Master Thesis

Development of a DuraPulp packaging demonstrator

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Division of Machine Design • Department of Design Sciences
Faculty of Engineering LTH • Lund University • 2015

LUND UNIVERSITY

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Preface

This report, as a result of a master thesis project has been written in collaboration with Södra Skogsägarna Ekonomisk förening, at the Division of Machine Design, Department of Design Science, Faculty of Engineering at Lund's University.

Several people have helped and supported me during this project, first of all I would like to thank my supervisor Per Kristav, LIC at Lunds University, whom has been a great support for me and without given order I would like to thank:

Urban Blomster, Business Development Manager, my supervisor from Södra Innovation and the DuraPulp team at Södra, for guidance and encourage during this project.

Rasmus Malbert, Teodor Johnsson and Katarina Elner-Haglund, for helping me understand DuraPulp's properties and for encouraging me to explore this new material.

Everyone who took time for ideation, brainstorming sessions and testing.

Finally I would like to thank the employee at the Division Product Development, whom helped me with ideation, guidance and building prototypes.

Lund, September 2015

Louise Melin

Abstract

Plastic and paper are well known materials, each and everyone can find it in their homes. Paper made from cellulose has been produced for over hundred years and also plastic is a very well-known material, but still there is not too much to find about a combination of these two materials. The objective of this thesis is to develop a packaging, which highlights the unique properties of the new material DuraPulp, containing cellulose and the polymer PLA (polylactic acid). The unique properties are obtained when DuraPulp is activated with heat pressing.

The main goal with this project was to demonstrate possibilities with this new material, when designing a packaging demonstrator. The method used in this project is the *Design Thinking* process, an iterative method splitting the process into six steps.

To obtain knowledge about the material first pulp and PLA (polylactic acid) was studied seperately. The material properties and the manufacturing method, wet moulding and heat pressing was thoroughly studied, at the workshop in Varberg and interviews was held.

With gained knowledge about the material and the manufacturing method, the market segment and the target group was defined. With those two segments defined ideation and prototyping occurred. A package design, which balances; being a demonstrator highlighting DuraPulp's properties, testing new technics and challenging the material as well as appeal brand owners and converters, was developed.

The designed product is a packaging for the on-ear headphone Zinken, from Urbanears. The packaging is designed to cover the headphone like a second skin, it will promote and display it in stores, but also protect the headphone after being sold, as a case. The packaging consist of one part, with a frontside and a backside, with a specially designed folding and sealing technique for an easy opening and re-closing. It will be coloured throughout for an ideal match with the headphones.

Keywords:

DuraPulp, bio-composite, wet moulding and heat pressing, product development, packaging

Summary

I denna rapport beskrivs processen för examnensarbetet *Development of a DuraPulp packaging demonstrator*. Arbetet är en del av Mastern Maskinteknik med Teknisk Design på Lunds Tekniska Högskola. Examensarbetet har utförts i samarbete med Södra Skogsägarna Ekonomisk förening, Sveriges största skogsägarförening. Innventia har i samarbete med Södra tagit fram det nya materialet DuraPulp, vilket är en bio-komposit av pappersmassa och polymeren PLA (polylactic acid). Målet med detta examensarbete är att utforska hur man kan dra nytta av DuraPulps unika egenskaper. Identifiera möjliga marknadssegment och tillämpningsområden samt att designa en förpackning, vilken demonstrerar egenskaperna och utmanar materialet.

Papper och plast är idag två välkända material och går att finna i var hem, men när det kommer till dessa två material kombinerade till en komposit finns det fortfarande mycket att utforska. DuraPulp projektet startade 2000, med målet att utveckla ett nytt cellulosa baserat material. En av drivkrafterna för att ta fram nya material är behovet av lättare fordon, att byta ut glasfiber polymerer till cellulosa baserade fiber kompositer. Det finns även en efterfrågan på marknaden av miljövänliga, biologiskt nedbrytbara och förnyelsebara material, då många plastprodukter fasas ut och behöver ersättas.

DuraPulp produceras idag på Södra Cell i Värö, det kan användas aktiverat eller oaktiverat, när materialet aktiveras skapas en matrix mellan cellulosa- och PLA fibrerna. Detta medför att, materialet blir vatten resistent, får en jämn fin blank yta och blir betydligt stabilare än endast cellulosabaserade material samtidigt som det fortfarande är förnyelesebart och biologiskt nedbrytbart, dessa egenskaper tillsammans gör materialet unikt.

Innan projektet startade lades en projekt plan upp och en designbrief formulerades, vilka delar upp och förtydligar målen med projektet. Vilka var; dokumentera och redogöra för den valda tillverkningsmetoden våtforming och varm pressning, identifiera intressanta marknadssegment samt målgrupp, designa en förpackning vilken demonstrerar och utforskar DuraPulps egenskaper efter aktivering. Metoden som används i detta projekt är den iterativa sex-stegs processen *Design Thinking*.

I början av projektet spenderades mycket tid vid Södras pilot anläggning i Varberg för att dokumentera tillvägagångssättet vid tillverkningen och för att förstå vilka möjligheter, våtformning och varmpressning med DuraPulp erbjuder, samt dess begränsningar. Litteraturstudier gjordes och många intervjuer genomfördes för att öka förståelsen för materialet och tillverkningsprocessen samt för att inhämta information om vilka typer av produkter som redan har tillverkats i DuraPulp, för att senare kunna designa en förpackning som kan uttrycka och utmana DuraPulp på ett nytt sätt.

För att hitta ett passande marknadssegment och målgrupp, till vilken förpackningen skall designas gjordes först en bred och senare en fördjupad marknadsanalys. Det utsedda marknadssegmentet är on-ear hörlurar, då detta är ett segment där DuraPulp kan vara mer än bara en förpackning. Med en smart design kan förpackningen återanvändas som ett fodral efter försäljningen. Att designa för en specifik hörlur underlättar kontakten med kunder och varumärkesägare. I kombination med förvärvad kunskap från marknadsundersökningen, DuraPulps egenskaper och kännedomen om tillverkningsprocessens begränsningar och fördelar valdes hörlurarna Zinken från Urbanears. Urbanears är attraktiva på den svenska marknaden idag med deras distinkta design. Zinken är en av deras största hörlurar och kan på så sätt utmana DuraPulps formingsegenskaper och lyfta fram dessa i en smart designad förpackning. Urbanears kontaktades för mer information och bättre förståelse kring varumärke och förpackning, därefter specificerades målgruppen till personer intresserade av musik, stil och mode, 18-40 år gamla med låg- till medelinkomst och en persona skapades.

