ratio between handle and heating unit compared to the rotational point can vary. Consequently, the force that is exerted on the heating unit (while the person presses equally on the lever) can vary. This means the heating unit needs a method to give feedback about how much force is applied when pushing the lever down, so the user can adjust the force on the lever to create a constant force at the heating unit.

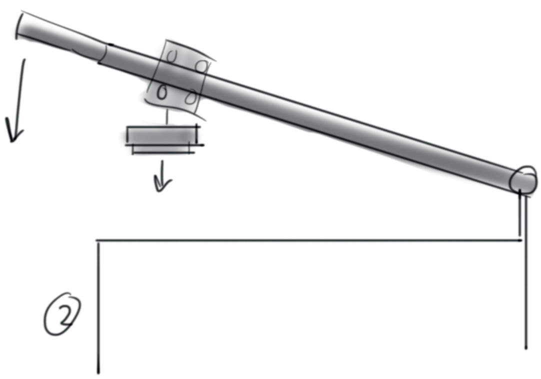


figure 93. The chosen lever. The heating unit is attached to the lever but can slide along its axis to change position on the table.

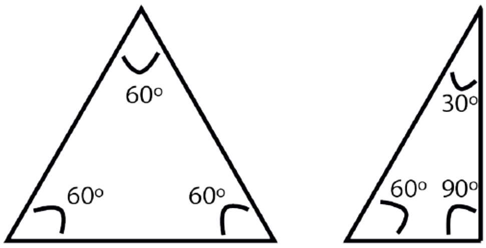


figure 94. Two triangles, one with 60-60-60 angles and on with 30-60-90 angles

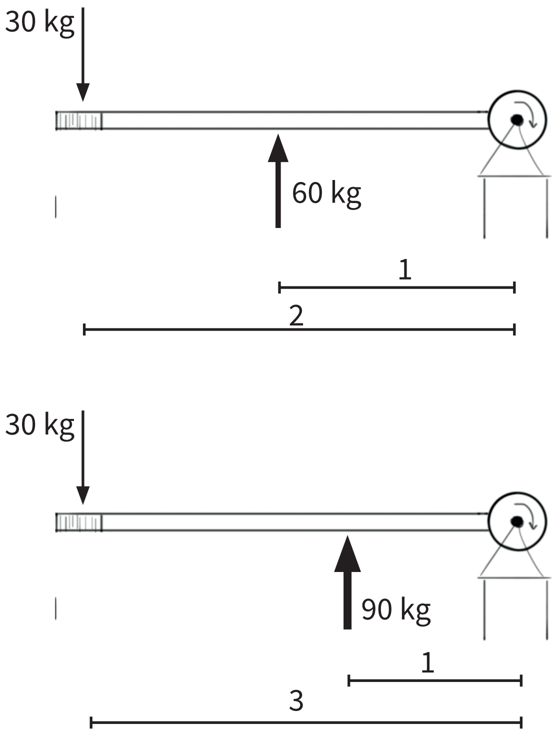


figure 92. Influence on lever ratio and force variation

9.3 Pressing Head

Shape of pressing head

During a brainstorm session many kinds of head shapes were introduced (appendix E). One idea was most promising, see figure 94. A basic triangular shape that has three corners, which are 30, 60 and 90 degrees (30-60-90 triangle) was chosen to proceed with because of its versatility in origami pattern-making, as shown during our tinkering phase. This head is about 50 cm2 and has to heat up to temperature of 150° *C*. These patterns can be made as follows:

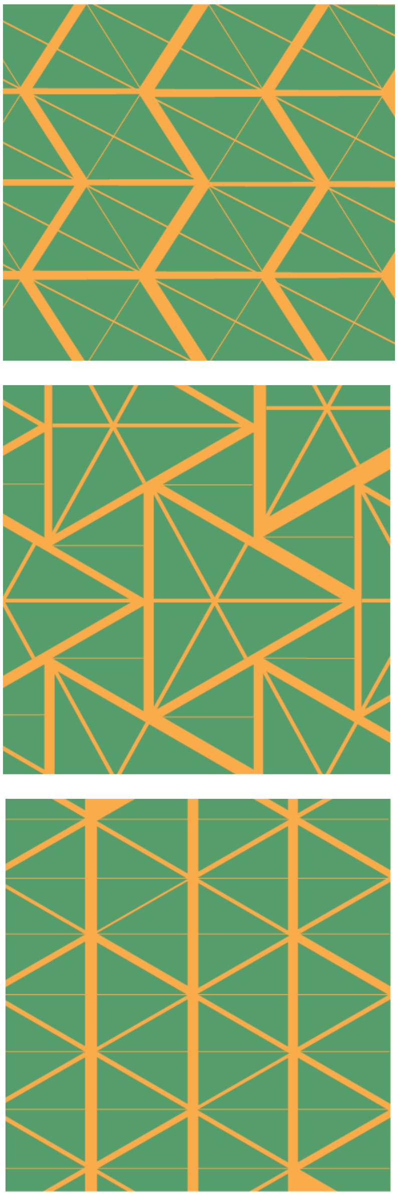


figure 95. Three origami crease patterns made with the same triangle. From top to bottom: a mountain and valley pattern, a plateau pattern and last, a random folding pattern.

During a test it became clear that this triangle should be symmetric in shape, otherwise it cannot press the desired patterns without changing the press head to another shape. For instance, when creating a 60-60-60 triangle with this shape, it needs two pressing heads that are reflective images of each other.

The solution to this problem was making a head in the form of the triangle 60-60-60.The 60-60-60 triangle can make three kinds of origami (see chapter 5 tinkering #6), when an extra way of folding is added. This extra folding method folds the 60-60-60 triangle into two 30-60-90 triangles (figure 94). This is done with a dotted fold, fold # 1.

Size of triangle

The size of the pressing head is dependant on:

- The amount of force that is available
- The intended appearance of the origami

We first tested at what size surface area the force was enough to press the RECURF flat and melt it on both sides, with a heated shape at one side and wood at the other side.
During a basic test, a triangular shape was heated up in an oven to 190° *C* and pressed with 80 kilogram on a surface of 50 cm2. Creating a pressure of 800 N /0.005 m2 = 160 kPa. After 60 seconds the bottom of the sample was also molten. During this test the RECURF sheet was placed on a wooden underground. We did another test where the RECURF sheet was instead placed on a steel underground. During this test it took 90 seconds and a heat of 200° *C* before the RECURF started melting at the bottom side.

Due to time constraints we were not able to test pressing surfaces of RECURF larger than 50cm2. Nevertheless, these tests prove that it is possible to successfully press the RECURF material with 80 kg on a surface of 50cm2.

Material of pressing-shape
Aluminium was chosen as the material for the pressing-shape as it is both lightweight as well as heat conductive. It also has the advantage that the whole aluminium shape often has a relatively homogeneous temperature.

Heating of the pressing head
The pressing head is heated indirectly by 4 small heating elements that together have a power of 800 Watts. These elements can reach a maximum of $200°C$. These elements are attached to a square block of aluminium, the base-plate. 15 cm x 15 cm x 1.0 cm. This base-plate is in direct contact with the heating head. It is this size because it is generic and many pressing head will fit this base plate. The thickness of the base plate of 1 cm is enough to endure forces up to 150 kg according to the simulation. This can be seen in figure 97 and is further explained in appendix F.

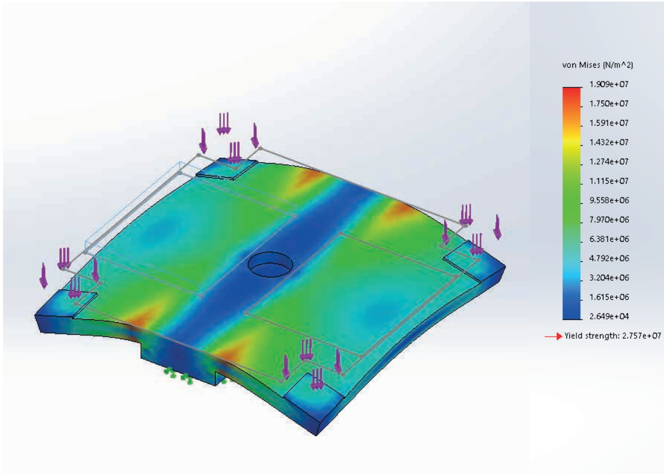


Figure 97. Force simulation of the base plate and pressing head. The maximum stress the occures is about 30% under the yield strength of aluminium. The means the base plate has enough thickness.

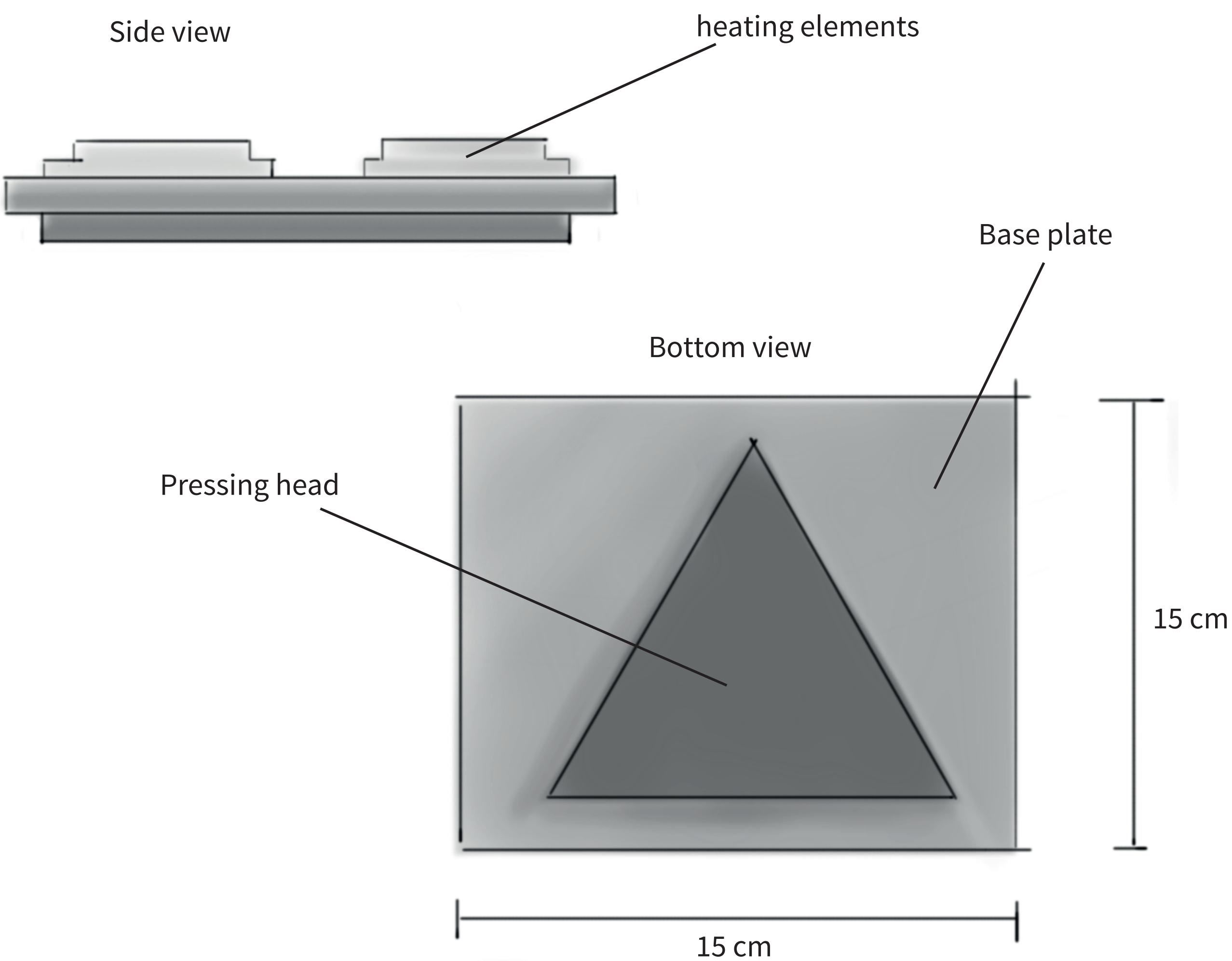


FIgure 96. Base plate and pressing head

Changing the pressing head

Interchangeable pressing heads can support the exploration of RECURF with the demonstrator. This creates the possibility for a versatile exploration. Three different ideas of creating such a interchangeable pressing-head have been made. These are in appendix G. The chosen idea, seen in figure 98 makes use of a standard pulling clamp to clamp the pressing head to the base plate.

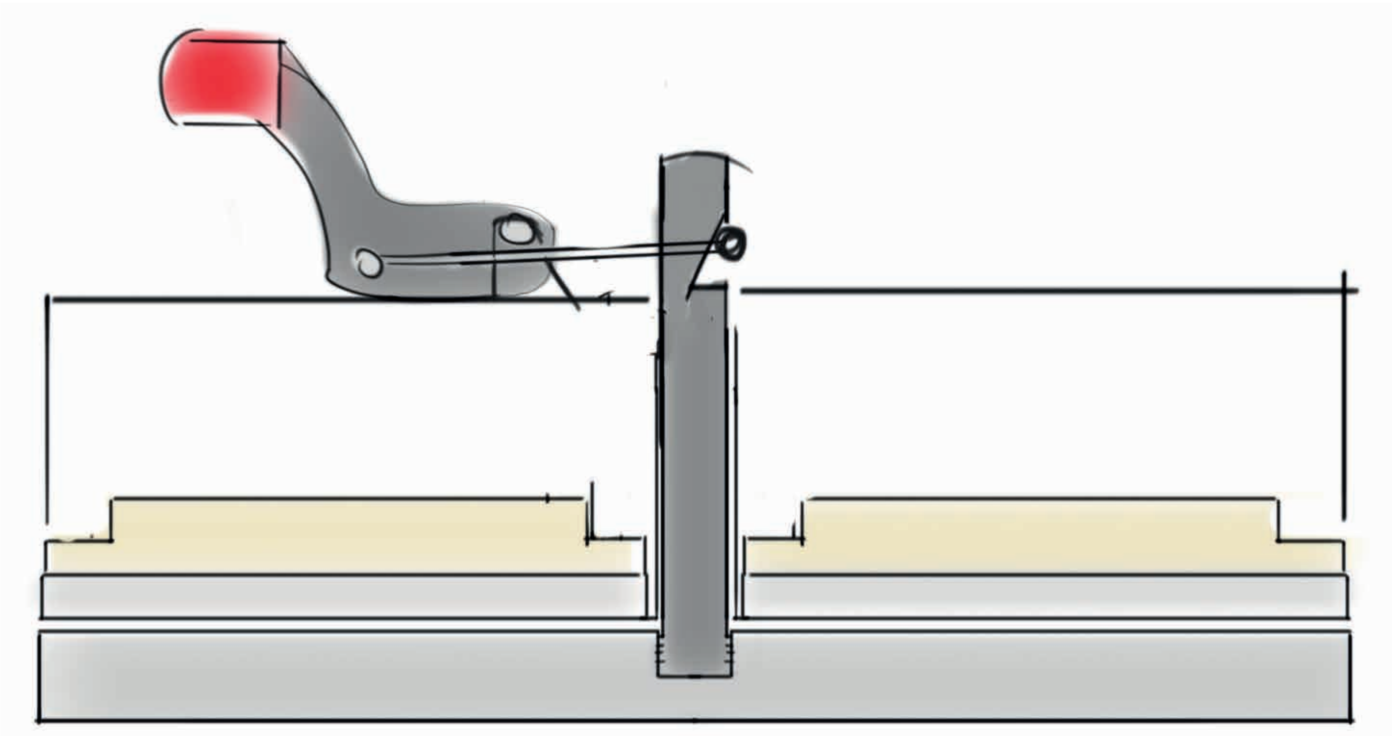


FIgure 98. Pulling the pressing head onto the base plate with a simple mechanism

9.4 Positioning

The positioning of the heating-unit will be done by hand. This allows for exploring, trying out and for instance changing your mind during the process of positioning and shape-making of the RECURF. However, as the method of applying force has changed from magnetic force to using a lever, the method of positioning also has to change from the initial design.

While the user positions the heating unit, the lever can get in the way, and make the working area of the user small. The chosen solution is to attach the lever to the heating unit.
However, the heating unit will be in need of complete freedom in linear and rotational movement in all directions. To give the heating unit this freedom of movement and simultaneously have it be connected to the lever, several additions have been made.
A sliding rail was first added to the lever, and then the heating unit was attached to it with a sliding block . Now a person can hold the lever with one hand, and the heating unit with the other hand to slide the heating unit along the lever.

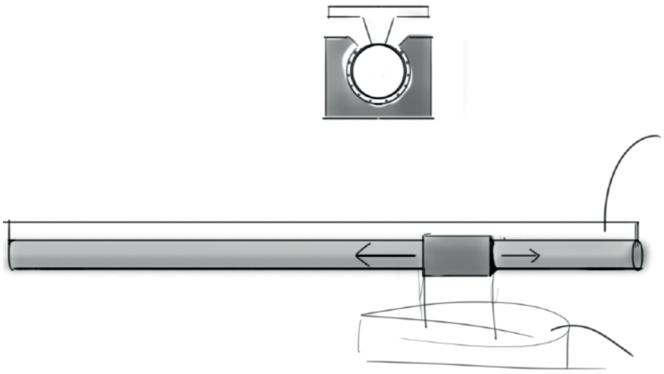


Figure 99. Sliding rails with a sliding block on it

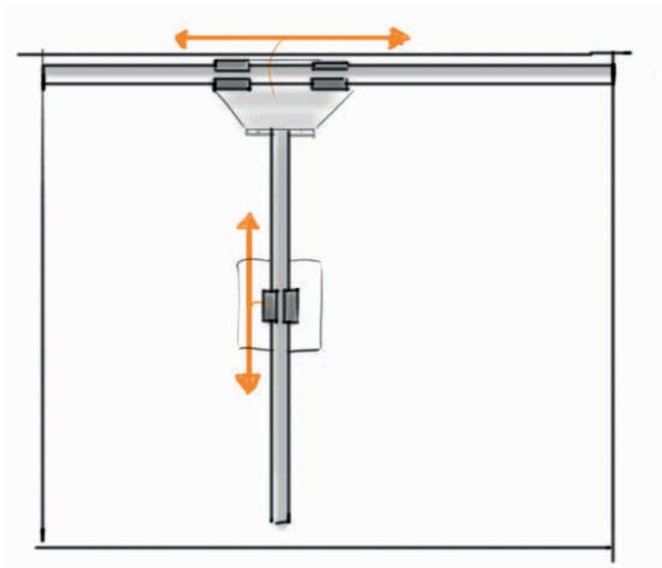


Figure 100. This figure shows the movement the lever can make from top view. The two linear degrees of freedom, x and y.

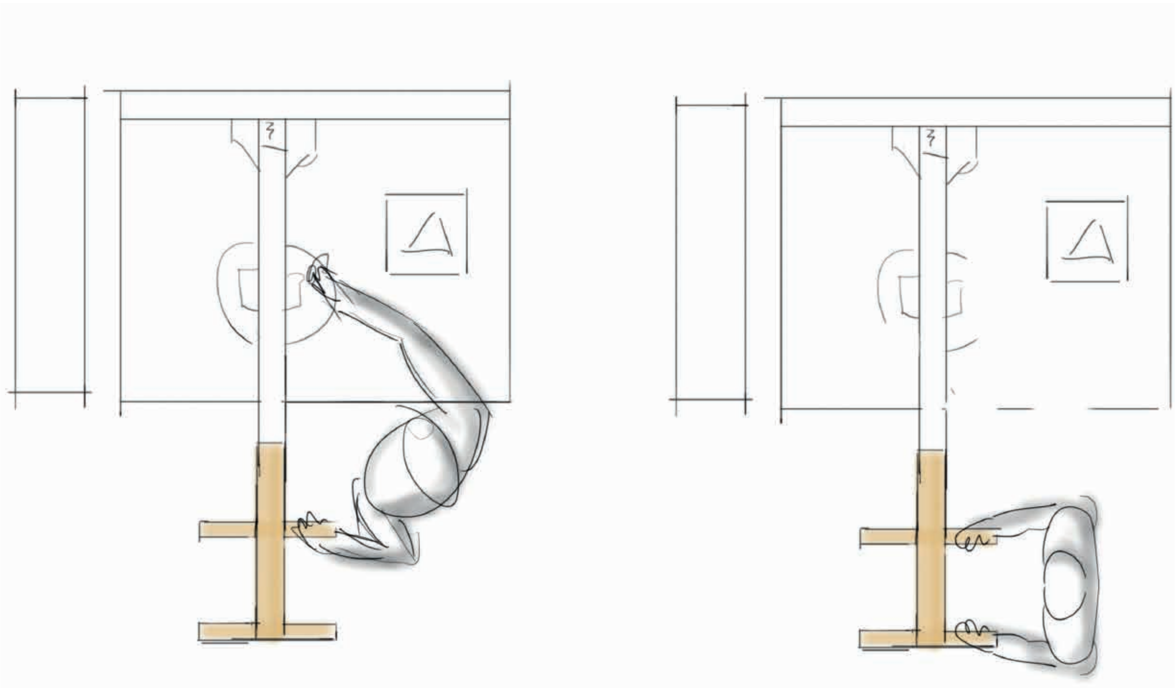


Figure 101. Top view of user of the demonstrator.

To give the heating-unit freedom in the other length axis, perpendicular to the lever, another slide rail is used. This sliding rail is attached to the table and the sliding block is attached to the end of the lever. This way the whole lever and the heating-unit can be moved from left to right.