Med identifierat marknadssegment och målgrupp gick processen vidare, in i idégenereringsfasen. Där koncept genererades med hjälp *How to* frågor, olika typer av brainstormingar samt en funktionsanalys. För fler och mer detaljerade idéer vid brainstormingarna delades konceptet upp i delproblem innan det sedan sattes ihop till ett koncept.

Med det valda konceptet från idegenereringen påbörjades prototypbyggandet och konceptutvecklingen. Kritiska funktioner identifierades och studerades, quick and dirty mock-ups tillverkades och 3D-modeller för att till sist ha ett slutgiltigt koncept redo att 3D-skrivas. Den 3D skrivna modellen testades och itererades innan den slutgiltiga designen på förpackningen kunde färdigställas och levereras till Södras verktygsmakare för framställning av verktyg och senare tillverkning av förpackningen i deras pilotanläggning i Varberg.

Förpackningen består av ett stycke, det har en framsida och en baksida. För att underlätta vikningen av förpackning vid öppning och stängning har en speciell skåra designats mellan framsidan och baksidan. Förpackningen kommer endast att addera minimalt med volym till hörluren, den kan liknas vid ett skinn som täcker och skyddar hörluren. Efter försäljning av hörluren kan dess butikshängare vikas och rivas loss och förpackningen transformeras till ett fodral. Vid tillverkning kommer pappersmassan att färgas i samma färg som hörluren, för en fulländad matchning.

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1 Introduction

In this chapter the collaboration partner Södra Skogsägarna Ekonomisk förening will be introduced, the design brief and research questions as well as scope and limitations for this project.

1.1 Introduction and background

Biodegradable and renewable materials are demanded on the market. Many plastic products are being phased out and there is a need for a replacer. 2000 the industry cluster Innventia started to research for lighter and environmentally friendly material, originally for the vehicle industry, by combining cellulose fibres and bio-based polymers into composites, in order to substitute traditional glass fibre reinforced polymer systems [1].

Paper and plastic are well known materials today, but there is a lot to explore when combining these into a composite. Around 2008 the base to DuraPulp was compiled and Södra Skogsägarna Ekonomisk förening, as a part of the industry cluster Innventia, decided to continue to develop the material but then in cooperation with the design trio ClaesonKoivistoRune and 2009 was the first DuraPulp product born [2].

One of Södra Skogsägarna Ekonomisk förening's (here after named Södra) three business areas is to produce and sell paper pulp, with a new cellulose based material Södra can gain new market segments and strengthen its trademark.

DuraPulp is today produced at Södra Cell in Värö, when activated the material gains a combinations of properties, which makes it unique. Compared to pure cellulose based materials is it much more water resistant and stabile, with a tactile nice surface, still being renewable and bio-degradable.

In this report the manufacturing method wet moulding and heat pressing will be investigated. It will be explored how to take advantage of DuraPulp's properties, in combination with the manufacturing method's possibilities and limitations, when designing a packaging demonstrator. This for a selected market segments and target group.

1.2 Södra Skogsägarna ekonomisk förening

In Södra's world everything starts with the forest. The forest provides our constant supply of raw materials and is the essential requirement for Södra's many different operations [3].

More than 50,000 forest owners in southern Sweden are members of the economic association that is Södra. Södra is also a large employer. 3,500 people work for the Group, in areas that range from forestry management and environmental conservation to accounting, sales and product development. The Group's three business areas produce sawn and planed timber goods, interior products, paper pulp and biofuel [3].

1.3 Brief

The aim with this project is to design a packaging, which explores DuraPulp properties. The activation and manufacturing process wet moulding and heat pressing will be investigated in order to understand its potential and to compile information for converters and designers, for an easier understanding about how DuraPulp can be used.

The packaging shall highlight DuraPulp's unique properties, when activated and fulfil a task. This in a suitable market segment, with the goal to gain attention from converters and brand owners and tools shall be produced in cooperation with Södra's toolmaker.

1.4 Research questions

Manufacturing and activation process:

- How does the manufacturing process wet moulding and heat pressing with DuraPulp operate?
- Which are the limitations and possibilities with wet moulding and heat pressing?
- Which is the process window?

DuraPulp:

- Which are the unique properties of activated DuraPulp?
- How can DuraPulp be recycled or reused?

Design process:

- What have been produced in DuraPulp before, how can it be explored in a new way?
- Where are DuraPulp's qualities an advantage on the market?
- In which market segments are DuraPulp applicable?
- Which target group request new environmentally-friendly materials?
- How to design a packaging, which highlights DuraPulp's properties?
- How to gain attention from converters and brand owners?
- What is an optimized packaging?

1.5 Scope and limitations

The project started in February 2015 at Lunds University. Scope and limitations have been set in order to make it suitable for the time span of 20 weeks.

Scope:

- A very good knowledge about the manufacturing process wet moulding and heat pressing and an understanding for similar manufacturing processes.
- A general understanding for material components and production.
- Find a suitable market segment and target group.
- Express and challenge DuraPulp in a new way.
- Designing a packaging, which highlights DuraPulp's unique properties when activated.
- Produce a tool for the packaging in cooperation with Södra's toolmaker.

Limitations:

- No mechanical tests or measurements will be carried out.
- Market research will be set to packages.

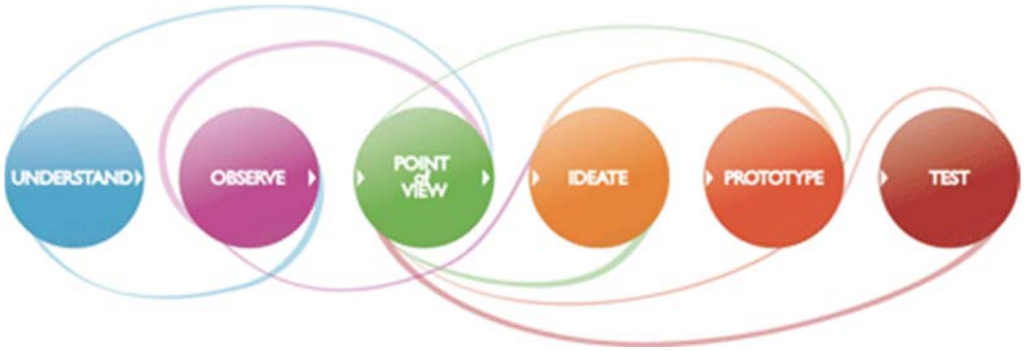
2 Method

In this chapter the used method will be described and how it is implemented in the project. The project plan will be presented connecting the scope of the project with the chosen method.

2.1 Course of action

The method used in this project is the *Design Thinking* method. In the nineties designers from the agency IDEO developed *Design Thinking*, as a method for solving complex problems. In 2003, David Kelley, Larry Leifer and Terry Winograd founded the d.school Stanford, supported by SAP founder Hasso Plattner and in 2007, Hasso Plattner founded the HPI School of Design Thinking in Potsdam, where they today teach *Design Thinking* in multidisciplinary teams [4].

Design Thinking supports and encourages collaborative creativity to solve problems in a holistically and user-centred way. The method offers an even balance between creative and analytical methods. The solution space of design innovation opens at the crossroads of user wishes, feasibility and cost-effectiveness. The six-step iterative *Design Thinking* process, Figure 2.1, combines the methodology from engineering with experimental aspects from the teaching of design [4].



Source: School of design thinking, basic track 2013

Figure 2.1 The six step iterative *Design Thinking* process.

The *Design Thinking* process step by step, see Figure 2.2:

- *Understand* is about broaden your perspective, the problem and prerequisites need to be understood, in order to approach the problem in a correct way.
- *Observe*, observing is about gaining empathy, the market segment and the user is defined. Users are observed and interviewed, in order to gain needs and pain points.
- *Define POV*, recently gained knowledge is narrowed down to a fictive person, a persona and its needs, then a point of view is created, expressing the main need.
- *Ideate*, ideation is about inspire, imagine and innovate, in order to build a wide range of concepts. This is done with different brainstorming technics.
- *Prototype*, thinking with your hands, identifying critical functions and refining details.
- *Test*, testing is carried out in order to collect input and feedback. To be able to test and for a meaningful test, critical functions need to be defined. It must be determined what to test, how to test and why it is relevant, before the testing is carried out.
- *Iterate*, one or more iterations are done until a final product or concept is selected and defined.

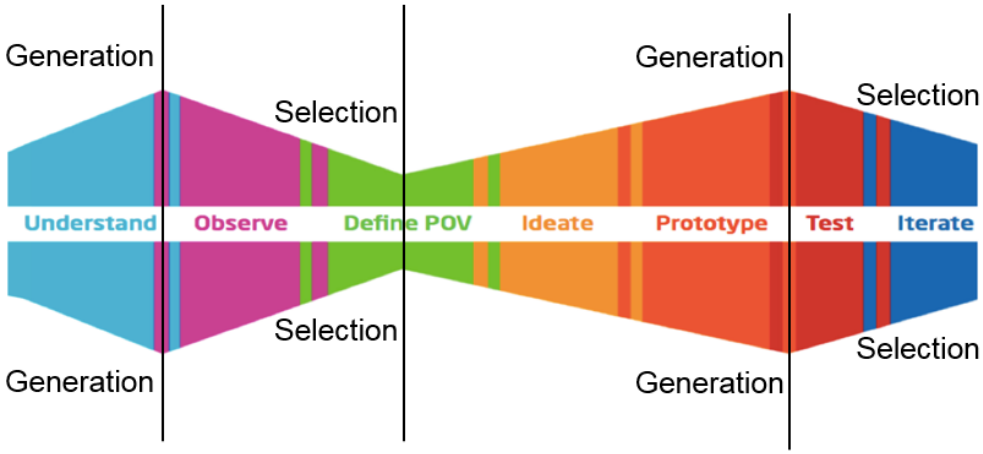


Figure 2.2 Generation and selection phases in the *Design Thinking* process.

During the three first steps; understand, observe and point of view a generation and a selection phase takes place and the challenge is reframed. The three last steps do also start with opening up in a generation phase and then selection occurs. These steps is about solving the challenge, which is done with idea generation, prototyping and testing, followed by iteration, see Figure 2.2.

The chosen method *Design Thinking* is an iterative process, tasks have been carried out parallel in a non-linear process, allowing an iterative process throughout the project.

Deadlines were set up between the phases for structure and to force progress, the results were presented for the supervisor at Södra and at Lunds Tekniska Högskola.

Design Thinking is a method designed for groups of five to six persons. For innovative and inspiring ideation and brainstorming sessions persons with different backgrounds and education will be invited to take part.

As a supplement to the Design Thinking method, techniques *from Product Design and Development* by Karl T. Ulrich and Steven D. Eppinger [5] have been used.

2.2 Project plan

Before starting the project a project plan was created, based on the selected method. In reality, it differed slightly from the project plan and some changes had to be done during the project.

See Appendix A for the original project plan and the outcome.

3 Understand

In this chapter the background research will be presented including; how and why did DuraPulp get born, conversion techniques, DuraPulp's properties when activated and products produced in DuraPulp.

3.1 Method

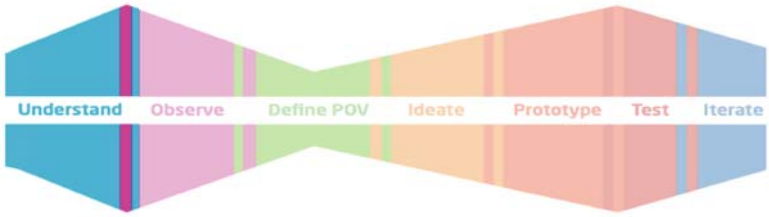


Figure 3.1 Understand, the first step when approaching a challenge.

Background research is done in order to understand, the first step in design thinking, see Figure 3.1. Make sure the question and problem to be solved is understood. A good knowledge about the material and the manufacturing method wet moulding and heat pressing need to be gained, to be able to take advantage of possibilities and understand the limitations. This was done through interviews, literature studies and tests at Södra's pilot plant in Varberg.