The heating head is still in need of four degrees of freedom: One length-axis upwards (often called the z-axis) and all the rotational movements (rotation around the x, y and z-axis). Movement upwards is made possible by the lever.

The mechanisms that create the the three degrees of freedom in rotation are positioned in the top part of the heating unit. These rotational mechanisms are shown in figure 102. The most important rotational degree of freedom is the one that rotates around the z-axis. This creates the possibility to rotate the pressing-shape and to make different patterns.
The other two degrees of freedom are there to make sure that the force on the heating unit is evenly distributed to the pressing-shape . If the heating unit or the RECURF is not 100% level compared to the table, these two degrees of freedom will give it room to rotate slightly to the angle at which the pressing head is level with the RECURF.

When the heating unit is positioned the user lets go of it. Then he/she applies force to the handles of the lever by pressing on them.
We decided to use two handles instead of one because it is more comfortable to distribute your weight over two handles when applying force. This reduces the risk of losing your balance when pressing on the lever and pressing with two hands also allows you to press with more force than with one hand.

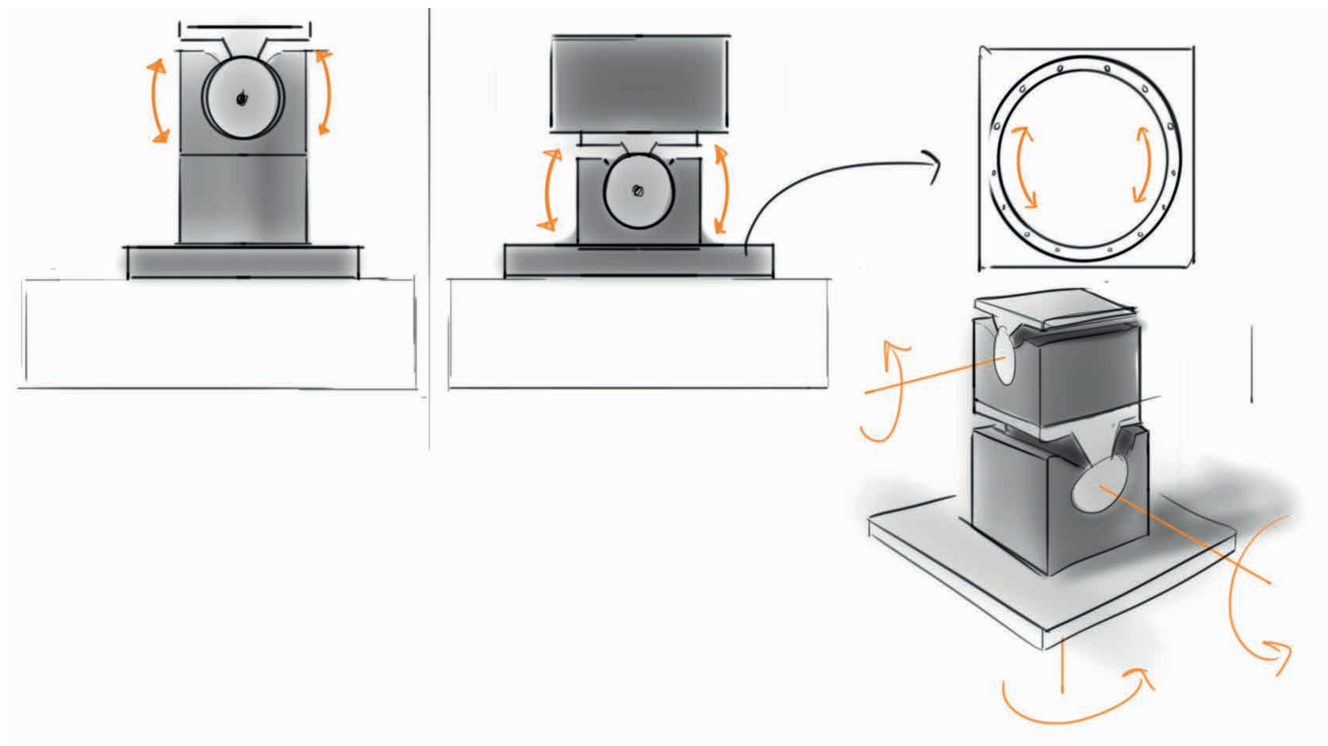


Figure 102. Three degrees of freedom on top of the heating unit

Handles

The heating unit is moved and rotated by the user using one hand. The handles are therefore important. It needs to be practical in every position and angle. Therefore several visualizations were made of possible handles. The most useful handle is the one that is circular and stretches all around the heating unit as it can be safely grabbed from every position and angle.

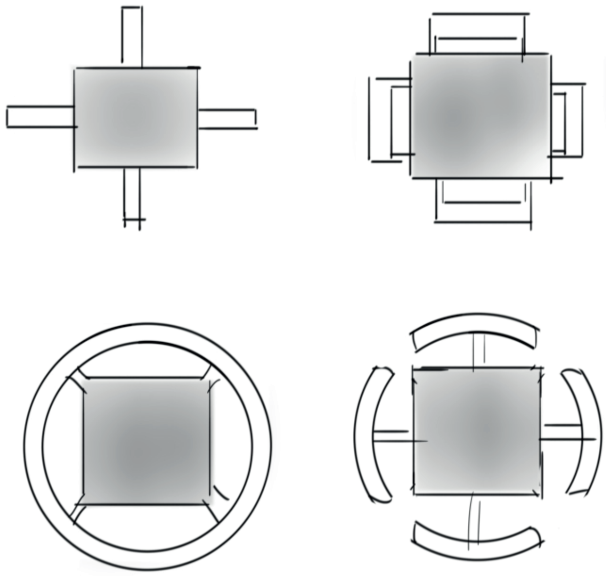


Figure 103. Four versions of handles. The handle on the left below is the chosen handle

Accuracy in positioning

For origami it is important that the folding lines do not alter the predetermined pattern too much. This means that the positioning of the pressing head needs to be accurate. How accurate can be seen in figure 104. Here the soft folds differ in size between 1 and 2 cm's. Even this small difference is too much as it breaks the pattern. This accuracy has not been broadly tested. For now we prefer to make the difference between the thickness of soft folds no larger than 10%. This can be noticed in figure 104. As this shows the difference between the fold of 15 pixels vs the fold of 16 pixels and the fold of 10 pixels. The 10 pixel wide fold is clearly thinner than the other two. Fold 15 and 16 do not clearly differ in width.

For the positioning of the heating unit we have chosen a flat plate (positioning-plate) that behaves like a guiding tool. The other concepts that tackle the positioning problem are in appendix J. The chosen concept, seen in figure 105, has the shape of the pressing head cut out of it (with some additional cuts for line out). The positioning plate is positioned exactly where the material needs to be pressed. The heating unit is then placed on the positioning-plate with the pressing-shape exactly in the cut-out section of the positioning-plate.

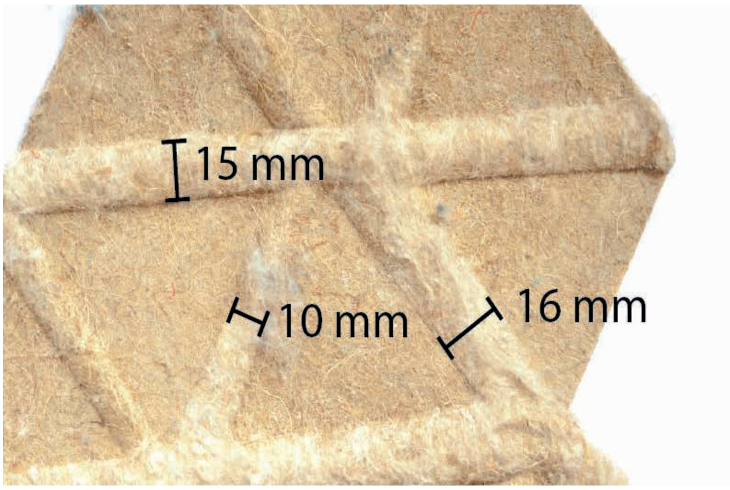
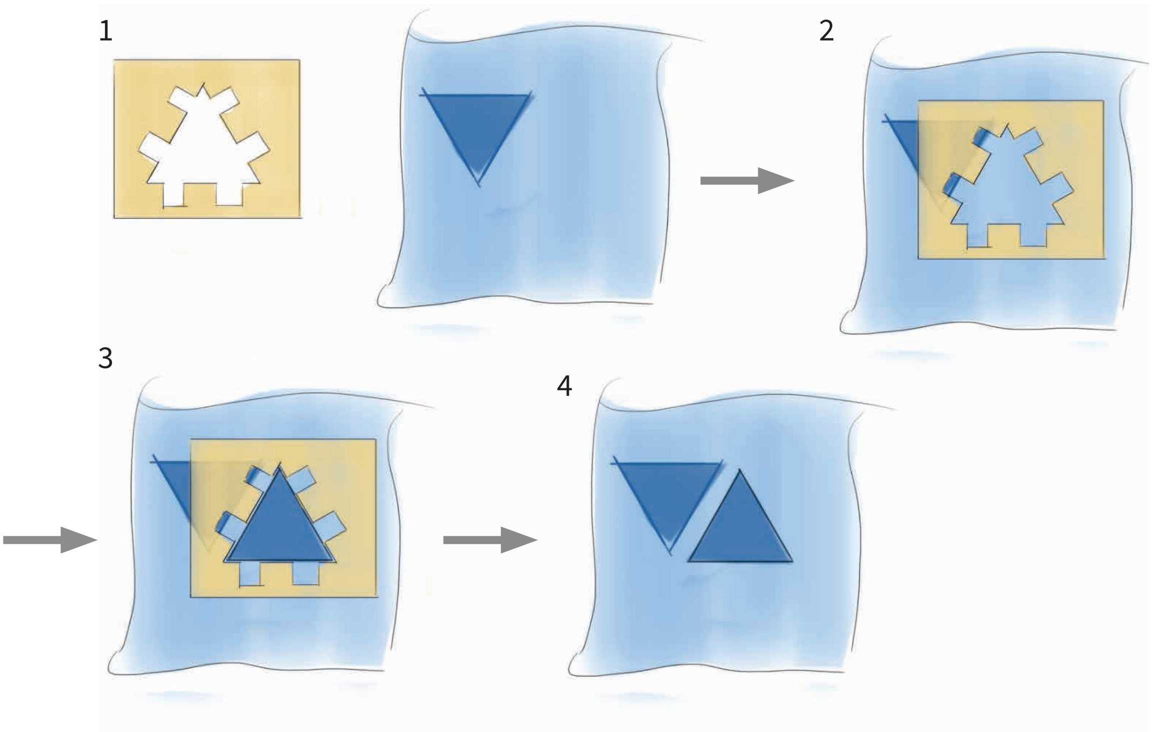


Figure 104. Accuracy on a sample of RECURF

Figure 105. The positioning plate and the heating unit

Figure 106. A visualisation of how the positioning plate works. step 1 and 2: take the plate and put it on the location you want to press. Step 3: press the material. Step four: remove the plate.



9.5 Sensors

Force sensor

To measure the force that is applied to the heating unit, a force sensor was built between the lever and the heating unit. A sensor was chosen that can measure force up to 1000N. This sensor is visible in figure 108. The sensor bends a few mm downwards when pressure is applied. This is inconvenient as it would cause a small rotation every time it is pressed. Although this will not affect the heating unit much, we chose to add another sensor to balance the movement out (figure 108).

Temperature sensor

The heating element heats up to 200° C. To control the temperature and reach the prefered 140° C, an electric control system (PID controller) is needed that can measure the temperature and control the heating elements by turning them on and off. This way, the heating elements will be turned off whenever 140℃ is reached in the pressing head. The element will be turned on again when the temperature goes below 140℃. For such a system an Arduino with a thermocouple is most practical and feasible to use. The used setup is shown in appendix H.

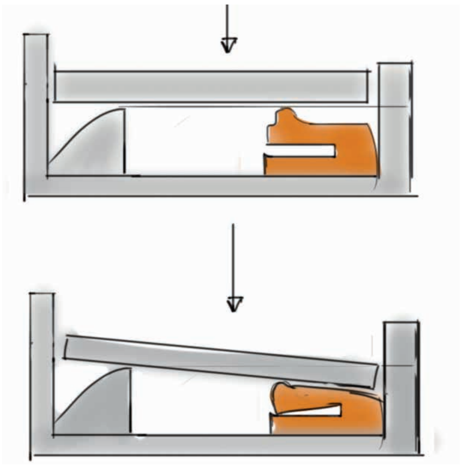


Figure 108. Drawing of what happens to the force sensor.

Figure 109. Two sensors make sure the press stays level.

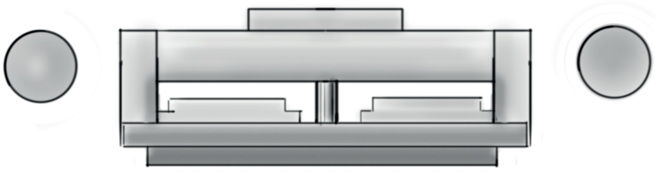


Figure 107.

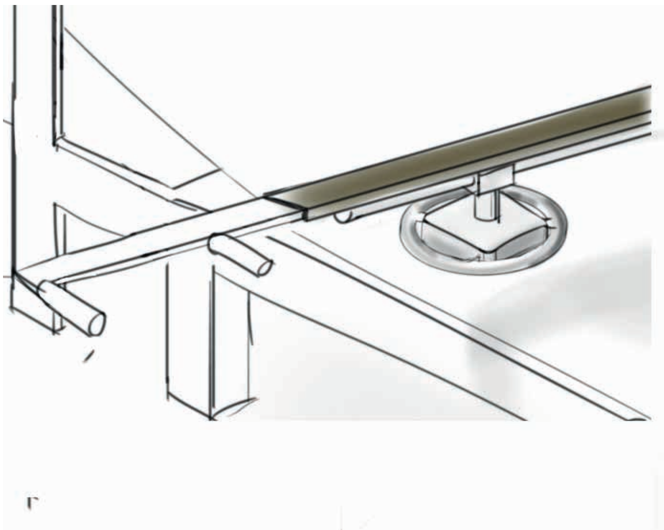


Figure 110. Visual of the heating unit.

9.6 General Shape

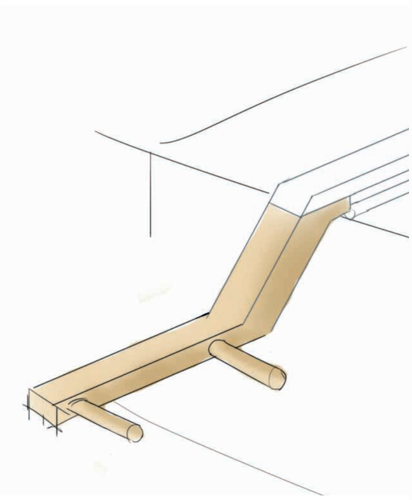
General shape heating unit

The entire heating unit needs to be compact and light because it has to be lifted by a single person. It also needs to be efficient in height because the lever has to be on top of the heating unit and a person needs to push on the lever.
The shape of the heating unit is simply following the shape of the baseplate. With the use of basic components, such as rectangular aluminium tubes, a small frame with the same shape is made and attached to the baseplate.

General shape demonstrator

For the general shape of the demonstrator several small prototypes are made.(appendix K) These show that the table of the demonstrator should be level, around hip-height and have the roll of RECURF material at the same height as the table.

Due to the size restriction of the exhibition, the demonstrator should be not larger than 100 cm x 100 cm in total. The table itself should be about 80 cm x 80 cm. This gives room for the lever and the roll of RECURF on the side. The lever will be longer than 80 cm because it should enlarge a force on the heating-unit, even when it is positioned close to the user. The longer a lever is at one side of a rotational point, the larger the force it can transfer to the shorter end of the lever. For ergonomic use, the table should be high enough for people to touch the RECURF while standing upright. To calculate this measurement we used Dined, a TU Delft database which focuses on anthropometry in design and helps designers apply anthropometric data to design challenges. We calculated the average hip height at 95 cm.



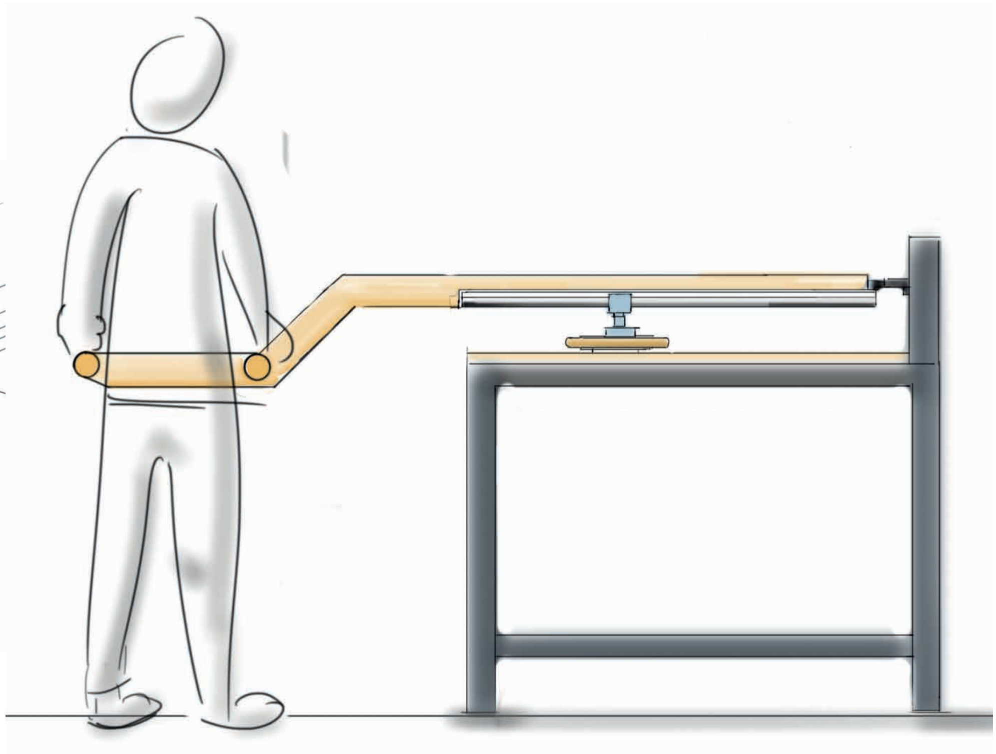


Figure 111. Side view of the demonstrator.

Additional spring

The lever and heating unit combined have a weight of about 5 kilograms. We discovered this was quite heavy to lift for more than a minute at a time, and therefore was seen as uncomfortable. The solution we found to this problem was to install a spring that compensated for the weight, making the lever and heating unit almost weightless.
The spring exerts force in the opposite direction of the user when being pressed, therefore the spring is placed close to the rotational point of the lever. When the spring is in line with the rotational point (figure 112-B), the spring does not 'help' rotate the lever upwards. When the lever rotates upwards, the spring is no longer in line with the rotational point. The distance created between the spring and the rotational point causes the spring to pull the lever upwards. The higher the lever rotates, the more force the spring can exert on it, making the lever feel lighter in weight.

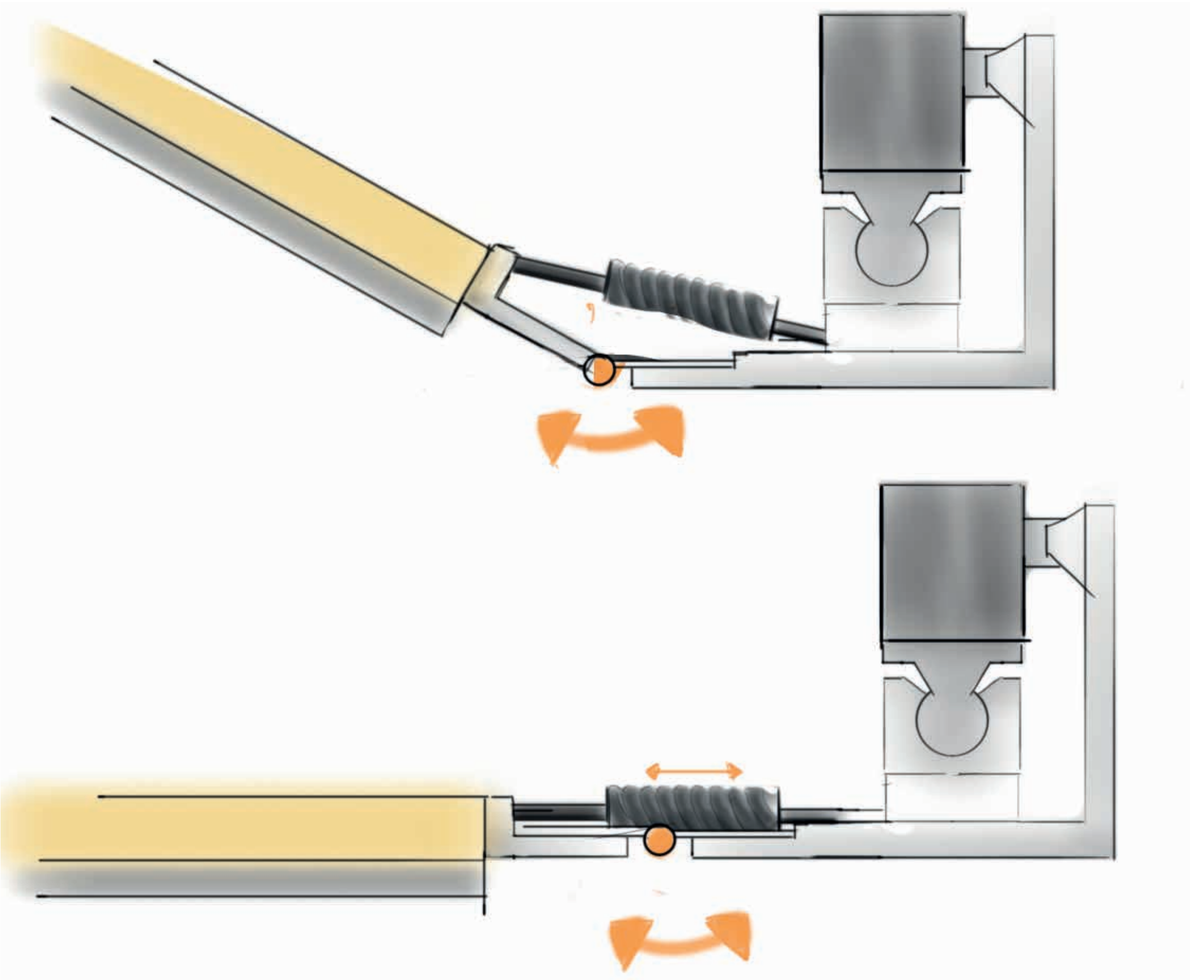


figure 112. A (top) and B (bottom). Position of the spring. Left is the lever. In figure A the spring is further away from the rotational point than the spring in figure B, and creates therefore a larger rotational moment.