Questions to answer:

- How and why did DuraPulp get born?
- How to produce DuraPulp products with the manufacturing method wet moulding and heat pressing?
- Which other manufacturing methods can produce activated DuraPulp?
- Which are the differences and similarities between wet moulding pure pulp and wet moulding and heat pressing with DuraPulp, when is it to prefer wet moulded and heat pressed DuraPulp?
- How to activate DuraPulp?
- Which are DuraPulp's properties, after activation through wet moulding and heat pressing?
- What has already been produced in DuraPulp?
- How can DuraPulp be explored and displayed in a new way?

3.2 Background research

Since DuraPulp is a new material on the market, there is limited documentation and data to be found, especially regarding wet moulded and heat pressed DuraPulp. It is important to have a solid understanding about the manufacturing process as well as DuraPulp's activation conditions and properties after being activated. This in order to be able to find a suitable market segment and design a packaging highlighting DuraPulp's properties. Therefore a lot of time have been spend at the pilot plant in Varberg, manufacturing different pieces in DuraPulp with the method wet moulding and heat pressing.

DuraPulp contains cellulose fibre and fibre from the polymer PLA (polylactic acid). These have been investigated one by one for a better understanding of the final material as well as similar manufacturing methods in pure cellulose pulp for guidelines.

3.2.1 The DuraPulp project

The industry cluster Innventia started to research for a composite combining cellulose fibres and bio-based polymers that can substitute traditional glass fibre, one of the driving forces behind the project is the need for new materials for lighter road vehicles [1]. The research started 2000 and around 2008 was the base to DuraPulp developed [2].

Södra is now alone exploring the material and different manufacturing methods. The business concept is to produce DuraPulp, package it in bales and sell them to the converters who process the material further. In order to reach DuraPulp's full potential, existing conveting processes need to be adapted to some extent. Therefore, it is important for Södra to have a close cooperation with converters, machinery suppliers as well as end customers. Södra are now investing in a wet forming and heat pressing pilot line, in Varberg, in order to be able to define the process window.

The converters are the key in order to reach out on the market, see Figure 3.2. To increase the driving force throughout the value chain, the goal is to work with projects, which have brand owner or final costumer involved. With a final customer involved increases the incentive for the converter and Södra gains valuable information

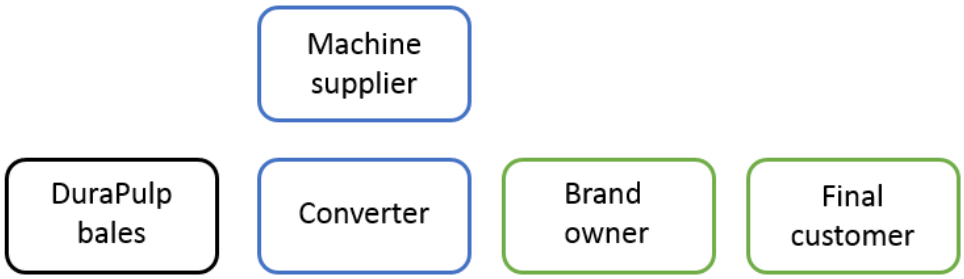


Figure 3.2 Stakeholder map, displaying the converters key position.

regarding requirements for product performance. Commercial reference projects with end products reaching the market, which can verify DuraPulp's excellence are required.

3.2.2 Pulp production

Pulp contains of cellulose fibres, the pulp used in DuraPulp is produced at Södra Cell Värö and consists of virgin fibres mostly from pine trees. These fibres are preferable for DuraPulp, since they have long cellulose fibres and therefore provide stability in the material.

The used manufacturing process to produce pulp, at Södra Cell Värö, is the kraft process also known as sulphate process. The process converts wood into almost pure cellulose and residues, see Figure 3.3.

The process operates as follows [6]:

1. First the bark needs is removed. Then the wood is cut into small wood chips, with a length between 15-25 mm and a thickness between 1.5-4 mm.
2. The next step is the impregnation, now the wood chips are heated with stem and treated whit black and white liquor (strong alkaline solutions).
3. The main part of the process is the pulp cook, when the wood chips are cooked in pressurized vessels the cellulose fibres separate from the lignin and other wood substances.
4. After cooking, the pulp is sieved and washed. The pulp is washed in three to five steps to remove some of the dissolved organic material.
5. Black liquor, containing lignin and other wood substances, is treated and reused for further cooking. Also green liquor is produced after the cook, it will be converted to white liquid with lime.
6. After washing the pulp is bleached in three steps, first with oxygen, which also reduce the lignin in the pulp, and then with chemicals.
7. The last step before drying is a second sieving where the last pollutions will be separated from the pulp. The pulp is now ready to dry, first it occurs naturally then it is siphoned with vacuum.

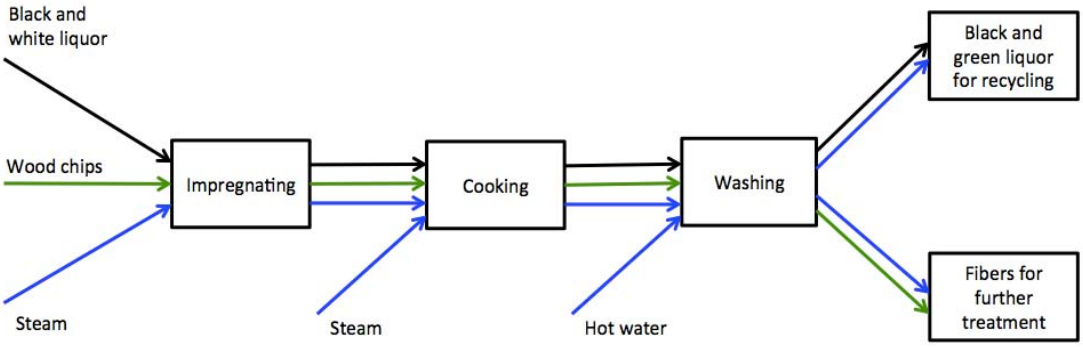


Figure 3.3 The kraft process used to produce cellulose fibers at Södra Cell Värö

3.2.3 PLA (polylactic acid)

Polylactic acid (here after named PLA), is a thermoplastic aliphatic polyester (polymer). PLA is mainly produced from corn starch, but other starch-based plants can also be used, for example, sugar cane and tapioca. PLA is biodegradable and renewable, the one used in used in DuraPulp is made from corn starch [7].

3.2.4 DuraPulp

DuraPulp is a fibre-composite produced at Södra Cell Värö, containing virgin wood fibres and fibres from the polymer PLA. Virgin fibres is chosen since they are longer, have better affinity to PLA and hence more strength. Meaning less material can be used, with the same demand on strength. Virgin fibres are easier to colour and gives a higher cleanliness. DuraPulp is delivered flash dried, pressed and packaged in bales (50x80x60 cm), ready to be converted. DuraPulp is delivered white and can be coloured during the converting process to any colour [7].

3.2.5 Conversion techniques

There are three main ways to produce activated DuraPulp products, the one investigated in this report is wet moulding and heat pressing. The other two are airlaid and heat pressing and heat pressed sheet, these will be presented for a better understanding regarding when wet moulding and heat pressing is a suitable manufacturing method.

3.2.5.1 Wet moulding and heat pressing DuraPulp

In order to understand the manufacturing process and its advantages, it is also essential to understand how wet moulding with pure cellulose pulp operates. Since wet moulding with pure cellulose pulp is well known and have many similarities with wet moulded and heat pressed DuraPulp, the data from wet moulding can be seen as guidelines when working with wet moulding and heat pressing DuraPulp.

Typically products made with wet moulded pulp are egg boxes, fruit protection, corner protections and flowerpots. The material thickness can vary from 1 mm to 5 mm, pulp mouldings can be up to 400 x 1,700 mm and 165 mm deep. To increase strength wall thickness is increased or ribs are added in the design. Draft angles are critical in this manufacturing process, the tools come together on one single axis, and the moulded part must therefore be extracted along that axis. Draft angles usually have a minimum of 5° but depend on the design of the tool [8].

When wet moulding and heat pressing with DuraPulp, first the bales need to be dissolved in water, see Figure 3.4. The water shall preferably be warm, since warm water dissolves cellulose better, has a higher viscosity and enables therefore a higher drainage in the cold press. When dissolved staining can occur, the material can be stained to any colour. Staining at this step gives a throughout coloured end product. The DuraPulp solution is then diluted to a concentration of 0.5 %. It is showed by tests that this concentration allows an even mould in the vacuum-forming phase [9].

When wet moulding with pulp or DuraPulp an aluminium tool is used, the tool is covered with a fine stainless steel mesh, the mesh acts like a sieve, it separates the water from the cellulose fibres and provides the mould with an even surface, see Figure 3.5. The tool is covered with holes roughly 10 mm apart, which provides channels for the water to be siphoned up.

Figure 3.4 Diluted and colored DuraPulp.

Figure 3.5 The aluminum tool covered with a fine mesh separating water and pulp.

To produce a mould the tool is dipped in the pulp, see Figure 3.6 and a mould is formed over the tool by a vacuum. The tool is dipped in the pulp until the wanted wall thickness is achieved, typically 2-3 mm with pure cellulose pulp, with DuraPulp the time is measured and the tool is dipped in the solution for 3-6 seconds depending on wanted thickness. The vacuum is kept constant to fixate the mould on the tool, see Figure 3.7.

Figure 3.6 The tool is dipped into the pulp in order to create a mold.

Figure 3.7 A mold is created and fixated on the tool with vacuum.

For pure cellulose pulp the mould is thereafter transferred to a transfer tool, which continues to apply a vacuum. The transfer tool places the mould in an oven or presses it into a hot tool to dry it.

When working with DuraPulp the mould is not transferred to a transfer tool but put in a cold press, before pressing the female tool is placed on the male tool with the mould, see Figure 3.8. The vacuum pump is on during the whole process in order to soak away water, after the cold press the vacuum is turned off and the female tool and the wet moulded product is detached from the male tool, see Figure 3.9.

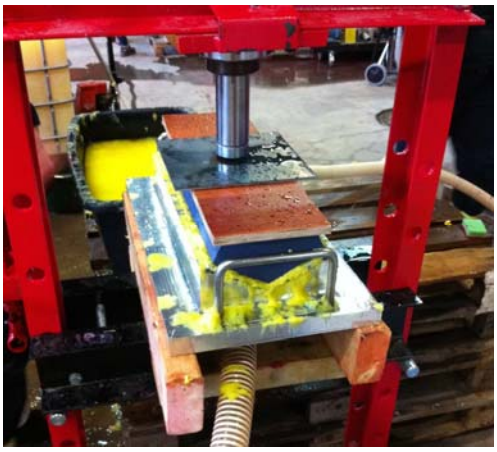


Figure 3.8 The cold press.

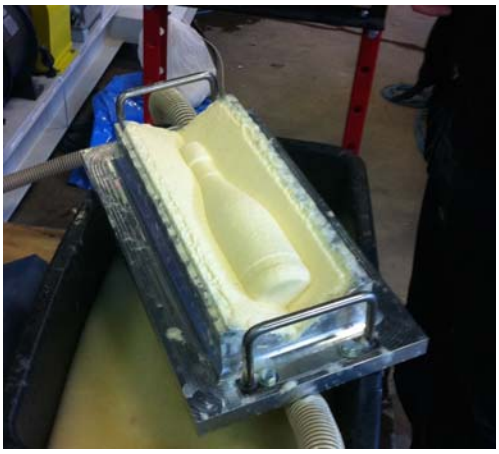


Figure 3.9 The mold after being cold pressed.

The wet moulded product is then transferred for heat pressing, once again it is placed on the male tool and a female tool is placed on top of it. Then the tools with the mould in-between are heat pressed. The press is equipped with two heating elements, one under the male tool and one above the female tool, which heats the tools, when pressing, see Figure 3.10. The tools need to have a temperature between 170-190°C and press with 30-40 kg/cm^2 to activate the material [7]. Under these circumstances the PLA melts and creates a matrix with the cellulose fibre, activation occurs.

When heat pressing, see Figure 3.10, vapour need to be evacuated. If the steam cannot be evacuated steam explosions will occur when the pressure is released, therefore is the male tool provided with small canals, to evacuate the vapour. To establish an even surface the tool is first covered with a coarser mesh and then a finer mesh in order to leave only a small pattern on the inside of the activated product, it gives the product a math finish on the inside. The female part is not covered which gives the side of the product facing this tool a shiny and tactile nice surface. Directly after the activation the product has a temperature around 180°C and need to cool down for a completed activation.