Appearance

Many materials that were used for the realization of the demonstrator were decided on because they were considered as the most functional. Examples include the aluminium used to transfer the heat and the steel used for parts that needed high strength and stiffness. For several aspects, however, the material used was chosen for its appearance. To get inspiration for the kind of appearances that follow our design criteria, we looked at three projects. These are shown in figures 113, 114 and 115. The projects are, just like this demonstrator, production machines for at an exhibition or fair with the intention to teach and inspire people.

We gained four notable insights on appearance from these examples:

- Use of thin simple frame looks open
- Use of light coloured parts draws attention
- Use of simple shapes: Square, circle, triangle
- Repetition of details: Shapes, colours, materials etc.

Following this analysis, we decided in our project to build the frame from steel, as it is dark in colour and therefore stays in the background. The lever was made of a light coloured wood, so that it looked approachable, organic and inviting for the user to touch. The handles were made light in colour to match the lever.

Figure 113. “Made in Kenya”, the bachelor project of Niklas Kull and Gabriella Rubin [35]

Figure 114. The Machine by Jan Boelen[36]

Figure 115. Plastic recycling machines by Dave Hakkens [37]

9.7 First Build

The first build incorporated all the design challenges that were made. The build succeeded in this regard. Both functionality and testability were accomplished. Small challenges and unseen possibilities were dealt with during the build by adaptation and quick redesigns. The building materials were mostly aluminium and wood. And were often standard parts that were available at the IDE faculty from the TU Delft.

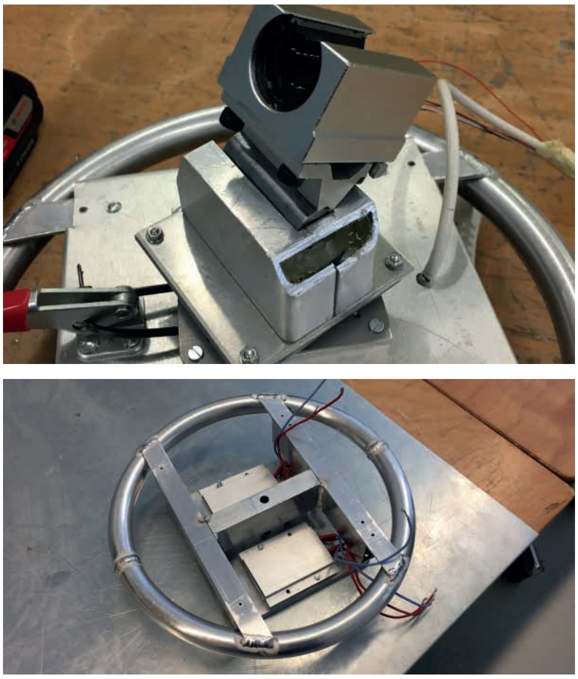


Figure 116. Building the heating unit

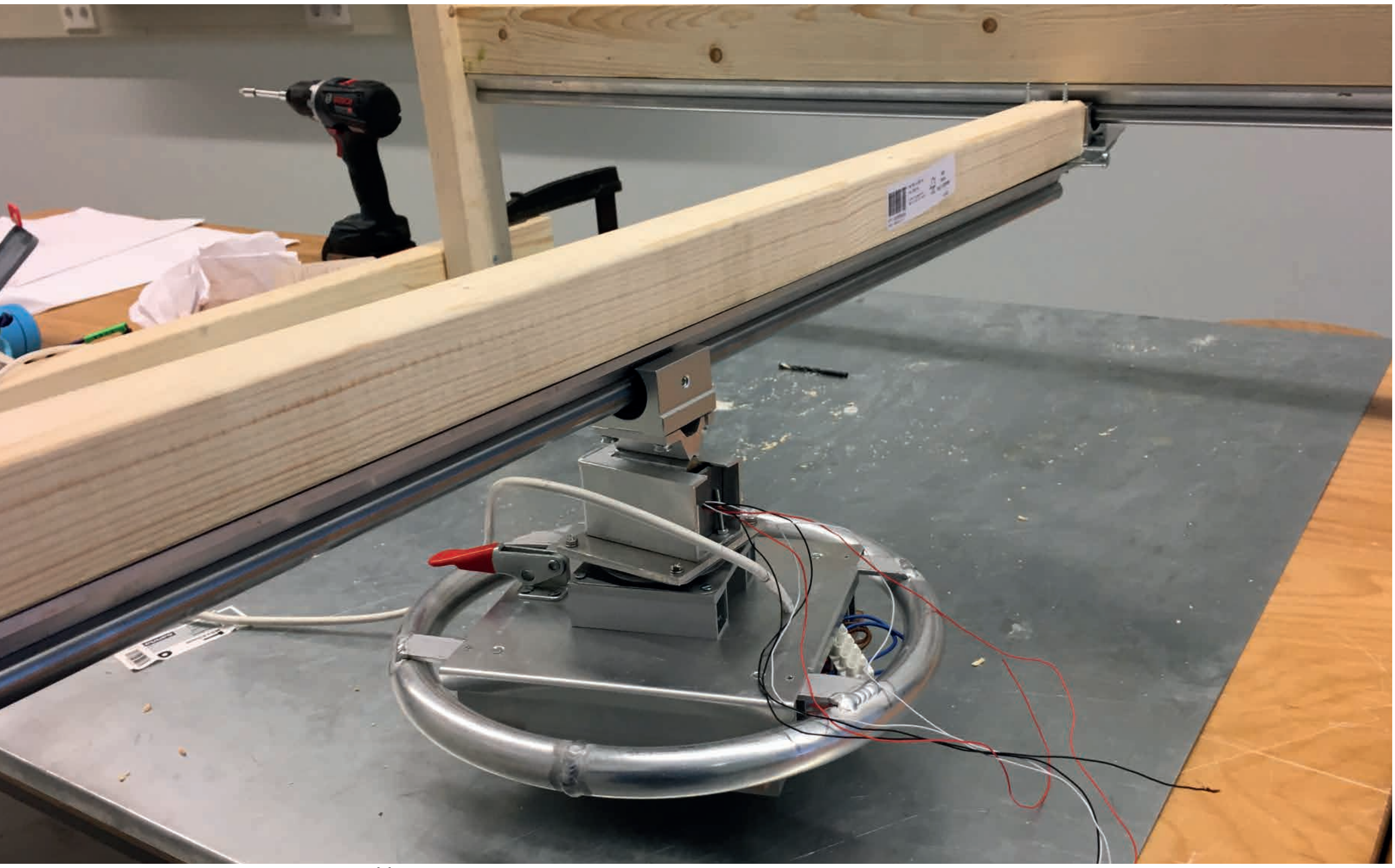


Figure 117. Heating unit and lever

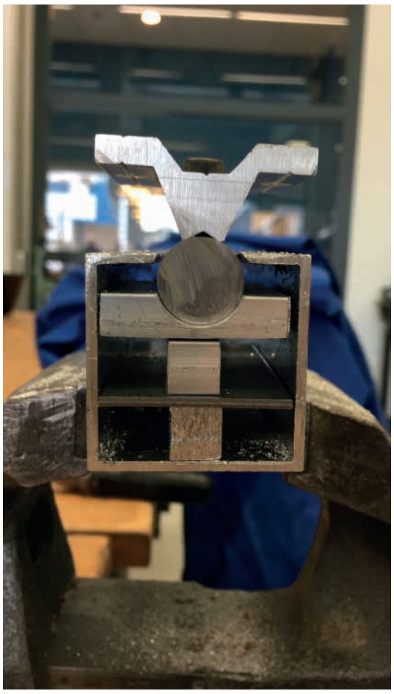


Figure 118. Weight sensor

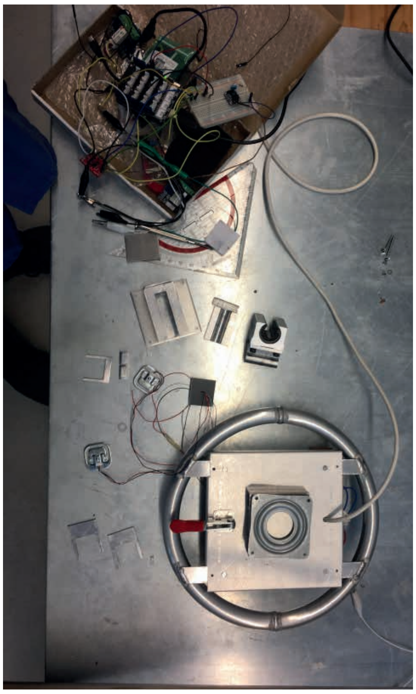


Figure 119.Use of electronics

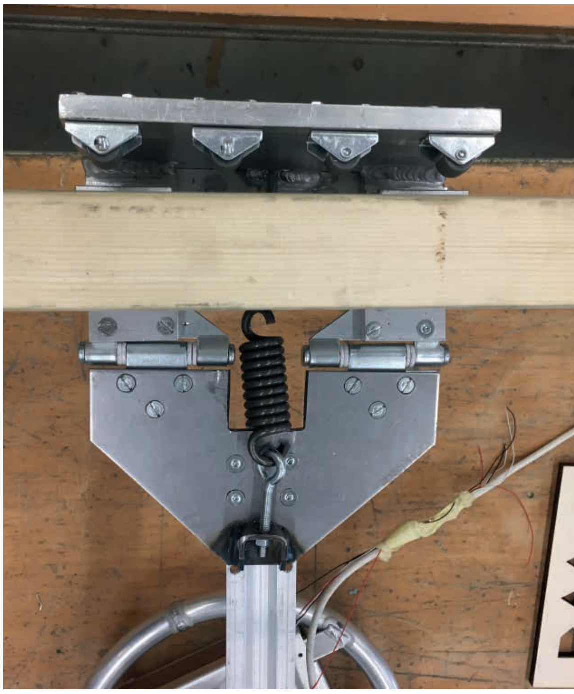


Figure 120. The hinge at the end of the lever

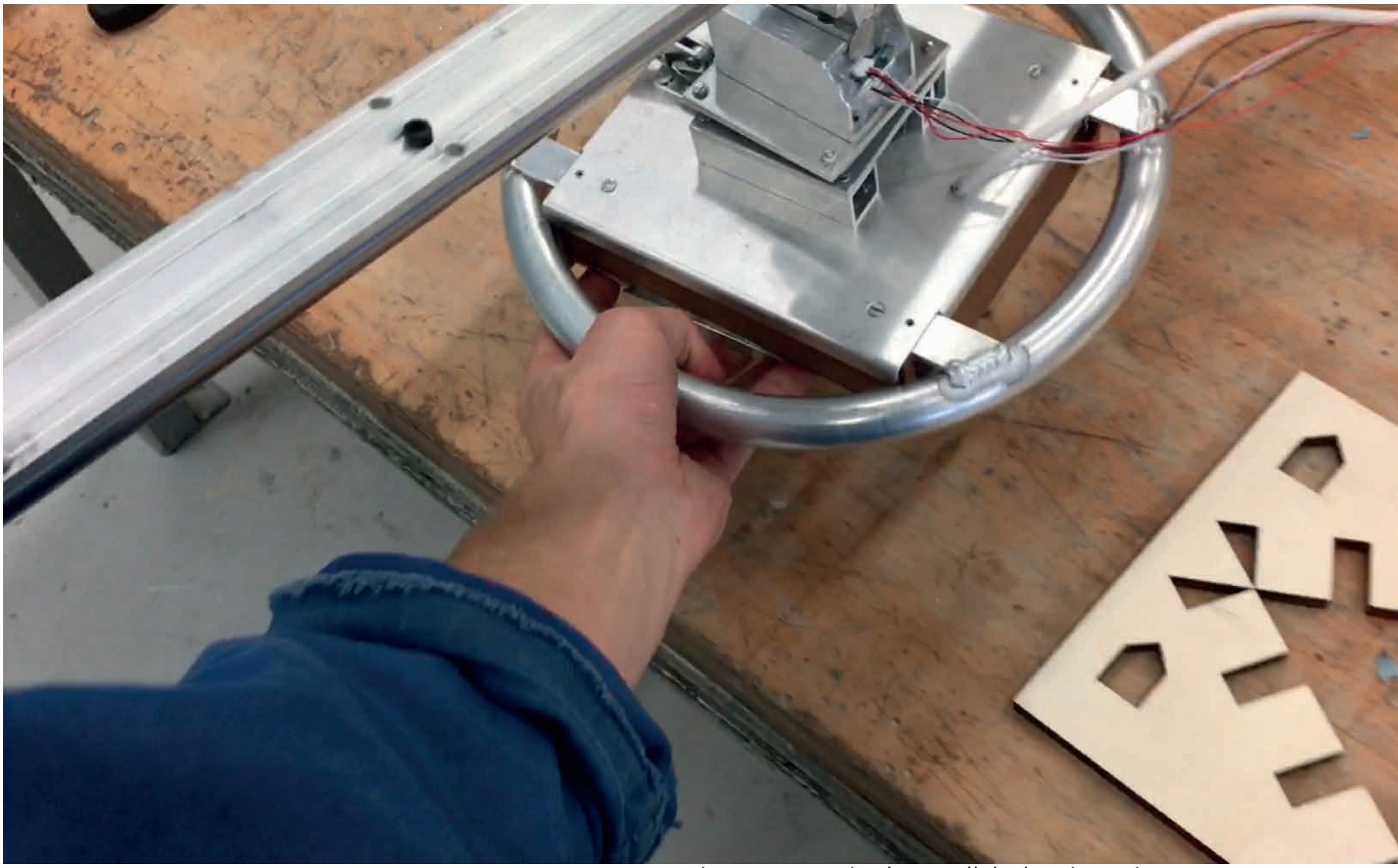


Figure 121. Testing how well the heating unit moves

9.8 User Testing

Introduction
After a month of designing and building at the BMP at the faculty of IDE the first build was finished. following the choices during that time, we moved to the next phase of design. the first build was used to test how practical and usable the demonstrator was, if it could hold the forces applied to it and if all of the sensors worked. This test allowed us to check the use of moveability, force, heat, size, positioning and pressure of the demonstrator, and revealed problems to be addressed in some of these areas.

Moveability
During our first test we discovered that there were several problems in the design in terms of moveability that needed to be solved.
First, the positioning of the heating unit did not go as expected. When moving the lever from left to right and vice versa there was a high amount of friction in the connection between the lever and the sliding rail attached to the table. The main cause for this friction was the tilting forces created by the movement. During testing, we discovered the tilting was reinforced by the spring that carried the weight of the lever, but without the spring the lever and heating unit would be uncomfortably heavy.

Second, we found the lever got in the way of comfortable movement even though the heating unit was attached to it. There was a lack of space to comfortably choose the right position to press.

Lastly, we discovered that it was quite difficult to hold the heating unit with one hand. Overall it was too heavy to rotate and move along an axis at the same time. This interaction worked better when using two hands to move and rotate the heating unit.

Force
The force measuring sensors functioned as expected. With the help of software, the sensors were calibrated and only had a slight deviation, less than 5 kg, which did not disrupt the usability of the machine.

Heat
When heating the base plate to 150° C, the frame of the heating unit heated up to about 50° *C* and the handles had a temperature of about 38-40 ° *C*. With rubber around the handles, the rise in temperature was hardly noticeable to the touch. The isolation that was applied was therefore sufficient. The method used for isolating the heating unit is explained in appendix I.

Size
The surface area of the table was large enough to make several patterns, and the height was high enough for most of users to reach the RECURF without bending their legs and/or back. This did not require further adjustment.

Positioning-plate
The positioning of the pressing-shape onto the positioning-plate was difficult because the shapes only match in one way. It was determined that If the positioning-plate would have slanted surfaces, the pressing-shape would be easier to slide in the corresponding hole. The material of the positioning plate was currently wood with a low density. This meant that this plate could move and shift quite easily. A heavier material would add to the accuracy of the positioning plate. For instance, heat resistant glass. That would also mean the RECURF can be seen better. However due to time constraint, and having a low priority, this change is not added in the final design.

Pressing RECURF
The test to press and heat RECURF resulted in the expected pressed piece of RECURF. However, it did not melt the material all the way through. This difference between this test and the initial test was that now the RECURF material used was BiCo. Therefore the temperature of the press was about 150° *C*. The initial test was executed with normal PLA at 190° *C*. The exact correlation

normal PLA at 190°C. The exact correlation is unclear. However, due to time constraints, we decided to proceed with RECURF that did not melt on both sides, namely the BiCo RECURF because the heating unit cannot reach the 190° C.

Conclusions

The first build showed us several problems with the demonstrator. Comfort and moveability of the heating unit had the most urgent problems. For these problems a quick redesign and rebuild was executed.

9.9 Second Iteration

After the lessons learned from the first build, we addressed the problems in a second iteration of the demonstrator. This iteration resolved problems in moveability, and also applies the criteria considering the appearance seen in other demonstrator projects. It also explains the problems with the force sensor and the final sheet of origami RECURF.

Lever and heating unit

The user test led to the decision to change the method of positioning the heating unit due to its problems with friction when sliding the lever. The chosen solution fo this problem envisions that the lever and heating unit are separated from each other.

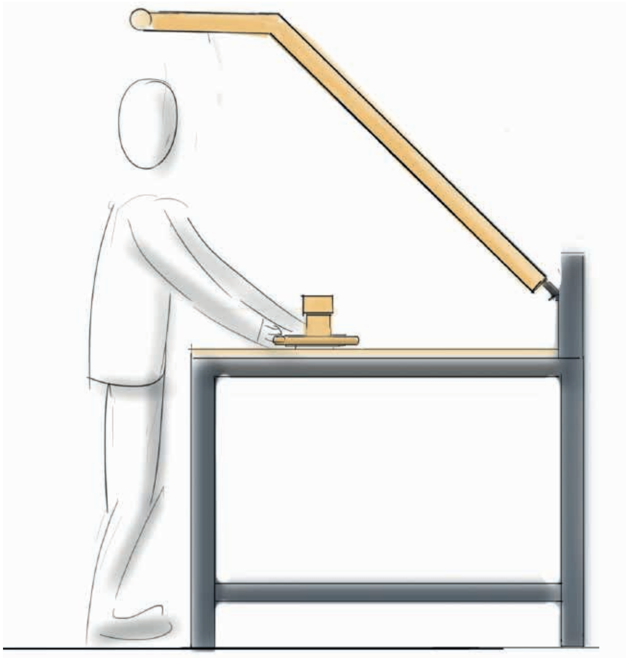
Instead of keeping them attached, we decided to separate the lever from the heating unit. This made it possible to lift the lever upwards when not in use, with the use of a spring, creating more room to position the heating unit. This made the demonstrator look more open and inviting, and also created more movement.
This meant the heating unit needed to be positioned by lifting it up with two hands and placed on the RECURF with the use of the positioning-plate. The lever then needed to be positioned onto the heating unit before you can start pressing. To create more room for the user to position the heating unit, the lever must be upright when positioning. This is accomplished using a spring. Only after positioning the heating unit in the right position, the lever is pulled down on to the heating unit. This makes the actions of positioning and pressing two separate steps. As a consequence, these separate steps take slightly more time. Time however is not one of our design criteria, and therefore is not considered to be an issue.

For the placement of the lever onto the heating unit, a clear design needed to be made. The area on top of the heating unit needs to intercept the lever and be stable enough to transfer the forces from the lever to the heating unit without the possibility of sliding off the heating unit while pressing. This was achieved by the design steps and build seen in the following text.

Due to the fact that the lever and heating unit are separate, the handles of the lever should also be redesigned as the lever and heating unit are now positioned separately. (For this design choice, see appendix D) Therefore, we opted for a T-shaped lever that is wide enough for two people to use. It can be comfortably used by one person, but it is also wide enough for a second person to join in, making it possible to invite visitors to help pressing. Pressing with two people can also increase the force applied to the heating unit.
The chosen material for the lever is a light coloured wood. A long circular wooden pole is used made from scots pine. This light coloured wood has an inviting and simplistic look. The top of the heating unit is also made of light coloured wood to match the lever as these two parts have to connect during the pressing.