Depending on the design of the tools the margin, see Figure 3.11, can either be cut after activation, with laser or knife or during the heat pressing. If it is supposed to cut during heat pressing this need to be taken into account when producing the tool.

Figure 3.10 Heat pressing, the mold is placed between the two tools and activation occur.

Figure 3.11 Activated tri-shells ready for finishing work.

When wet moulding with pure pulp draft angles usually have a minimum of 5°. Wet moulded and heat pressed products have today been produced with draft angles measuring less than 1° [10], this is possible thanks to two pressing steps. The angle can be decreased from the first cold press to the second warm press enabling it to be very small.

Products have been produced with the thickness between 1mm and 3mm and with corners having a radius with less than 1 mm. The biggest produced product is the Papuru chair measuring 350x350 mm and 500 mm in height, which is the maximum dimensions of the pilot plant in Varberg.

Wet moulded and heat pressed DuraPulp is very allowing regarding formability and can be shaped to almost any shape without cavities, since cores cannot be used in the manufacturing process. Engravings can be done in the tool, leaving text or pattern on the product. Very thin and detailed and thin engravings can be done in the tool, the limit will be set by DuraPulp's formability [11], which need to be tested.

3.2.5.2 Heat pressing sheet or roll

When starting from a DuraPulp paper, it is relatively easy to produce an activated DuraPulp product. Existing equipment can be used, the basically need is only a hot press and a tool. This converting technique suits smaller series and exclusive products, since the process is relatively expensive, labor and time intensive. Formability limitations need to be taken into account, the paper is not very stretchable and the lamination is critical [12].

3.2.5.3 Airlaid and heat pressing

To produce airlaid products, DuraPulp is milled and brought out on a wire to a uniform fibre mat. The mat will then be pressed in three different steps and heated to form the final product. Airlaiding is a relatively simple conversion process and it can form a

wide range of 3D shapes. It is suitable for smaller products like take away trays and similar since the fibre mat have a stretch limitation, limiting the depth [12].

3.2.6 The tool

Trifilon and Cliff are today Södra's toolmaker. To be able to design the tool Cliff need a 3D model from Trifilon and Trifilon need the 3D-model from the designer, as a stl file or similar. When designing a product in DuraPulp for wet moulding and heat pressing it is essential that the designer follows the guidelines for depth, with and length as well as draft angles and thickness. Cliff can manufacture any tool needed for wet moulding and heat pressing DuraPulp [11].

3.2.7 Durapulp's properties

By combining fibres of cellulose and PLA a strong network structure can be created with activation. This provides increased rigidity, reduced weight and greater water resistance, properties more comparable with plastic than traditional cellulose-based materials. To obtain this unique composition of properties the material has to be activated. Activation occur between the temperature 170 and 190°C and with the pressure 30-40 kg/cm^2 [7]. Then the PLA melts and creates a matrix with the cellulose fibres, which is an irreversible process [13].

Properties for both activated and inactivated DuraPulp [2]:

- Renewable
- Biodegradable
- Food grade
- Certified to FSC and ISCC [14]

Properties only for activated DuraPulp [2]:

- Nice tactile feeling
- Dimensionally stable
- Low water absorption
- Light weight with high stiffness
- Lint-free
- Ability to create even and smooth surface

3.2.8 Recycle activated DuraPulp

Activated DuraPulp cannot be recycled as plastic or paper, when milled 5% activated DuraPulp can be reused in new DuraPulp products [13]. It is biodegradable and can be energy recovered or composted, it is approved for both home composting and industrial composting according to SPCR141 [7] [15].

The time it takes to decompose activated DuraPulp depends on the temperature, moisture content in the compost and the structure of the item made of DuraPulp (e.g. thickness, density and shape). Tests shows that it takes around 100 days to degrade 90% of the material [7].

3.2.9 Produced in DuraPulp

Two products done in DuraPulp, which have gained a lot of attention is Papuru, a child chair, see Figure 3.12 and the lamp W101, see Figure 3.13. The chair illustrates the strength and stiffness in the material, it is produced through wet moulding and heat pressing DuraPulp. The lamp W101 is made from heat pressed sheets, it was never put into production due to problems with the lamination of the sheets. Both are design by the design trio Claesson Koivisto Rune.

Source: http://www.sodra.com/en/DuraPulp/How-to-use-DuraPulp/Demonstrators/Parupu/

Figure 3.12 Papuru, a child chair in wet molded and heat pressed DuraPulp.

Source: http://www.sodra.com/en/DuraPulp/How-to-use-DuraPulp/Demonstrators/w-101---lamp/

Figure 3.13 Lamp W101 made from heat pressed DuraPulp sheets.

Other demonstrators have been done in DuraPulp to illustrate the properties of the material one is a seed pod see Figure 3.14, designed by Rasmus Malbert 2010. It is shaped like the fruit from the Norway maple. At the and is a cavity created where a seed is stored, ready to be planted, which displays DuraPulp's biodegradable properties in an excellent way. First cavities are created in the paper sheets, these are then laminated together and the seed pod is created see Figure 3.15 for cross cut. These cannot be reclosed, when opened.

Source: http://www.sodra.com/en/DuraPulp/How-to-use-DuraPulp/Demonstrators/Seed-pod/

Figure 3.14 Seed pod made from heat pressed DuraPulp sheets.

Figure 3.15 The seedcase cavity in cross cut.

Rasmus Malbert has also done a box, the black box, see Figure 3.16, both are made from heat pressed sheets. The black box consists of two parts, a top and a bottom, which creates a cavity in between, when placed on each other. These can be reopened and reclosed but they cannot be attach to each other without external attachment, see Figure 3.17 for cross cut.

Source: www.rasmusmalbert.com

Figure 3.16 The black box with top and bottom part.

Figure 3.17 Tray cavity in cross cut.

A packaging named tri-shell have been produced in DuraPulp, designed by Rasmus Malbert, see Figure 3.18. It consists of one mould which is used three times and is then creating the packaging, see Figure 3.19. With this method a cavity is created in the middle, the individual parts cannot connect to each other and need to be attached external. This kind of packages are suitable for objects which are symmetrical around the central axis.

Source: http://www.materialist.se/Tri-shell-Packaging

Figure 3.18 The Tri-shell packaging with premium leather.

Figure 3.19 Tri-shell cavity in cross cut.

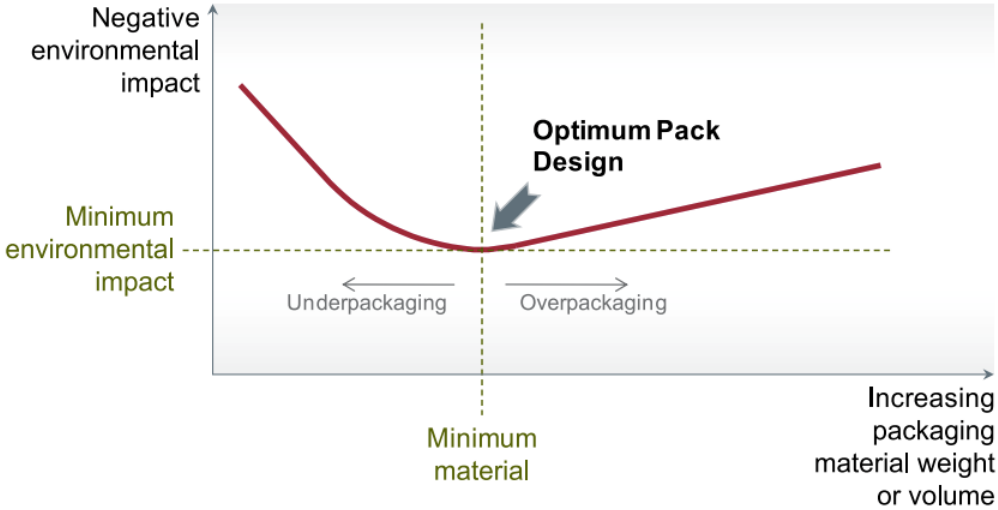
Boxes have been produced with only one big cavity, consisting of two parts a bottom and a top, see Figure 3.20. Closing is done by pressing them together, the top part on the bottom part and opening by pulling them apart. Closing works fine, thanks to DuraPulp's ability to stretch but opening is complicated, since there is nothing to pull in, no edges are reachable, they are all covered by the lid.

Figure 3.20 Box cavity in cross cut.

3.2.10 Packages

"Good packaging uses only as much of the right kind of material as necessary to deliver what is required, without damaging the product, and is presented in a format suitable to meet consumer needs." [17]

The most important roll a packaging has is to protect the product. A general view is that packages are waste and that they shall be minimized. A bad packaging, giving a bad protection cannot secure the product. A damaged product is an uninteresting product and can cause more waste in the end. It is important to find a balance, the product shall neither be over packed nor under packed. The packaging has to protect the product, there shall never be any compromises on the protection, if the product has been damaged it will not be bought.



Source: http://www.innventia.com/Documents/Beyond/2011/beyond_2011_2.pdf

Figure 3.21 Over-packaging results in unnecessary resource consumption, if the packaging material is decreased so that the packaging is under-packaged, the risk of the product being damage and wasted increases.

Under-packaging is usually far worse for the environment than over-packaging, see Figure 3.21. Over-packaging by 10% means that 10% of the resources needed to produce the packaging are wasted and extra fuel to distribute it. Under-packaging that results in the product being spoilt or damaged wastes 100% of the resources used to produce, the contents of the pack and its packaging, and all the fuel used to distribute it [18].

Another important aspect is the filling ratio, for an efficient transport it necessary with a primary packaging, which optimize the filling ratio. The primary packaging does also need to be optimized itself. A primary packaging, which optimizes the secondary packaging but contains a lot of unnecessary space, is not efficient. A good filling ratio is also important in order to decrease the movement of the primary packaging in the secondary packaging and then also minimizing the risk for damages and scuff marks [19].

The measurements, which are important to follow and design after are the European pallets measurements, 1,200 x 800 mm. It is a standard specified by the European pallet Association (EPAL). When working with these pallets it is common to divide them in ½ pallets 800x600 mm and ¼ pallets 600 x 400 mm. Working with this measurements it is important to take the thickness of the cardboard, approximately 5mm into account, giving the inside measures 790 x 590 mm for ½ pallets and 590 x 390 mm for ¼ pallets. The maximum weight is 1000 kg and the maximum height is 1,800 mm.

3.3 Method discussion

To be able to design a useful product and to highlighting DuraPulp's potential fully, it is important to have a very good understanding about the properties of the material. An understanding for the manufacturing process with its possibilities and limitations is critical.

Today there are limited data on wet moulded and heat pressed DuraPulp, an exhaustive research has been done on heat pressed laminated DuraPulp sheets, this data cannot be applied direct on wet moulded and heat pressed DuraPulp since the structure, the matrix which occurs after activation will be different. A wet moulded and heat pressed DuraPulp product is massive and will not have the same properties as a product produced from laminated sheets, therefore the final packaging cannot be designed depending on data regarding durability, strength, stability, water resistance or tear strength.

The process window is not fully known, there are still variables to explore. When working with plastic is it common that shrinkage occur, which is usually presented as a percent and the mould must then be designed a bit bigger than the wanted size in order to achieve an accurate end product. The shrinkage is important to take into account, it is very small for DuraPulp but still unknown and it need to be identified. Moisture migration, tear strength, exact maximum and minimum thickness are also variables which need to be discovered, as well as the ability to keep inactivated parts in an activated product.

Tests with wet moulded and heat pressed DuraPulp have been carried out, an aroused problem was that the DuraPulp was not activated at all locations. The reasons is unknown, a fully activated DuraPulp requires great accuracy from tool producer, defects in the tool could be one reason.

One effect you have today on fully activated DuraPulp is marbled pattern on the outside, more deep colour on some spots and lighter on other, this is today unwanted appearances. The marbled pattern is an uncontrolled pattern which is unique on each produced part. If the same pattern occurs in an industrialised process it could be used as an advantage since it is very hard to produce unique parts in an industrialised process. The reason to why this pattern appear is unknown. It could depend upon the matrix created between the cellulose fibres and the PLA or accumulated colour pigment. There could also be a chemical reaction between the PLA and cellulose during the activation.