Frame

A big part of the appearance of our demonstrator is the frame on which the lever is attached, and the wooden table that it lies upon. This frame has been constructed by welding standard square iron tubes into a frame. When building this frame we had several constraints to take into account: First, the frame has to be able endure the forces exerted by the lever. Even though the forces that are created during the pressing of the lever are in all probability not nearly enough to reach the limits of the steel frame, the metal tubes used for this construction have to be intrinsically strong and stiff. Second, there has to be room for the sliding rail and the attached lever. These were also made using these iron tubes to fit the shape of the table. Third, there has to be room for a roll of RECURF to be placed on the side of the demonstrator. And fourth, the whole frame needed to be transported to the Dutch Design week, therefore the legs of the table were made detachable so it fits in a small car.



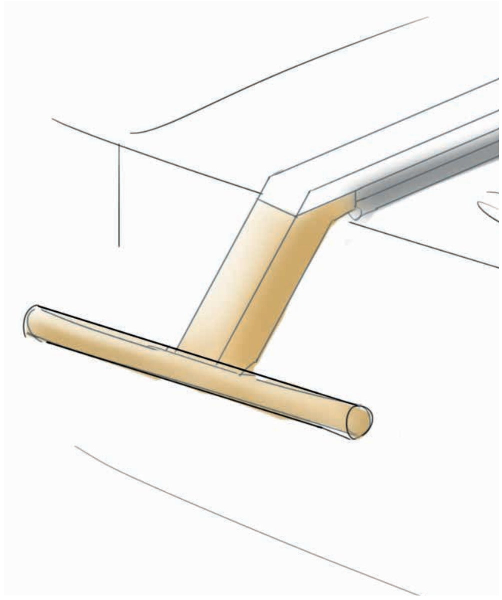
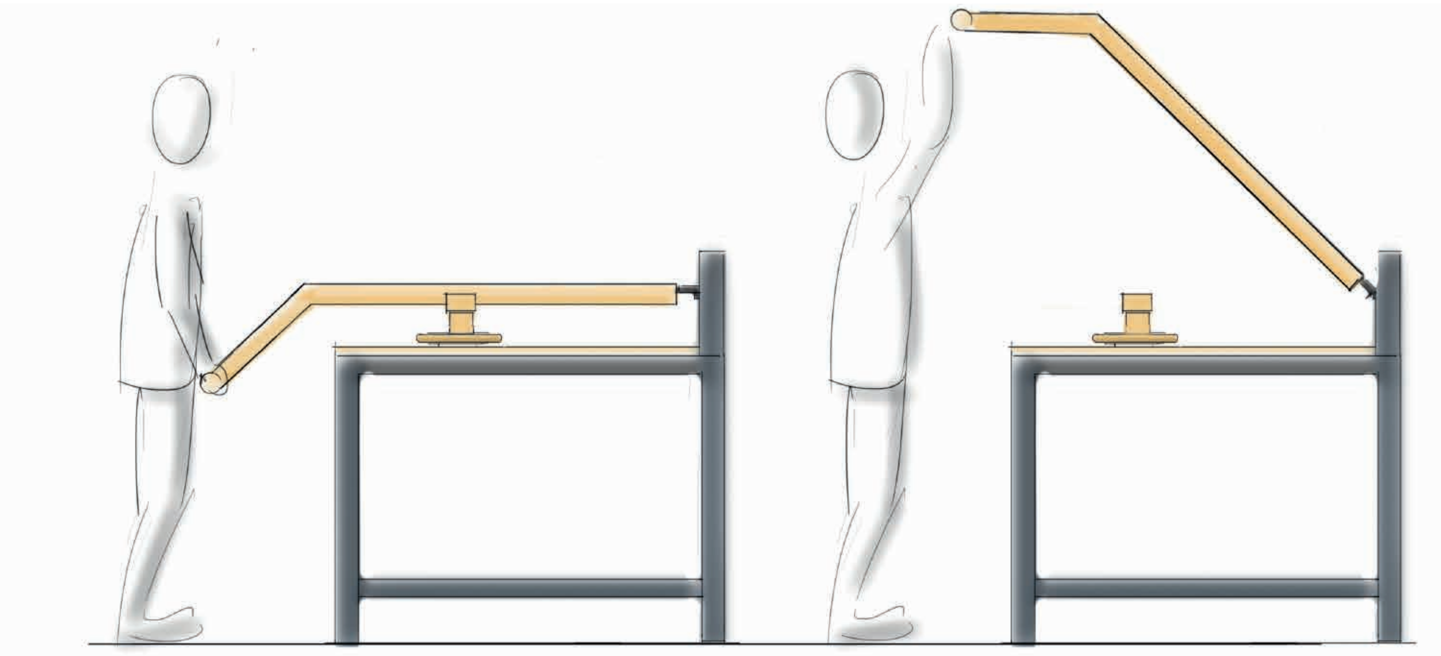
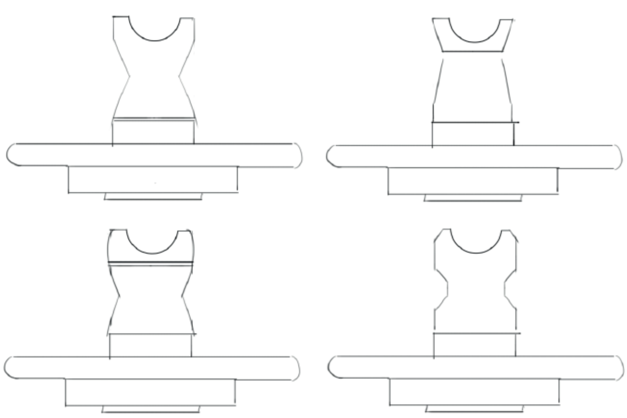


Figure 122. Sideview. Visualised are the steps a user has to take to press. First position the heating unit. Second, lower the lever on the heating unit and press, third, release the lever.





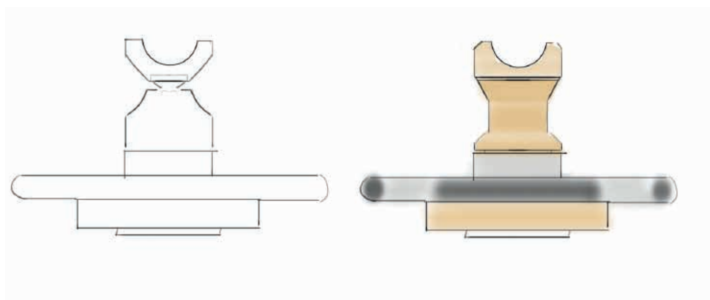


Figure 123. Sideview. Heating unit. Sketches of the top part that connects to the lever.

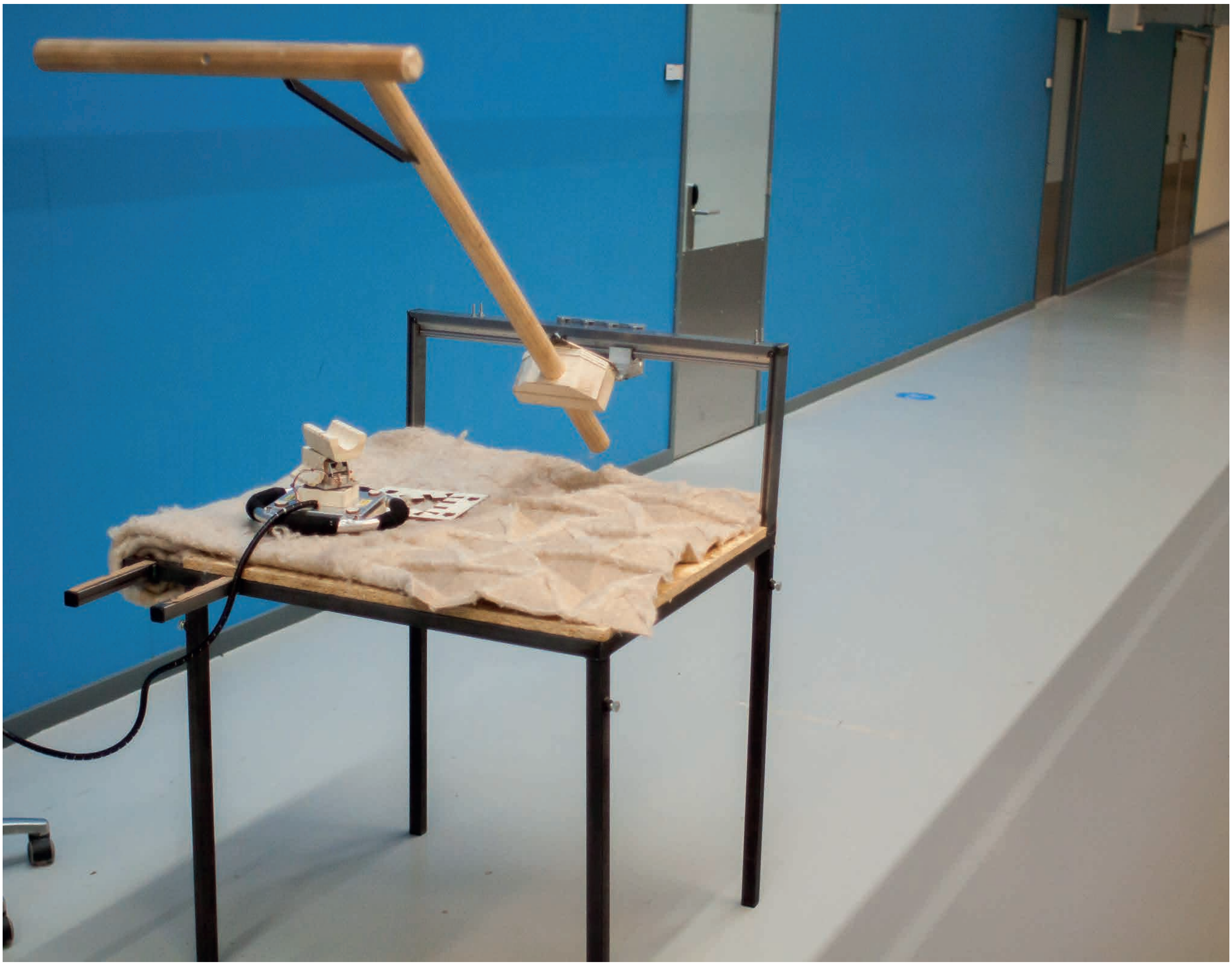


Figure 124. The demonstrator


Figure125. The lever handles


Figure 126. The pressing head

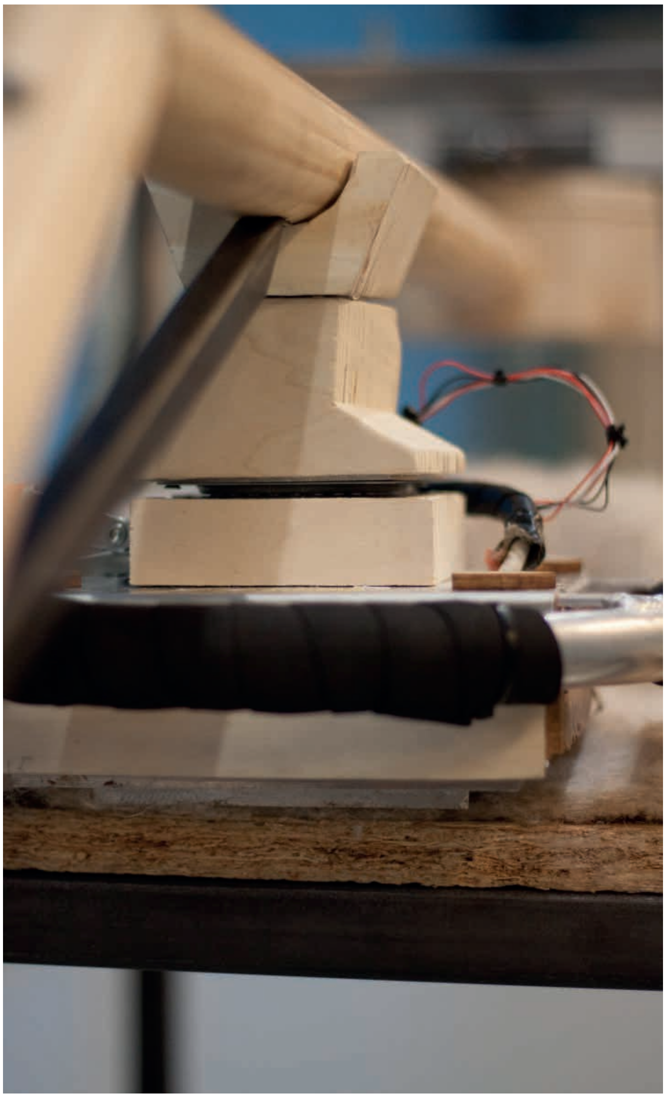


Figure 127. The heating unit with lever on top

Figure 128. Heating unit and positioning plate

Sensors

During testing, after completing the build of our second iteration, the force sensor broke down. We were not able to immediately repair this problem as new parts needed to be ordered. Due to time constraints we were not able to fix this in time for the DDW exhibition. This shows how fragile these sensors are. A solution would have been to change the sensor for a mechanical one, which uses a pretensioned spring that will deflect after applying a predetermined force. But again, due to time constraints designing and building this was not a viable option.

Final piece of RECURF

The original plan was to press an optimized tessellation origami sheet following the second iteration of our final design so we could show this at the DDW. This was essential for telling the story of RECURF through our demonstrator as it represents a potential end product. However, due to the unforeseen breaking of the force sensors, and due to the fact that the building of the machine took longer than expected we were not able to create this piece of origami RECURF in time for the DDW.

Conclusion

During the second iteration the lever and heating unit were separated for better useability of the demonstrator. This led to a redesign of the lever and heating unit. The appearance was taken into account during this final design step. With the build of the final frame, the demonstrator was finished except for the final sheet of tessellated origami RECURF and the force sensor. Due to time constraints we were not able to finish and fix these as the demonstrator had to be transported to the Dutch Design Week.

The final step would be to observe the user's experience and interaction with the RECURF demonstrator and material at the DDW.

Figure 129. Step one: placing the positioning plate

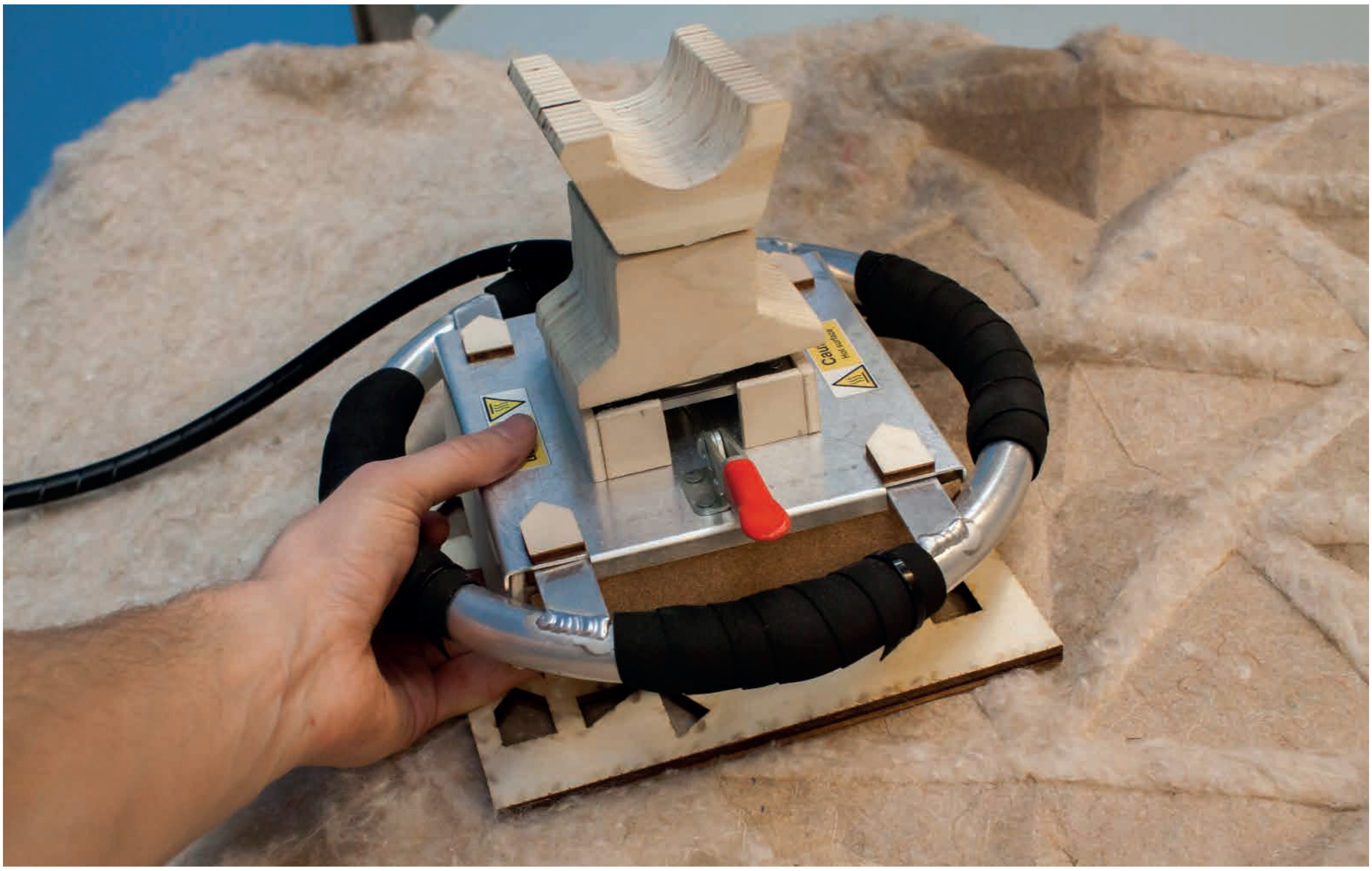


Figure 130. Step two: placing the heating unit on the positioning plate

Figure 131. Step three: take hold on the lever

Figure 132. Step four: Apply force onto the lever

10. Dutch Design Week Observations

10.1 Introduction

In this chapter we describe our findings regarding how the demonstrator performed at Dutch Design Week (DDW) 2018 in Eindhoven. he demonstrator was placed at the event for a ten-day period, and out of the ten days it was actively manned for three days. During this time the demonstrator attracted the attention of hundreds of visitors and received a lot of enthusiastic responses. The Direct Press was originally designed with the idea that visitors can experience the pressing of RECURF themselves. However, due to the size of the event and the amount of visitors, we came to the conclusion that it was too crowded to have the visitors use the Direct Press themselves. Therefore, we manned the machine ourselves and when in use visitors would continuously approach us and ask questions about the demonstrator and the material. It is unclear precisely how many designers and engineers we managed to reach and potentially inspire, as it was difficult to distinguish the general visitors from the designers and engineers. Due to time constraints, we were unable to produce a fully tessellated origami RECURF sheet, so unfortunately this could not be included in the exhibition.Nevertheless, we did manage to create positive awareness about RECURF among the visitors.

Figure 133. The RECURF stand at the Dutch Design Week

10.2 Kind Of Interaction

In our design, we created several ways in which a visitor could interact with our demonstrator. The visitor could press the RECURF material by pressing the lever, they could interact with and reposition the heating unit, and they could explore the RECURF material by touch. During the first morning of using the demonstrator at the DDW, it became clear that rather than letting the visitors press the Direct Press, it was better, in order to attract more attention, to demonstrate the machine by pressing the RECURF material ourselves. This was due to several reasons. Firstly, due to the size of the event and the sheer amount stalls to see, visitors did not spend a lot of time per exhibit, as they wanted to optimize the amount of designs they could see in a day. Therefore, visitors often only walked by and took a quick look at things they found interesting before continuing on to the next stall. In line with the nature of the event and our observation of the visitors behaviour, we decided on a new approach that would gain the most attention, putting the demonstrator in motion ourselves for the visitors to observe. Secondly, due to unforeseen circumstances the force sensor on the machine broke down which made it unclear to visitors how hard they had to push on the lever. This made it more practical to show the demonstrator ourselves, given that we had experience with how hard the lever needed to be pushed. Finally, the demonstrator had not been tested for a longer period of time, so it was unknown how it would hold up to continuous pressing by hundreds of inexperienced visitors for the ten-day period. In the interest of keeping the demonstrator viable for the entire period, and in conjunction with the previous reasons, we therefore decided to man the press ourselves for the duration of the exhibition.

Figure 134. The demonstrator

Figure 135. Visitors taking pictures of the RECURF

Figure 136. Visitors taking pictures of the RECURF

10.3 Observation Of Visitors

We received a lot of different reactions to our demonstrator at DDW, ranging from high interest to initial skepticism: “So, basically it’s just an iron”. When the machine was not in use people would often stop and spend around 10-30 seconds observing and trying to understand it. This happened hundreds of times a day. Out of all of the people who stopped to observe, about a fourth also asked questions about either RECURF itself or the demonstrator.

When we started using the demonstrator and pressing the RECURF we noticed a distinct contrast in participation. You could immediately see an increase of visitors that would stop and observe what was happening. Quite often, after only using the machine for a minute or so, a group would surround the demonstrator and a lot more visitors would start asking questions. These questions ranged from “What kind of material is this?” and “What are you doing with it?”, to “What can you make with it?” This usually led to an us providing an explanation of the story and development of RECURF. These questions arose because a person cannot see from the material that it is a biocomposite. People sometimes thought it was wool or an isolation material. They often did not notice that the heating unit actually heated the material.

Overall the interactions we observed of the visitors at the exhibition can be summarised as:

- Stop and observe
- Ask questions about the material and/or demonstrator
- Touch the material between thumb and fingers to feel the material
- When not in use, sometimes grab the lever to see what it does
- Take pictures

Most people reacted with enthusiasm. After visitors got a better understanding about the material composition they often sympathized

Figure 137. Reactions of visitors on the demonstrator

with the goal of reducing waste and using bioplastics. However, some parts of the demonstrator caused some confusion. At first glance, the heating part of the heating unit was often considered unclear, in contrast to the lever which was very easy to understand. Nonetheless, the heating part was quickly understood after showing the molten RECURF or explaining how the heating unit worked.

The final origami sheet was not yet finished and therefore not be included in the exhibition, making it harder for visitors to imagine what the material could look like and what could be achieved with it. Explaining the application of origami to RECURF was not as convincing as actually showing it. It was often observed that visitors reacted in a nonchalant manner to this explanation.

Of all the visitors that stopped to take a look at the demonstrator it was hard to differentiate our target group, namely the designers and engineers, from the general visitors. There seemed to be a lot more general visitors present in relation to the amount of designers and engineers. How many designers and engineers we have reached is therefore hard to determine. Of the people we spoke to, only about 5 of them told us that they were also a designer/engineer. Nevertheless, of those five designers one designer explicitly said he was interested in using RECURF for a future design. The other designers we spoke to were less clear with their intentions, but were still very interested and appreciated the potential of RECURF.

Figure 138. Me explaining the story of RECURF

10.4 Conclusions

From our observations during DDW, it can be concluded that the demonstrator in general had an inviting look as it attracted a lot of visitors.

It had sufficient movement to attract the attention of visitors and had an open and simplistic look, which created interest and curiosity, leading the visitors to approach the demonstrator. In this way, it had a low threshold to interaction, in line with the intended material experience vision and design of the demonstrator.

Not every aspect of the demonstrator was directly clear after approach, which could be seen from the questions that were asked by some visitors. In particular, visitors had questions about the material composition, the 'heating part' in the heating unit and the large origami sheets as the end product that comes out of the machine.

The RECURF material on the demonstrator was intended as part of the inviting look. The fact that the composition was unclear at first was a positive aspect for the exploration of RECURF.
It attracted people to the tactile experience and engaged visitors to talk to the designer that was using the demonstrator. This talk allowed visitors to get more information about the story of RECURF and to get inspired to explore with it themselves.

The function of the heating unit was often not fully understood. The lever, however, made it clear that the material needed to be pressed. The fact that the material also needed to be heated was not always clear to the visitor. The only visual cues to allude to the heating process were the 'warning hot' signs on the heating unit. The design of the heating unit itself did not make it clear that heat was added. As a result the demonstrator appeared slightly more complex.

Given that the origami was not yet produced before DDW, visitors could not see large origami sheets coming out of the demonstrator, which would have added to the whole story of RECURF. It would also have helped to better portray the intrinsic qualities, duality and considerable possibilities of RECURF, because the origami sheet shows all of these features. The use of origami RECURF has the potential to engage the observer fully in the experience of the material by exhibiting these qualities. Nevertheless, the demonstrator at DDW was able to attract attention from curious visitors and advance the discussion and awareness of RECURF.


Figure 139. The heating unit on a piece of RECURF

11. Conclusions

The main goal of this project was to shorten the gestation period of the innovative new material RECURF. Following our research on innovation acceptance and theories on experiential learning and material driven design, we decided to follow Ashby's recommendation of a demonstrator project (Ashby et al., 2000) as a means to shorten the gestation period of an innovative new material. We did this by designing a material experience exhibition in the form of a production process, which was then placed at Dutch Design Week 2018 in Eindhoven for the duration of 10 days. The exhibition tells the story of RECURF by showing different stages in the development of a product made out of RECURF, from the raw materials, to processing in our machine, which heats and presses large sheets of RECURF, to a finished large sheet of RECURF in tessellation origami design. With this 'demonstrator project' exhibition we aimed to teach as many people as possible, specifically designers and engineers, through experience about the technical qualities and possibilities of the RECURF material.

At Dutch Design Week, our experience was that there is so much for people to see that the visitors often only spend very little time per exhibition. Nonetheless, when the demonstrator was being used people would often stop and start asking questions, so our exhibition did evoke the curiosity of the audience. The design of our demonstrator not only focused on creating a new production process with new capabilities but was also designed with the aim to invite people in to get curious and excited about the RECURF material. It can thus be considered a success as it managed to do just that.
We found that it was quite hard to distinguish the designers from the general visitors due to the size of the event, therefore it is difficult to draw any conclusions as to whether we managed to reach and inspire designers and engineers with our exhibition. In some cases, however, designers and engineers identified themselves as such and had a positive reaction to the material. In general , the fact that we have been able to reach and teach so many new people about the RECURF material, whether they are designers or not, can still be seen as positive exposure for the material and a successful outcome for our project.

Although it is difficult to test whether our demonstrator project has actually shortened the gestation period of RECURF, several aspects of the project can be of great value for future developers of the RECURF material, including: the knowledge gained on possible production methods, the creation of a new more versatile production method, the knowledge gained on origami application possibilities with RECURF, and the increased exposure of the RECURF material to a larger public.

This project is a positive addition to the development of RECURF and the creation of the Direct Press allows for further experimentation and development.

Figure 140

12. Recommendations

The outcomes of this demonstrator project generate several recommendations for the future of RECURF use, exposure and development. The aim of this project was to shorten the gestation period of the innovative new material RECURF. Whether we were actually successful in shortening this period is difficult to test, as the period from invention to large scale acceptance and production of a new material typically takes around 20 years. Until we can make the observation that the RECURF material has been widely accepted and scaled up to large scale production in less than 20 years from its initial invention, we cannot make any concrete conclusions about the project's success in this regard. Even then it will be difficult to conclude whether or not our 10-day demonstrator project during DDW 2018 had any real influence on the gestation period of the material.
From our experience at DDW we concluded that even though this event is one of the largest design events in the world, there are too many visitors that are in reality not a designer or an engineer to adequately gauge the impact on these professionals. From the total audience, only a small percentage was our main target audience. Due to the sheer size of the event we may not have been able to fully reach this subgroup of designers and engineers that could be inspired and intrigued by our demonstration of the RECURF material.

In order to heighten the chance of a demonstrator project making a difference to the duration of the gestation period of RECURF, we recommend repeating this and/or similar exhibitions that teach designers and engineers about the technical specifications, production methods and possible applications of RECURF. This should be done at exhibitions that preferably have a larger ratio of engineers and designers to general visitors. During the further development phase of the RECURF material, we recommend continued exposure at design and art fairs to optimize the amount of people that we reach and teach about the RECURF material, and by doing so shorten the gestation period of the material.

In regards to our production process design, due to time constraints we have not been able to test the possibility of more types of origami with RECURF. We recommend further experimentation with RECURF and origami to gain more knowledge on the potential of origami in RECURF design. For this, we also recommend using our production process design as it provides a flexible and powerful heating and pressing production method.

Our final recommendation regards the RECURF material itself. During this project, we have focused considerably on the duality of RECURF, as the dual qualities of the material make it interesting in terms of structure and tactile experience. However, if future RECURF development means to continue with this duality, we recommend further research on the durability of the hard-soft RECURF samples, as we experienced during our tinkering sessions that the soft parts did not seem to be particularly durable and could easily fall apart. More research into the durability of the RECURF material is recommended.

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Appendix A

Samples of the soft fold. Tinkering #3

All the samples shown in the image on the right are made with BiCo in the heat press with the use of moulds. All these samples failed due to lack of contrast in duality. Every sample got completely hard, or completely soft.

Figure 139. 15 samples of BiCo.

The top left sample is the only sample that is not made fully within the press. It is pressed twice, each side one time. This is the only method of creating the soft fold with BiCo.
In these other samples can be seen dark spots. This often happens with high forces onto the burlap.

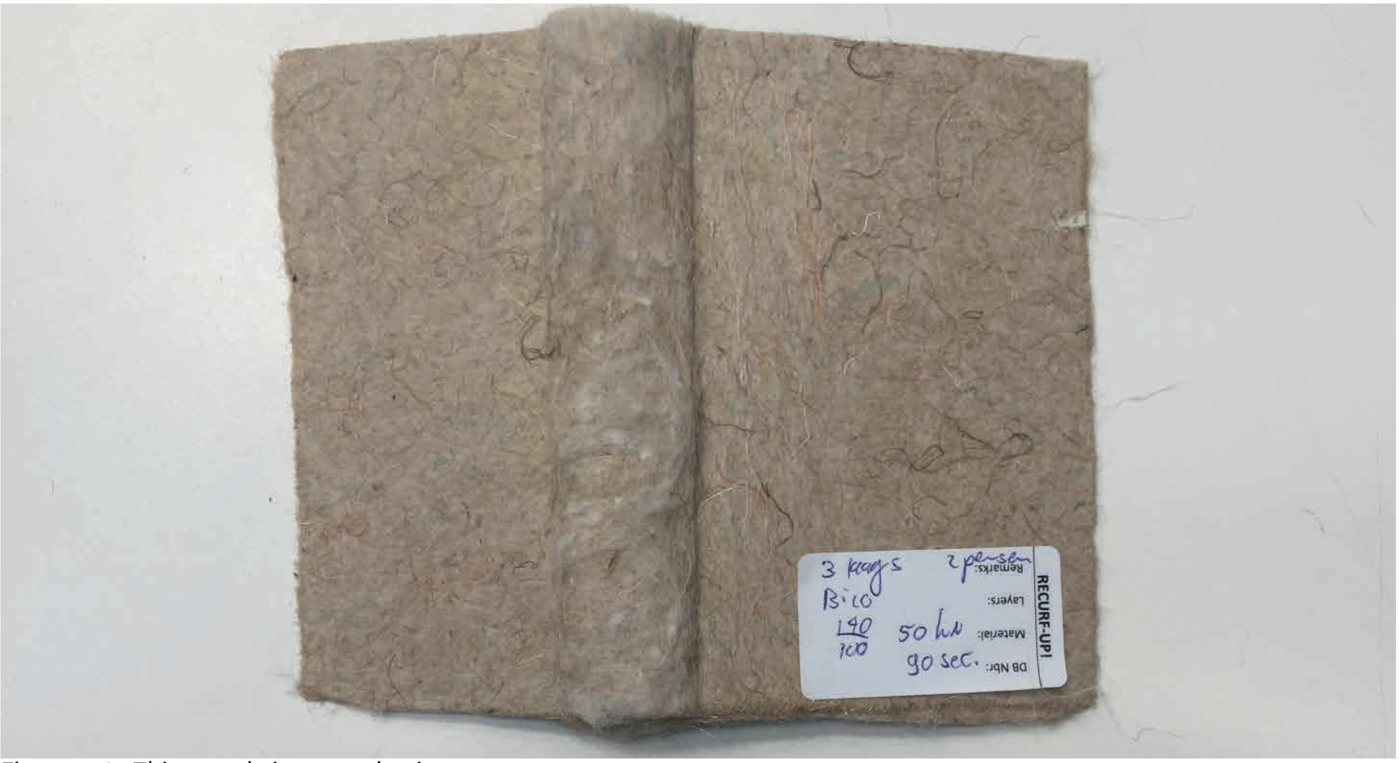


Figure 140. This sample is pressed twice

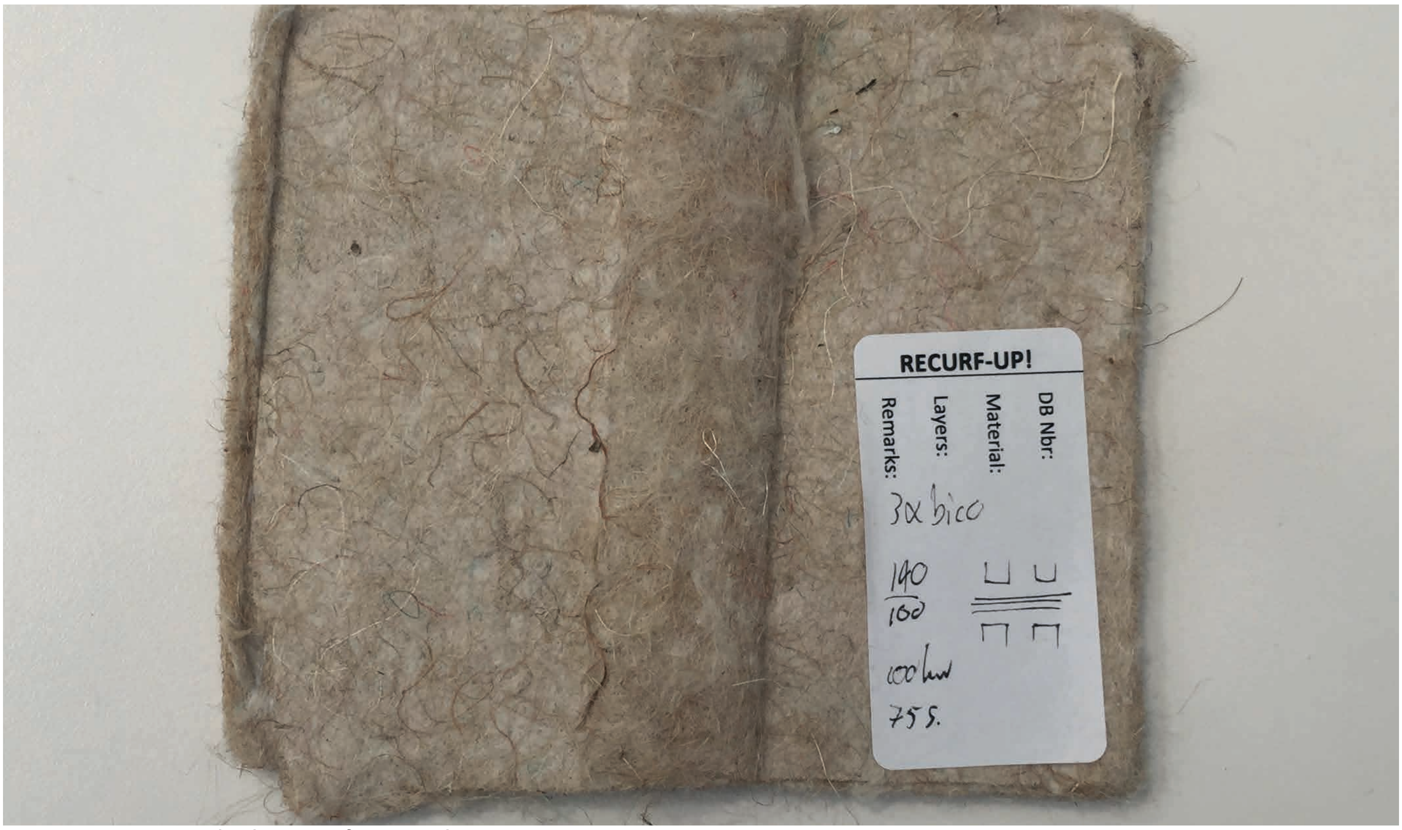


Figure 141. A sample that is soft everywhere

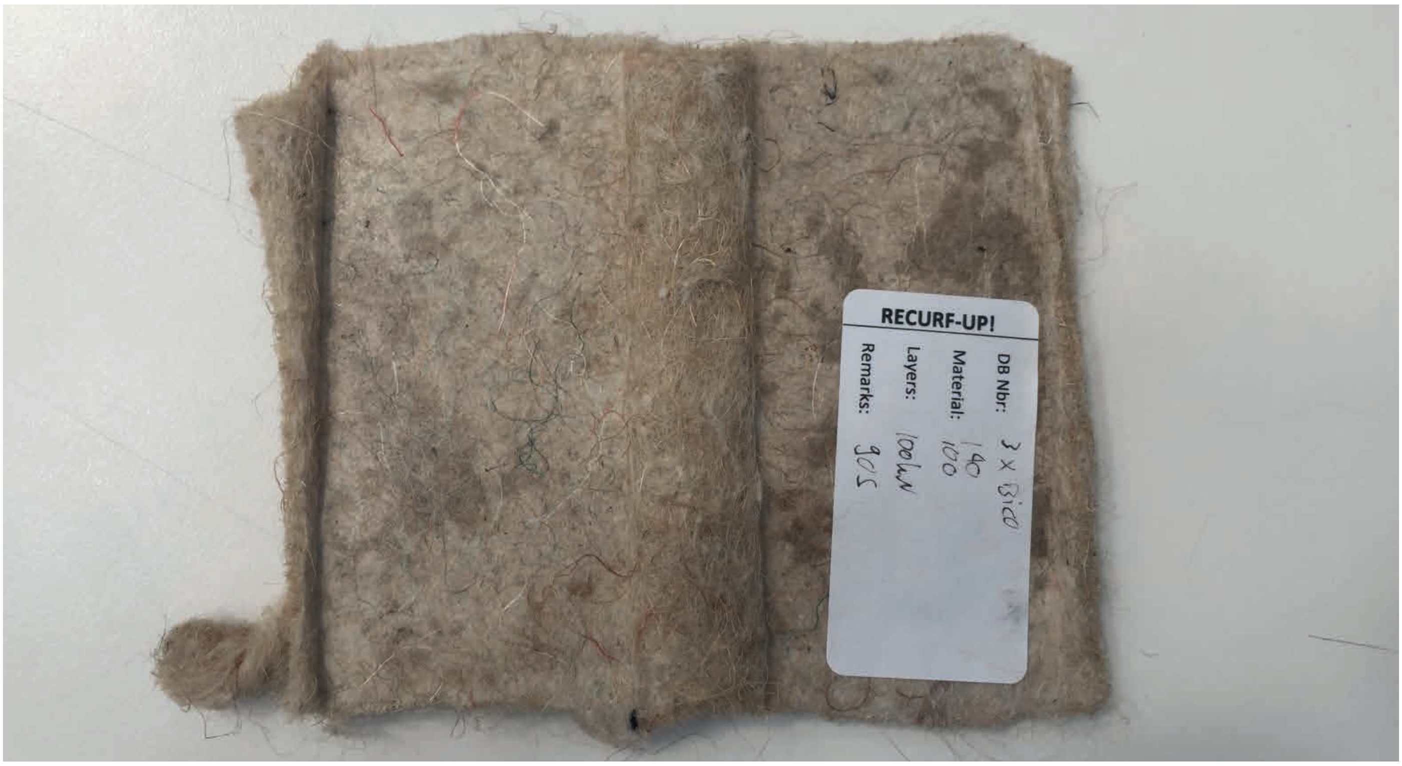


Figure 142. Dark spots visible. Often caused by high forces

Figure 143. Dark spots visible. Often caused by high forces

Appendix B

Strength of the soft fold

The soft fold is the weakest part of a pressed sheet of RECURF. To get a better insight in the strength of this soft fold, it is measured using a tensile testing machine and compared to uniformly pressed samples of RECURF. This machine pulls a soft fold slowly in two, while measuring how much resistance the soft fold creates. This resistance is called officially the ultimate tensile strength (UTS).

This test has been executed on 9 different samples, all with two layers. All these samples were made with normal PLA. Three samples were made with denim, three with burlap and three with wool.

The results are visible in figure 144.

In the data two different types of curves can be seen. The curves that have a distinct spike before reaching the 2 mm elongation are that of the uniform RECURF. The other kind of curve is that of the soft fold. It can be seen that this fold does not have a distinct spike.
It can be seen that the soft fold has a much lower ultimate tensile strength(UTS) than the uniformly pressed material. Most of the folds have a top UTS of between 80 and 150 Newton. While the uniform material is between 200 and 700 Newton. The fold is much weaker than the surrounding material. When we compare the soft fold sample with the uniform samples we noticed that there is a decline of 3 -5 times the UTS in the folds.

It can be concluded that the folds are noticeably lower in strength, 3 -5 times lower that the uniform material.

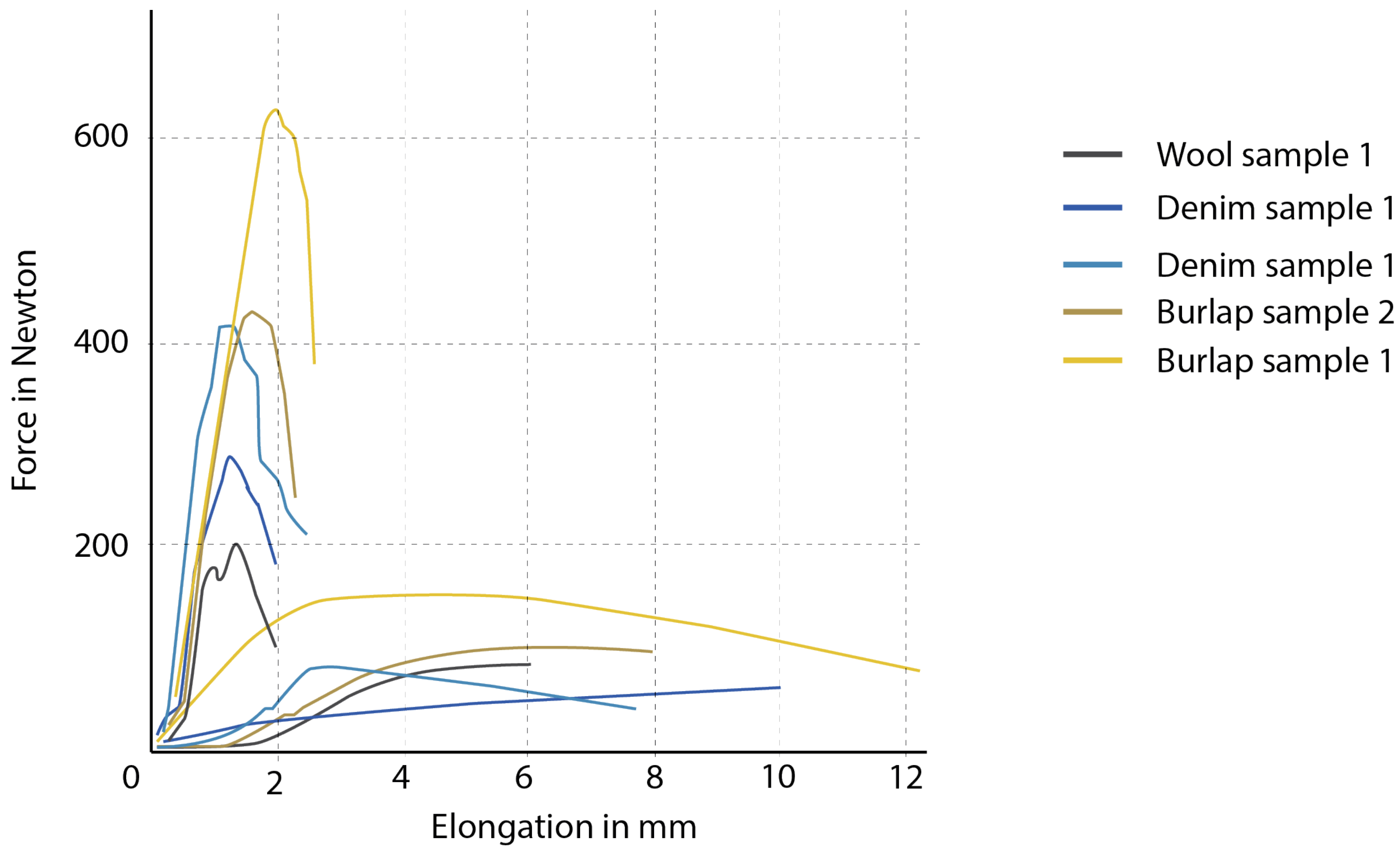


Figure 144. Force versus elongating of samples.

Appendix C

Interviews

Annalies de Leede

Let op de schaal

Probeer het uit, met de rol, maak er een proefopstelling voor

Kijk hoeveel werk het is om er tijdens de exhibition iets mee te doen. Het moet niet teveel werk zijn, vrij makkelijk.

Wat kan er mee gemaakt worden door iemand om mee naar huis te nemen?

Als het niet te groot is, is het leuk om te maken. Een heel kamerscherm is misschien teveel.

Hoe breed is de rol? 2 meter is groot.

Als het zwaar wordt en groot wordt het ook minder toegankelijk en uitnodigend.
Je wil wel de mogelijkheden communiceren.

Probeer het kleiner te maken. Waardoor behapbaarder.

Er zal wel iemand bij moeten staan.

Er is maar 4 m2 op de DDW dus zeer weinig ruimte.

Kijk of je ook kan snijden op kleine schaal. Dat maakt de mogelijkheden groter.

Hef boom is te proberen om de kracht te vergroten. Dan heb je geen enorme gewichten nodig.

Jon Stam

24 augustus

See it as a performance

How to involve the public

Let them do just one thing
Looking at the concept, people can do all these different things, pressing, positioning and discovering the material. It is too much for a person on the spot. Just doing one thing is enough. They can get stage fright. Get scared. They should get very clear instructions if they want to make something. Like a template.

Or let them watch
Or you could do the production by a designer who is making one thing in one day. So people could talk to them while they create something.

Standing
Standing on something could also be cool, they do just one thing, a bit awkward. They can look at their friends and laugh. It will be a very memorable experience for everybody. But you have got to lure them into doing something with them. And not everybody would like that.
This idea is much easier to get a interaction at the DDW.

Look:
It reminds me of THE MACHINE by jan boelen.
It is about what you can do with the material, not the design of the pressing head. Make it look DIY, safe and playfull to make it more approachable.

Think about LUMA maybe you should contact them ! could be very interesting.

New Material Award, new institute.

Bas Froon

Bas: i made pur sec my research and graduation existed out of a vision, translated in a material study translated in a machine into a product. DDW business model: I want to get a job. Promotion for myself. This is what I did with these material, I'm a designer. Looking for collaboration. I did not have the intention to test these materials with the big public. If you would like that, you should keep that in mind. If you go one step back. Do you start with a concept like this, which is mostly about local production, so not RECURF, I have other bio composites. This was not a goal but a means. I wanted to explain the public that we in the future should produce our products in a more useful way a better way in the far future. We will do this digitally and we will need new machines to do this. Use new materials. This machine is not finished, but its about inspiration. I also brought materials, sample to make the story compleet. And also a example product. These three were inseparably connected. I can recommend this to everyone. Are you looking for the consumer public, die looks at the baby carrier. The arty woman see the wool or felt and think hey! There are the textile ladies, they think ooee so fluffy. It's all good. All conversation starters. If you have them in your shop you can take them through the whole chain. And then the professional, see the machine, they think: i do not know this machine, and think what does it. They will automatically start thinking along, about what the machine would do. Does It look like something that already exists. Or can you do something else with it. What's most important in the end, is that the material, the technique and the application can be shown. I've 10 days at the DDW, draggin the machine was a lot of work, but it was worth it. When something moves and happens at the DDW, people will look at it immediately. Even when it was quiet, I put on the machine, and after 20 seconds there were 10 people surrounding the machine. People want to see the designer. They want to read, deeping in the subject, they want to know all the info, read the whole story. If one is chatting, suddenly 20 are chatting. In a nutshell that is what I did there. I was stand alone on the DDW.

Bas: You have to really divide these two things: I you want an interaction machine, like at the art academy, something very complex, make it very approachable. But no technical spectacular things. Or do it more manual. You should make a choice. Do you want a machine that has great technical operations, or do you want the user to clay, and design an experience. That's the choice. To do both things, that is unreachable. That's what I think.

Appendix D

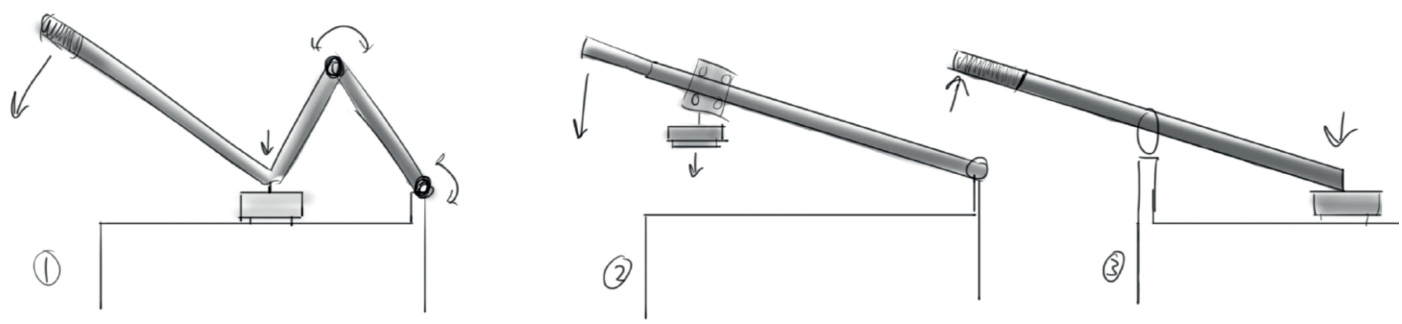
Choice: what kind of lever and handles

A lever can be applied in many different situations. In this case four different setups have been created from which one was chosen.

Lever 1
creates extra force in the perpendicular direction of where the force needs to go, straight down into the RECURF.
Lever 2
how much force the lever will amplify when a person is pushing varies because the heating head can change location.
Lever 3
presses when the lever is pushed up. This is not beneficial because then the person pushing cannot use his or her own weight to press. It also looks strange because someone pushes up, while the force is going down.
Lever 4
has a closed frame around the sheet of RECURF, giving the demonstrator a 'closed look' and giving the sheet a maximum width. The others have one side of the frame open, making it easier to press wider sheets of RECURF.

Lever 2 is chosen, as it scores best in:
Complexity
Inviting
Efficiently and ergonomically applying force

	1	2	3	4
Complexity	-	+	+-	+-
inviting	+	+	+	-
Efficiently applying force	-	+	+	++
ergonomically	+	+	-	+



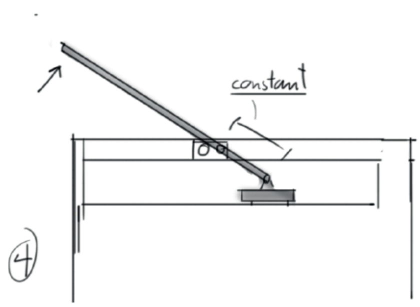


Figure 145. Four different levers.

The lever that was chosen for the final design was the one that looked most inviting.(most on the right) This lever has room for two people, but works just as wel for one . This lever has a very simple design, making it easier to understand what it is.

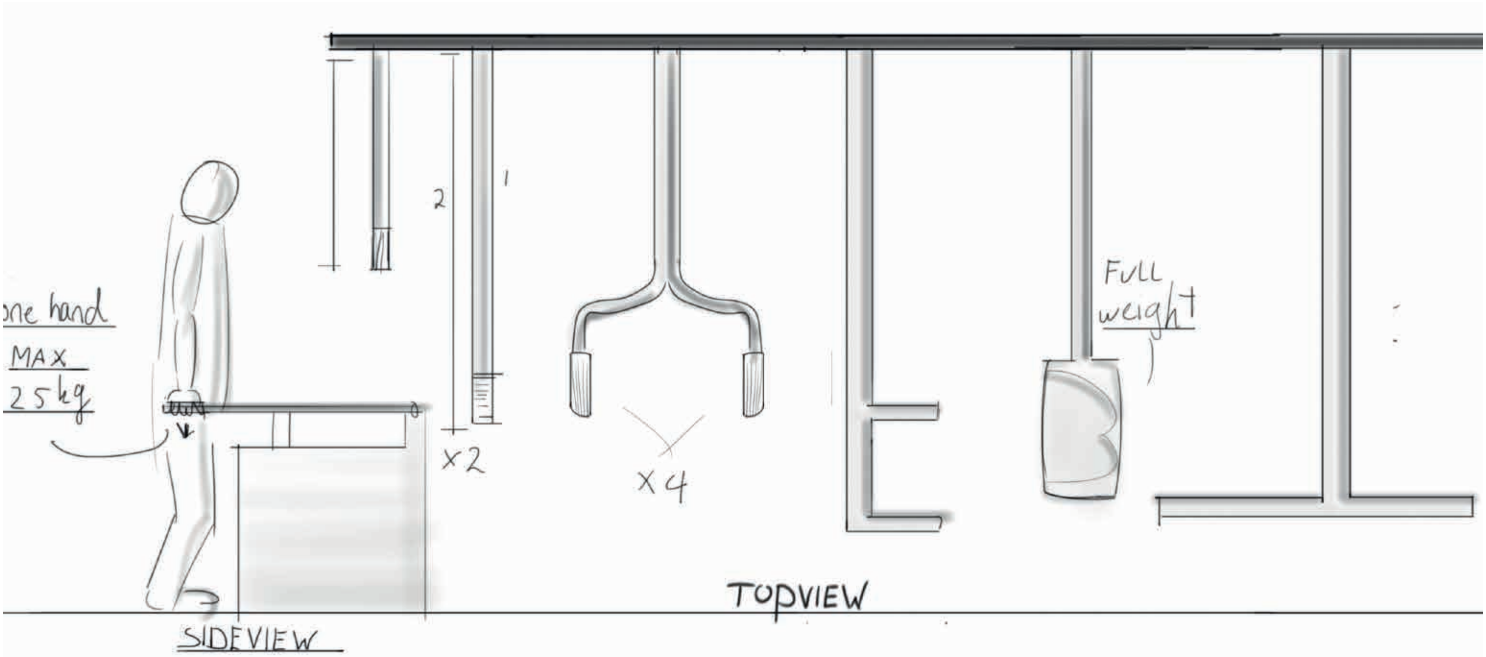
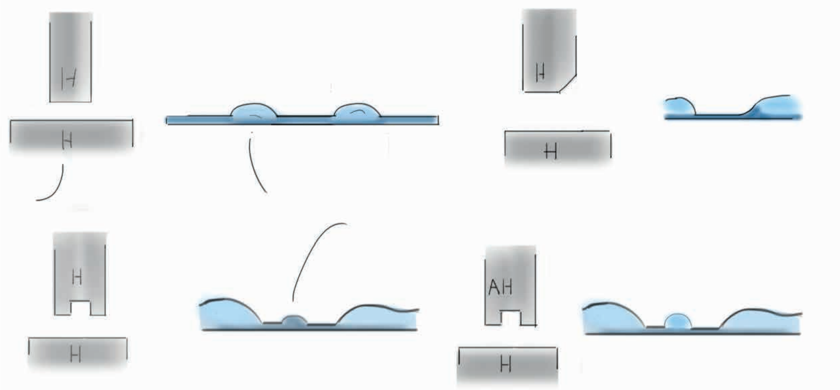


Figure 146. Six different lever handles

Appendix E

Pressing head

Many pressing head shapes were evaluated during the design phase. Most shapes were just unpractical because they made unusefull shapes. There were two methods that were interesting though. This was the iron like head and the rolling head. Both had the benefit that they could move while pressing. However this led to a series of new problems, making the demonstrator much more complicated, because they create forces in different directions than the pressing force. In conclusion a simple but logical shape was chosen that could press a lot of different kinds of origami.



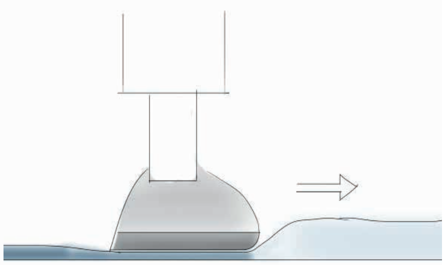


Figure 147. Iron like head.

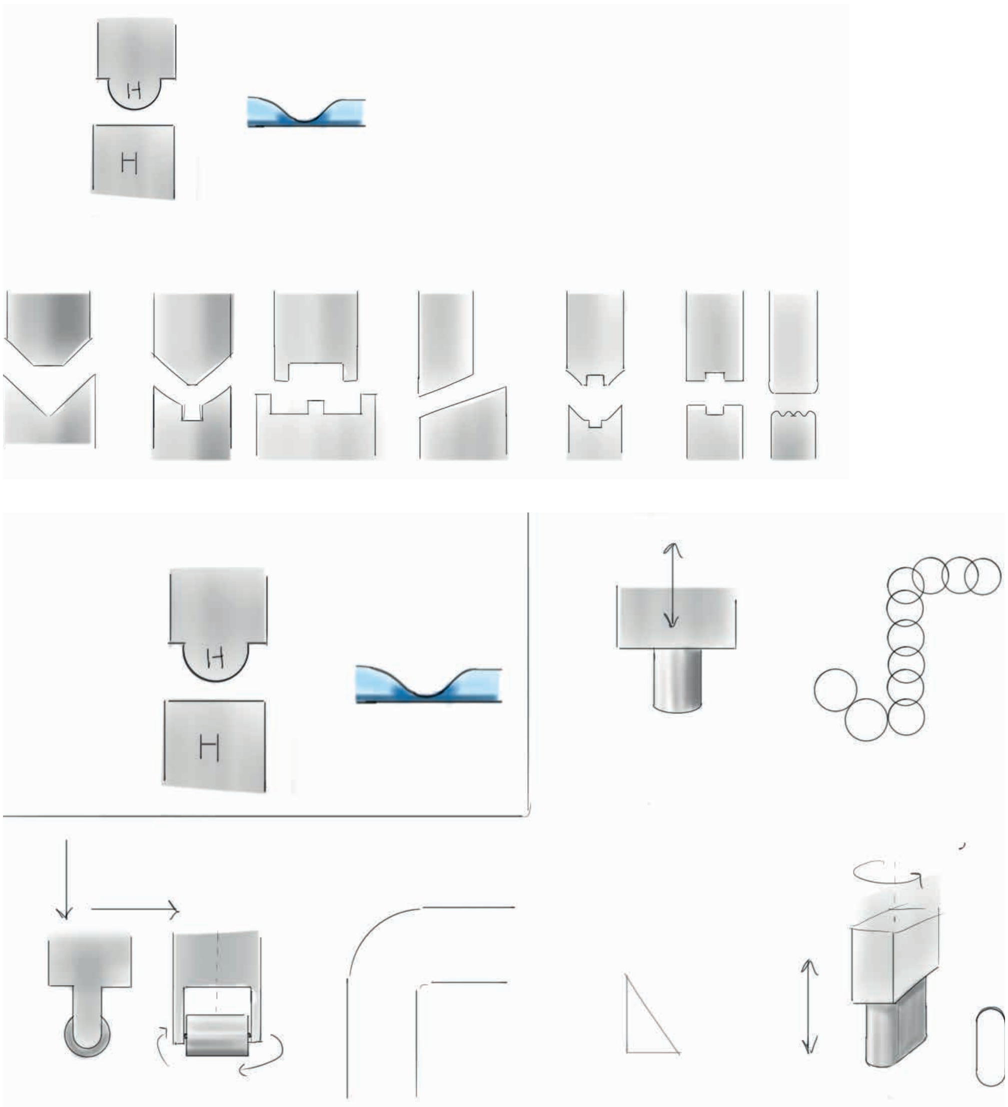


Figure 148. Rolling head

Appendix F

Force simulations

During the design phase several simulation have been made. These calculate the maximum forces and stress that occure and how much the simulated parts move under these forces and stresses. The base plate with a thickness of 10 mm has enough thickness to stay with a marge of 30% under the yield strength of Aluminium. The plate only bends so little that the sides of the base plate, that move most only move 0.07 mm.

The hinge at the end of the lever also stays well below the yield strength of the used aluminium.

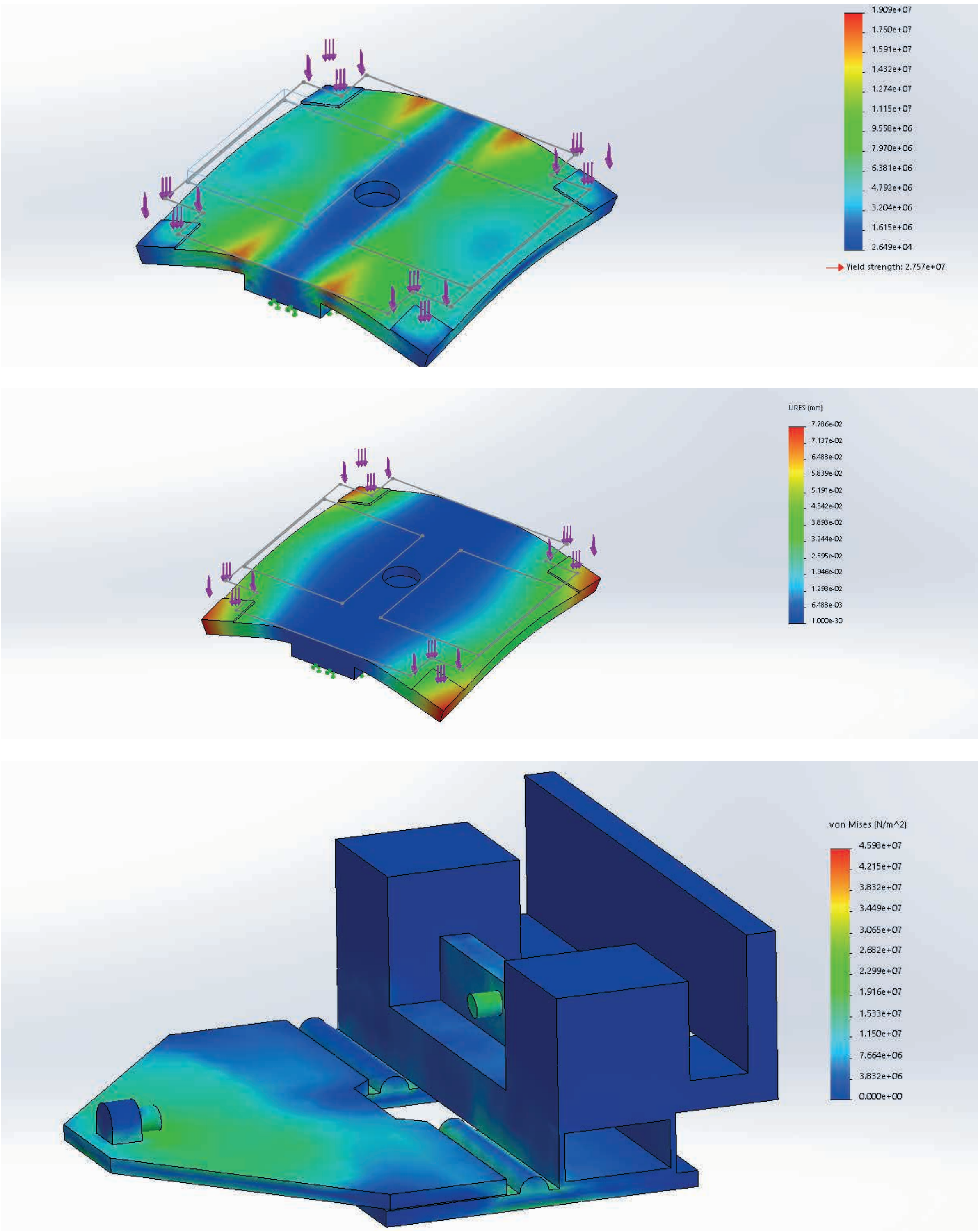


Figure 149. Three simulations

Appendix G

Change the pressing head

The pressing head is interchangable because that makes it possible to experiment with shapes. These two concepts show how the pressing head also could have been changed. The top concept does this with a magnet. However, a quite strong magnet was needed on a small iron tube. Because the tube was already made during the build, this idea did not work. The second made use of a complicated mechanism. It was in fact too complex for what it needed to do. That is why we choose the concept explained in chapter 9.

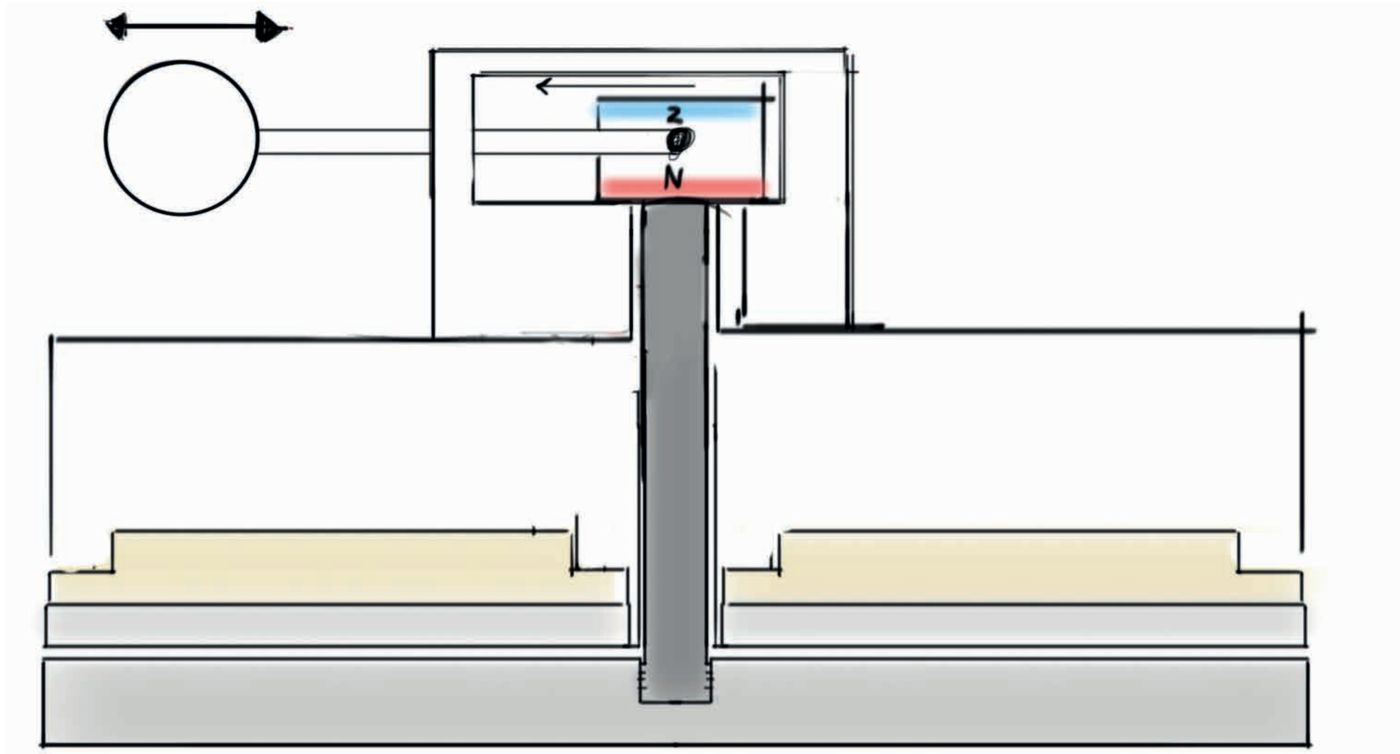


Figure 150.Change of pressing head by magnets

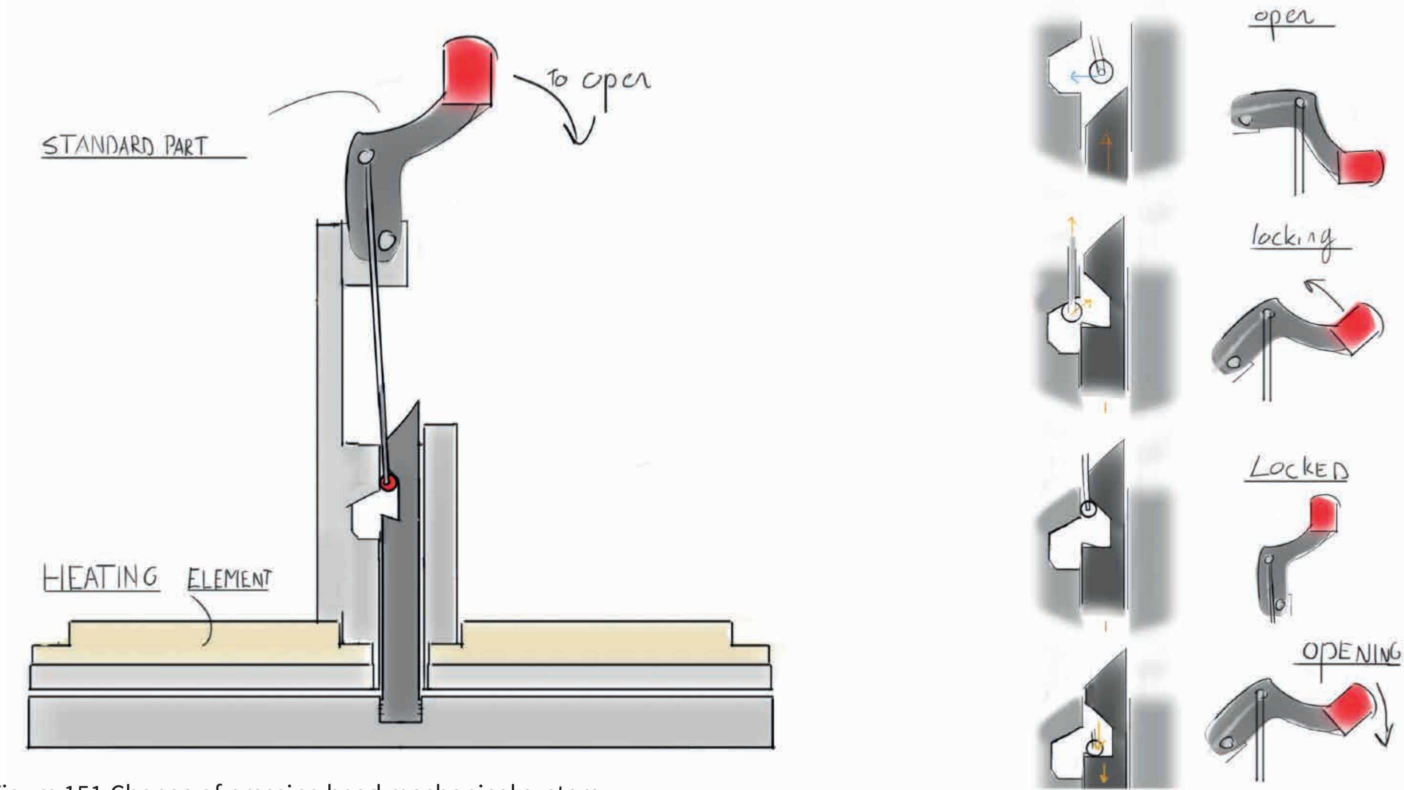


Figure 151.Change of pressing head mechanical system

Appendix H

The code and electronica

Used to control the Demonstrators temperature

Code for arduino C. Based on the code: PID _v1.cpp by Brett Beauregard

```
#include <PID_v1.h>
//#define LatchingRelay 3
double Setpoint;
double Input;
double Output;
double Kp=0, Ki=10, Kd=0;
int in1 = 3;
PID myPID(&Input, &Output, &Setpoint, Kp, Ki, Kd, DIRECT);
void setup()
{
   Serial.begin(9600);
// pinMode(LatchingRelay,OUTPUT);
 pinMode(in1, OUTPUT);
  digitalWrite(in1, LOW);
Setpoint = 175;
myPID.SetMode(AUTOMATIC);
myPID.SetTunings(Kp, Ki, Kd);
}
void loop() {
int A4 = analogRead(5);
double Vin=(5*A4);
   double vinl=Vin/1024;
  double Vout=vinl-1.25;
double T = Vout/0.005;
//int T_round = round(T);
//int T_b = T_round / 10000;
//input = map(analogRead(5),0,1024, 0,255);
//int i;
//i = (int) T_round;
Input = map(analogRead(5),250, 500, 0,255);//
myPID.Compute();
 if (Output > 120) { digitalWrite(in1, HIGH);}
if  (Output < 120) {digitalWrite(in1, LOW);}
//if (Output > 10 ) digitalWrite(LatchingRelay, HIGH);
//if ( output < 10) digitalWrite(LatchingRelay, LOW);
//delay(10);
  Serial.print("analog= ");
  Serial.print(analogRead(5));
  Serial.print("input= ");
  Serial.print(Input);
  Serial.print(" | output= ");
  Serial.print(Output);
  Serial.print(" | setpoint= ");
  Serial.print(Setpoint);
  //print temperature in Celsius
  Serial.print(" | T= ");
  Serial.print(T);
   Serial.println(A4);
  //print voltage read
    delay (1000);

}
```

In combination with an Arduino Uno, the electronica seen below was used. The blue board is ampifying the thermocouple for an accurate temperature measurement. The red board amplifies the signal created by the load cell to measure the force that is applied to it. They are both connected to the Arduino as explained on the websites that sold these boards.

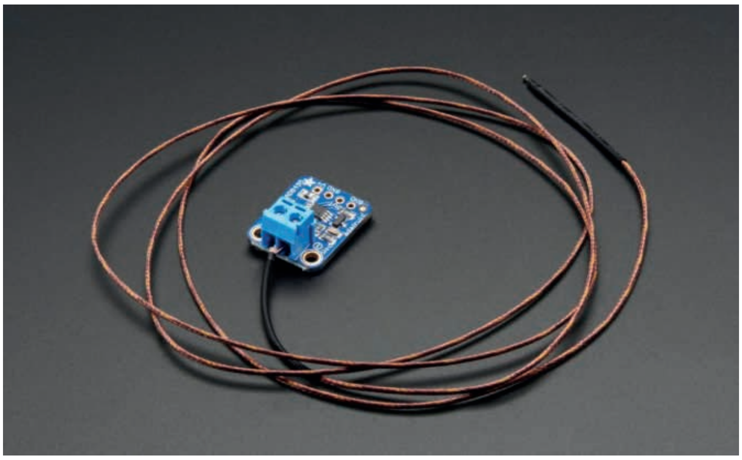


Figure 152. K-typ thermocouple by Adafruit and a breakout board

Loadcell up to 50kg by sparkful electronics
Sparkfun electronics

Figure 153. Load cell and load cell amplifier

Appendix I

Heating and Isolation

Heating options
Other heating options were also tested. The first test was heating with an induction coil. This would make it possible to send the magnetic radiation through the heating head and the RECURF to the metal placed beneath the RECURF. This would make heating from both sides possible. Unfortunately, the induction coil did not have the right specifications to radiate through a layer bigger than 1 mm of aluminium. Such an induction coil should be specially made. The time it would take, as well as the increase in both the complexity of the system and the weight and volume of the heating head, made it impractical for this project. Other heating elements such as the one in a kitchen grill work with heat radiation. This radiating bar will get so hot it glows with a red colour. Having such a hot part in the heating head was an unnecessary risk.

Isolation
When heating, the frame of the heating unit heated up to about 50° C . The handles had a temperature of about 38-40° C. This increase in temperature was inevitable. To slow down the heat transfer to the frame, isolation materials were placed between the baseplate and the frame. Aluminium foils surround the heating element to minimize heat radiation and convection through hot air. Nonetheless, the heating unit was small and did not have the isolation performance to stay exactly at room temperature. However, considering the handles remained at about the temperature of the human body, it was not urgent to do something about it.

Figure 154. Induction cooking plate

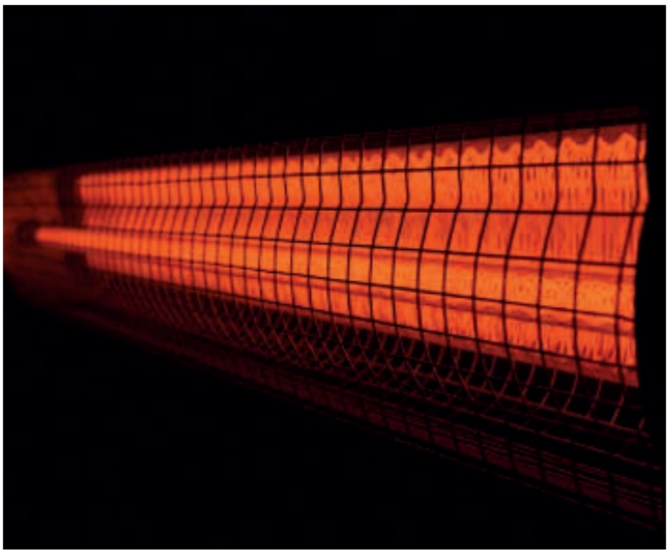


Figure 155. Heat radiation technique

Appendix J

Accuracy of pressing

We explored positioning a shape accurately and created three ideas. In this exploration, we considered whether or not the shape was feasible, ergonomic, inviting and complex.
The first concept uses a flat plate with a shape in it to position the heating unit. The flat plate is attached to the heating unit with four thin metal rods. These can slide through the heating unit, so when the heating unit is pressed down, the plate and the pressing shape touch. The shape in the flat plate is that of the pressing shape, with extra squares cut out at the edges of the shape.

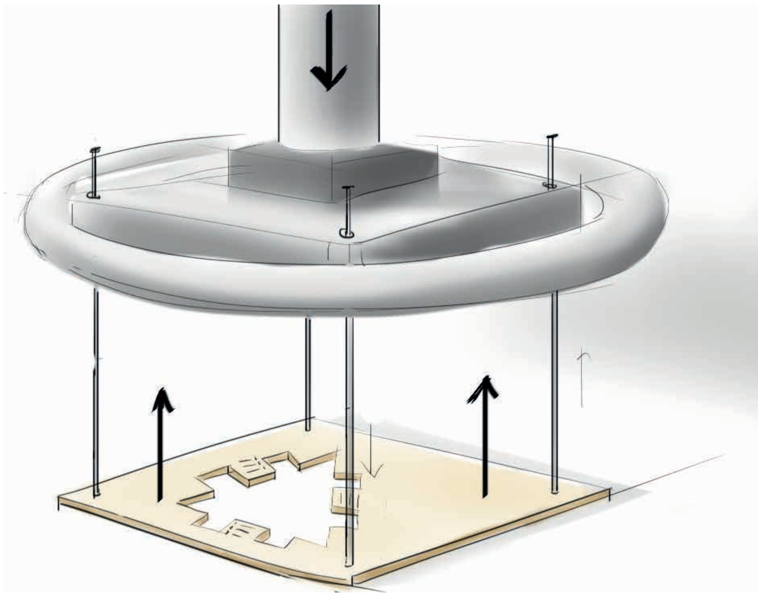


Figure 156. Idea: Positioning plate is attached to the heating unit

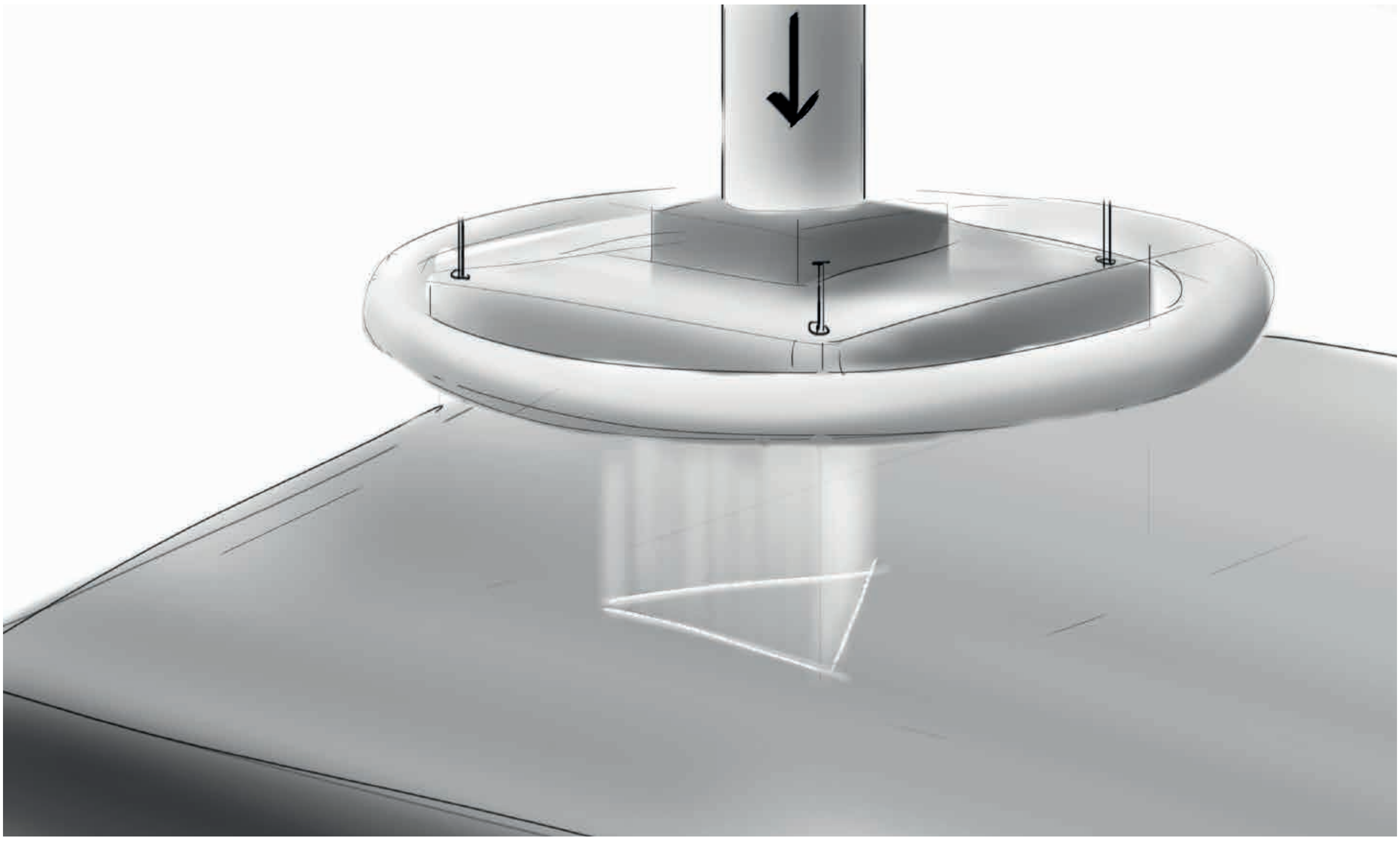


Figure 157. Heating unit shines with a (laser)light at what point there will be pressed

Appendix K

Size of the demonstrator

The size of the demonstrator was prototyped using foam. The height of the roll of RECURF was varied, just as the angle of the table and the size of the table.

Concluded was that the table looks interesting under an angle, but is not practical in use. The height of the RECURF roll is best when the centre point of the roll is at the same height as the table. Otherwise it blocks the view of visitors that are standing on the left of the demonstrator. The table looks best when it is square and 80 cm x 80 cm. This is also a practical size when making patterns.

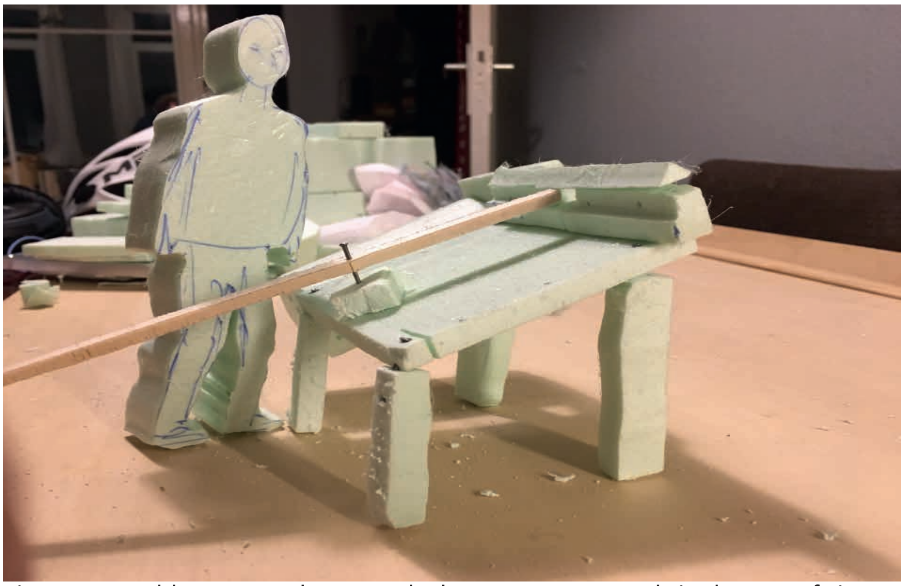


Figure 158. Table at an angle. Towards the user. Users stands in the way of view

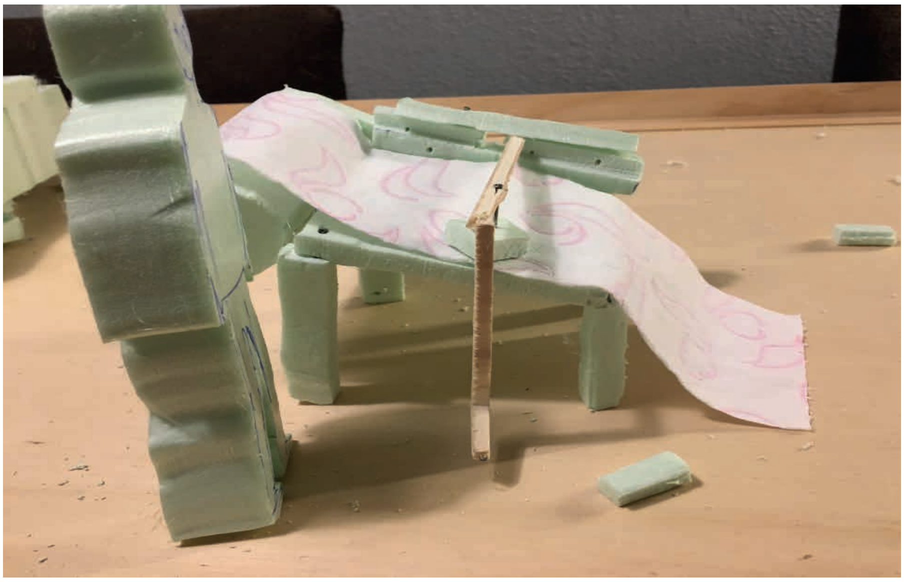


Figure 159. Table at angle. Visitors have great view on roll, table and origami result

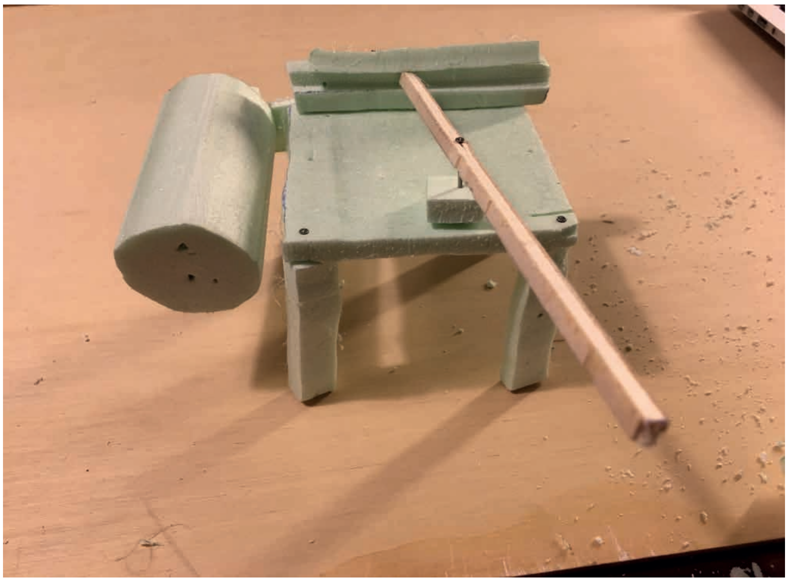


Figure 160. Roll is at same height as the table


Figure 161. Roll is higher than table

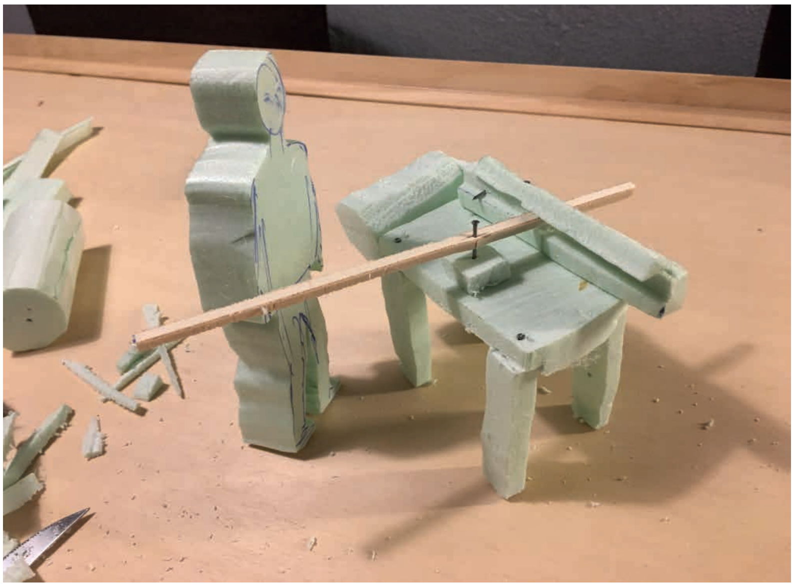


Figure 152. Table is smaller

2600 Rekenen

DESIGN FOR our future

TU Delft

IDE Master Graduation

Project team, Procedural checks and personal Project brief

This document contains the agreements made between student and supervisory team about the student's IDE Master Graduation Project. This document can also include the involvement of an external organisation, however, it does not cover any legal employment relationship that the student and the client (might) agree upon. Next to that, this document facilitates the required procedural checks. In this document:

- The student defines the team, what he/she is going to do/deliver and how that will come about.
- SSC E&SA (Shared Service Center, Education & Student Affairs) reports on the student's registration and study progress.
- IDE's Board of Examiners confirms if the student is allowed to start the Graduation Project.

USE ADOBE ACROBAT READER TO OPEN, EDIT AND SAVE THIS DOCUMENT

Download again and reopen in case you tried other software, such as Preview (Mac) or a webbrowser.

STUDENT DATA & MASTER PROGRAMME

Save this form according the format "IDE Master Graduation Project Brief_familyname_firstname_studentnumber_dd-mm-yyyy". Complete all blue parts of the form and include the approved Project Brief in your Graduation Report as Appendix 1 !

family name: Brink

initials: AJC given name: Alex

student number: 4024958

street & no.: Zaagmolenstraat 50A 02

zipcode & city: 3035 HC Rotterdam

country: The Netherlands

phone: 0681136410

email: ajcbrink@hotmail.com

Your master programme (only select the options that apply to you):

IDE master(s): ( ) IPD (selected) ( ) Dfl ( ) SPD

2nd non-IDE master:

individual programme: - - (give date of approval)

honours programme: ( ) Honours Programme Master

specialisation / annotation: ( ) Medisign

( ) Tech. in Sustainable Design

( ) Entrepeneurship

SUPERVISORY TEAM **

Fill in the required data for the supervisory team members. Please check the instructions on the right !

** chair: Dr. Elvin Karana — dept. / section: Emerging Materials, TU Delft

** mentor: Ir. David Klein — dept. / section: Circular Product Design, TU Delft

2nd mentor: Ir. Mark Lepelaar

organisation: Amsterdam University of Applied Science

city: Amsterdam country: Netherlands

comments (optional)

Chair should request the IDE Board of Examiners for approval of a non-IDE mentor, including a motivation letter and c.v..

Second mentor only applies in case the assignment is hosted by an external organisation.

Ensure a heterogeneous team. In case you wish to include two team members from the same section, please explain why.

Procedural Checks - IDE Master Graduation

APPROVAL PROJECT BRIEF

To be filled in by the chair of the supervisory team.

chair ELVIN KARANA date 28 July 2018 signature

CHECK STUDY PROGRESS

To be filled in by the SSC E&SA (Shared Service Center, Education & Student Affairs), after approval of the project brief by the Chair.
The study progress will be checked for a 2nd time just before the green light meeting.

Master electives no. of EC accumulated in total: ______ EC

Of which, taking the conditional requirements into account, can be part of the exam programme ______ EC

List of electives obtained before the third semester without approval of the BoE

YES all 1st year master courses passed

NO missing 1st year master courses are:

name ______ date - - signature ______

FORMAL APPROVAL GRADUATION PROJECT

To be filled in by the Board of Examiners of IDE TU Delft. Please check the supervisory team and study the parts of the brief marked **.
Next, please assess, (dis)approve and sign this Project Brief, by using the criteria below.

- Does the project fit within the (MSc)-programme of the student (taking into account, if described, the activities done next to the obligatory MSc specific courses)?
- Is the level of the project challenging enough for a MSc IDE graduating student?
- Is the project expected to be doable within 100 working days/20 weeks ?
- Does the composition of the supervisory team comply with the regulations and fit the assignment ?

Content: V APPROVED / NOT APPROVED

Procedure: V APPROVED / NOT APPROVED

comments

name A. Huwae date 21 - 8 - 2018 signature

Initials & Name A.J.C. Brink Student number 4024958

Title of Project RECURF XL: Designing A Foldable Room Divider from Recycled Textiles and PLA Composites Through Origami Techniques

RECURF XL: Designing A Foldable Room Divider from Recycled Textiles and PLA Composites Through Origami Techniques

project title

Please state the title of your graduation project (above) and the start date and end date (below). Keep the title compact and simple not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

start date 28 - 05 - 2018

30 - 10 - 2018 end date

INTRODUCTION **

Please describe, the context of your project, and address the main stakeholders (interests) within this context in a concise ye complete manner. Who are involved, what do they value and how do they currently operate within the given context? What are the main opportunities and limitations you are currently aware of (cultural- and social norms, resources (time, money,...), technology, ...

The amount of people on earth rapidly grows and unfortunately so does the amount of waste that is created. This is harmful for the environment and can be seen as a missed opportunity to profit from this waste. There are many ways of creating value from waste, such as recycling, reusing and upcycling. These methods are all part of the larger idea of a circular economy. Textiles are one of the resources that have the potential of being up-cycled. Upcycling is using wasted resources to create something of more value. A method of upcycling textiles is currently being researched at the AUAS (Amsterdam University of Applied Sciences). This development was the result of researching how to increase the use of bio-based plastics instead of petroleum-based plastics. They created a combination of used fabrics, a waste resource, and bio-based plastics such as polylactic acid, PLA, to fill the bio-based plastic. The plastic can be made out of renewably grown crops such as corn or sugarcane and is also biodegradable. Together with recycled textiles the PLA forms a composite named RECURF (Inge Oskam et al., 2017). This makes the composite more economical per kilo than pure PLA and has unique properties that cannot be found in just fabrics or plastics. The three most researched recycled textiles at the AUAS are: wool, denim and jute. The AUAS has been researching this material for the past years and collaborates with several SME's to support the development and find applications for the material. They also have a collaboration with Dr. Elvin Karana at Industrial Design Engineering, TU Delft, where RECURF is further explored and tested to find its unique qualities to be applied in meaningful products.

The AUAS has created three methods of producing the basic RECURF composite. The first method creates a filament thread for 3D printing by adding small textile fibers to the PLA when molten. The second method creates a flat sheet with the (still) woven textiles, in which a PLA is evenly added in the form of a granulate. The third method is also based on a sheet but now with the textile fibers randomly pressed together, just like felt. This sheet has the PLA as a fiber evenly spread within.

When a sheet of RECURF is heated above the plastic melting point and pressed, the plastic melts and flows all around the textile. When cooled, the plastic will cool and become rigid and hard. What is even more interesting is to partly heat and press the sheet. Where the heat is applied, the PLA in the sheet melts and the fibers get fixed in the plastic and together form a hard and stiff area. The areas that are not heated remain as flexible as the textile. This effect creates the opportunity to give one sheet of RECURF the properties of both textile and hard plastic in one. Stiff parts and flexible parts in one flat sheet make it possible to create a 3d object by using the flexible parts as folding lines and folding a 3d object from this flat sheet. The stiff parts function as the rigid structure of the object. An opportunity lies at researching different folding techniques such as origami when making 3d objects from a flat sheet. Other production techniques could also be explored to help optimize folding techniques, such as laser cutting and robotics. A second method of creating folds in RECURF is by laser cutting a origami pattern in a hard sheet. this pattern can thereafter be put on top of a soft layer and the total can be pressed on a different temperature to make it one sheet. The soft layer on the bottom will still be soft and function as hinges.

The combination of the design method based on folding techniques and flexible production processes such as the heated press create a very cost-effective method for product design. Because of the endless variety of shapes and sizes an object can have, is every object in need of a different particular production process, folding pattern and composition of RECURF. Currently there is an opportunity to research RECURF in combination with folding techniques to create a better understanding of its potential in general.

image / figure 1: An example of the composite RECURF. The difference in color between the sheets is due to the use of other kinds of fiber

image / figure 2: A variety of products that are made with the use of RECURF.

References

Oskam, I., de Jong, M., Lepelaar, M., Nackenhorst, K., Boerema, M., ten Kate, R., Blauwhoff, D. and Agrawal, P. (2017). RECURF HERGEBRUIK VAN TEXTIEL IN BIOCOMPOSIETEN Van materiaal tot toepassing. Onderzoeksprogramma Urban Technology Faculteit Techniek, Hogeschool van Amsterdam, [online] (11). Available at: http://www.hva.nl/kc-techniek/gedeelde-content/publicaties/publicaties-algemeen/recurf.html [Accessed 22 May 2018].

Karana, E., Barati, B., Rognoli, V., & Zeeuw van der Laan, A. (2015). Material driven design (MDD): A method to design for material experiences. International Journal of Design, 9(2), 35-54.

PROBLEM DEFINITION **

Limit and define the scope and solution space of your project to one that is manageable within one Master Graduation Project of 30 EC (= 20 full time weeks or 100 working days) and clearly indicate what issue(s) should be addressed in this project.

A lot about RECURF is still unknown because it is such a new material. Therefore the first part of this project explores RECURF using several techniques from the Material Driven Design method (Karana et al., 2015). During this analysis a benchmark study will be conducted, the tinkering techniques will be used, material testing will be conducted, and a personal material experience vision is will be created.
The second part explores how a flat sheet of RECURF can be turned into a 3d object using folding techniques like origami and besides that several production techniques, such as a heat press and laser cutting.
During the exploration of folding RECURF the focus will be at the transitions of heated and unheated areas of RECURF. Unheated areas will have the properties of textile, while the heated areas will have the properties of plastics, because these areas will have been melted and captured the fabric in the plastic. The transition areas between these two states is unique for a composite. Therefore, further exploration is needed. This can be done by varying the composition and properties of the composite, but also in the lay-out of the heated and unheated areas. Next to the design of the fold itself an exploration is needed of folding patterns and shapes. During this search, origami and other folding techniques need to be explored. This exploration combined with the folding exploration will be the foundation on which a set of rules can be based. These will function as general rules that can be applied when creating 3d structures from a flat sheet of RECURF.
In addition, production techniques have to be analysed that can be of interest for this project. Creating a stiff(heated) and flexible(unheated) area in a sheet of RECURF is done by applying heat (above the melting point of the PLA) and by applying pressure. There is a whole range of production machines that can heat and press. They can vary a lot in speed, accuracy and flexibility. These choices will affect the final design outcome.
In this project, we aim to show that these techniques will create the opportunity to realize a large product- e.g. an installation as a room divider- from RECURF material. The interior installation that is going to be designed will be a room divider because it is an worldwide used product and it is an object that people often touch, move or want to change its size. It is also convenient because no large forces are exerted on it, in comparison to a chair or couch.The main attention will be given to its foldability, and its performative qualities.

ASSIGNMENT **

State in 2 or 3 sentences what you are going to research, design, create and / or generate, that will solve (part of) the issue(s) pointed out in "problem definition". Then illustrate this assignment by indicating what kind of solution you expect and / or aim to deliver, for instance: a product, a product-service combination, a strategy illustrated through product or product-service combination ideas, ... In case of a Specialisation and/or Annotation, make sure the assignment reflects this/these.

This graduation project is aimed at designing a room divider made from the new bio-based composite named RECURF by using origami folding techniques. The design will be based on a study that explores the possibility to create 3d objects from a flat sheet of RECURF using folding techniques like origami and production techniques like the heat press and laser cutting. This study will lead to the composition of a set of general rules that can be used when designing 3d products from RECURF like materials. These rules will also be applied during the design of the room divider.

Initials & Name A.J.C. Brink Student number 4024958

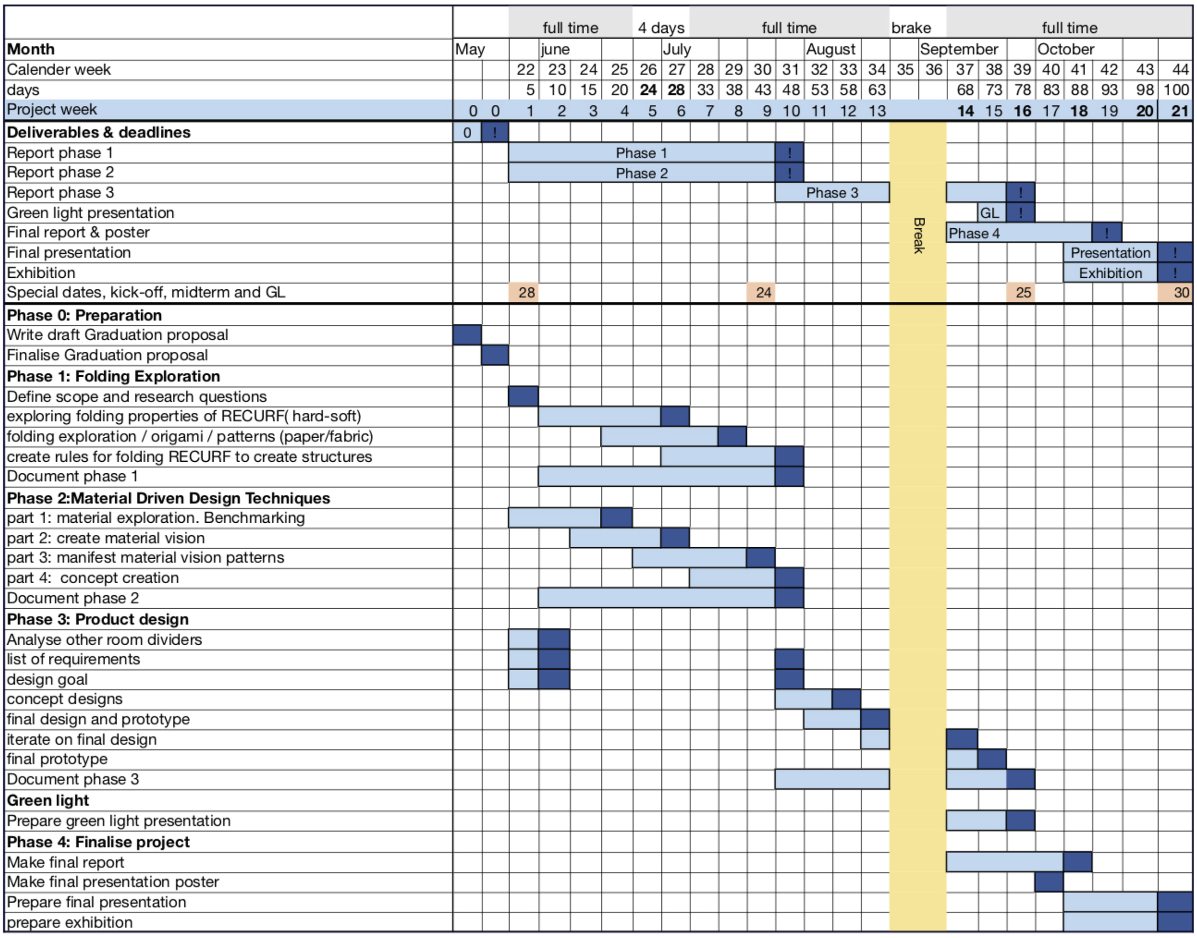
Title of Project RECURF XL: Designing A Foldable Room Divider from Recycled Textiles and PLA Composite Through Origami Techniques

PLANNING AND APPROACH **

Include a Gantt Chart (replace the example below - more examples can be found in Manual 2) that shows the different phases of y project, deliverables you have in mind, meetings, and how you plan to spend your time. Please note that all activities should fi the given net time of 30 EC = 20 full time weeks or 100 working days, and your planning should include a kick-off meeting, mid-term meeting, green light meeting and graduation ceremony. Illustrate your Gantt Chart by, for instance, explaining your approach, and please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any, for instance because of holidays or parallel activities.

start date 28 - 05 - 2018

30 - 10 - 2018 end date



The studies(phase 1 and 2) that are the foundation of the design of the room divider are all planned in the same weeks. The reason for this is that these two studies can influence and benefit from each other to make the studies more valuable. They form the base for the design. That is why the design is mostly planned after the studies.

Dates not working on the project:

Friday 22th of june
Monday 25th of june
27th of August up to and including 7th of September

Special dates:

Kick-off:	28th of May
Midterm:	24th of July
Green light:	25th of September
Presentation:	30th of October
Exhibition:	30th of October

MOTIVATION AND PERSONAL AMBITIONS

Explain why you set up this project, what competences you want to prove and learn. For example: acquired competences from your MSc programme, the elective semester, extra-curricular activities (etc.) and point out the competences you have yet developed. Optionally, describe which personal learning ambitions you explicitly want to address in this project, on top of the learning objectives of the Graduation Project, such as: in depth knowledge a on specific subject, broadening your competences or experimenting with a specific tool and/or methodology, ... Stick to no more than five ambitions.

Motivation

For a while now I have been wanting to explore origami/folding techniques and execute these in the design of products. Origami can have very interesting properties, while it is make from a single sheet of paper. Next to origami I always found materials to be fascinating. They can often be of great influence on a design. Exploring a new material can lead to many new possibilities. That is why I am thrilled to work with this new composite RECURF.

Competences

One of the competences I learned at the master IPD is to plan and execute a project. The only difference is that all these projects were in groups. In this project I want to prove to myself that I can plan a project on my own.

A competence that I haven't mastered fully is that of researching aesthetics and applying it when designing a product. Up till now the functionality of the product got most of the attention. In this project I want to discover if I can also research the aesthetics of the room divider in a useful matter.

As third competence I want to demonstrate that can carry out a technical/mechanical research: researching folding and production techniques and applying that into the design of a product. The reason behind this is my bachelor degree in mechanical engineering. I would like prove that I still have this competence.

FINAL COMMENTS

In case your project brief needs final comments, please add any information you think is relevant.