An important question to continue to work on is how to recycle DuraPulp, this can be a problem for DuraPulp when entering the market and trying to gain market segments since it is a central and high prioritised question in many countries. Today volumes of bio composites are still small, this is hindering the possibilities to develop commercial waste treatment systems. This is not unique for DuraPulp, it is the same for all fibre based composites.

PLA is more expensive than pulp, DuraPulp cannot therefore not just be exchange with paper, it is on the other hand much cheaper than pure PLA. Focus can instead be set on exchanging PLA products with DuraPulp.

DuraPulp is often compared with plastic today. Because of its strength and the marbled pattern, which occurs today, it could also be compared with wood, since wood also is a living material with unique pattern.

The goal with this project is to explore new areas where DuraPulp can be used and also how it can be used therefore already used technics will be avoided, if possible or further developed. It is not the goal to optimize the packaging as a package even though this will be taken into account when designing.

4 Observe (target area and user needs)

In this chapter the market research and the chosen market segment as well as product specifications and user needs will be presented..

4.1 Method

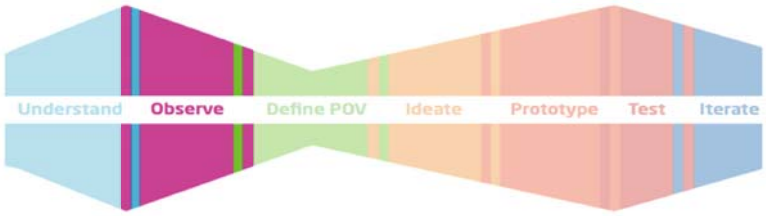


Figure 4.1 Observe, the second step, when approaching a challenge.

Observing is all about gaining empathy. DuraPulp is a new material and an appropriate market segment need to be identified. A product will be design for this segment, which benefits and highlights the unique properties of wet moulded and heat pressed DuraPulp. Finding a market segment and gaining empathy is done on the field, through observations and interviews, in order to find pain points and needs.

Questions for the observation phase:

- When are people trying to avoid plastic?
- Where can DuraPulp compete with plastic?
- When do packages cost?
- How can a DuraPulp packaging add value to a product?
- When are people willing to pay for packages?
- Who pays for packages?
- Which market segment is suitable for DuraPulp?

After deciding on market area:

- Interview users
- Find extreme users, lead users
- Find and define needs and pain points
- Framing insights
- Function analysis

With DuraPulp it is possible to replace fibre-based materials as well as plastic in numerous of different product applications and packages. There are many elements affecting the choice of material, therefore it will be hard to define which products and product segments that can be of interest, the two determining factors will probably be price and added value.

4.2 Market research

Södra have done a market research and one outcome is that designed unit packages in DuraPulp are of great interest for consumers but also for business-to-business. There is a strong incentive to replace plastic with fibre-based materials. One example is parts of packages for electronics, but also for consumable productions like fibre-based cups and lid as well as food trays [2]. In these areas wet moulded and heat pressed DuraPulp can add value. This will be further investigated with some limitations.

The research done in this report will focus on consumer packages where DuraPulp can have a possibility to add value, the segment is not strictly defined in order to not exclude interesting areas. Products that will be in contact with liquids, depend on the degradability or the stiffness and strength in the material will not be taken into account since there is not sufficient data.

So what is out there? In which applications will it be possible to use wet moulded and heat pressed DuraPulp? When can DuraPulp take advantage of its unique properties and how to display these as much as possible?

The areas, which were detected through market research, were areas where a more exclusive packaging can add value to the product. These areas were found and estimated as possible market segments:

- Packages for smartphone cases, see Figure 4.2.
- Headphone packages, see Figure 4.3.
- Jewellery display and jewellery packages, see Figure 4.4.
- Packages for watches, see Figure 4.5.
- Make up end beauty packages, see Figure 4.6.
- Praline and cake packages, see Figure 4.7.
- Cutlery packages, see Figure 4.8.
- Box wine, see Figure 4.9.
- Six pack beer, see Figure 4.10.
- Calendar and notepad, see Figure 4.11.
- Lampshades, see Figure 4.12.

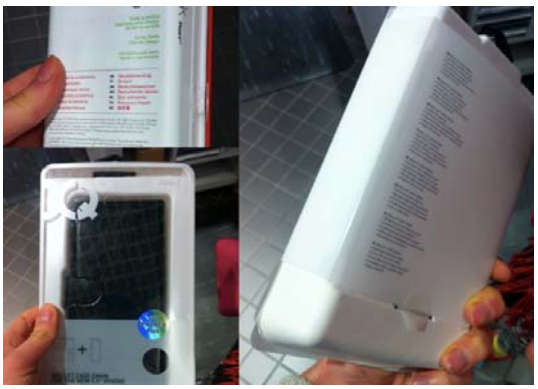


Figure 4.2 Packages for smartphone cases.

Figure 4.3 Packages for headphones.

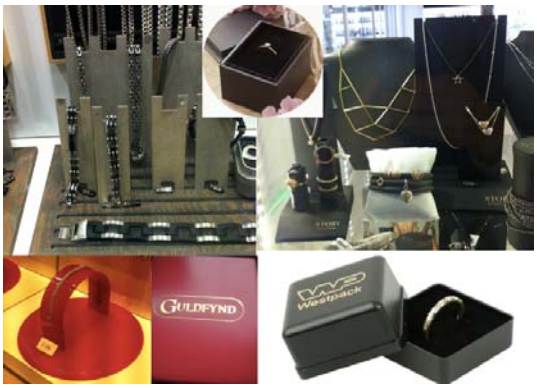


Figure 4.4 Jewellery display and jewellery packages.

Figure 4.5 Packages for watches.

Figure 4.6 Beauty and cosmetics packages.

Figure 4.7 Praline and cake packages.

Figure 4.8 Cutlery packages

Figure 4.9 Box wine

Figure 4.10 Six pack beer

Figure 4.11 Calendar and notepads

Figure 4.12 Lampshades

4.3 Selecting target area

The different areas were presented for Urban Blomster at Södra [20] for discussion and possible addition of segments, see Table 1.

Table 1 Possible target areas presented for Södra.

Market segment	**Outcome**
Packages for smartphone cases	These have many different designs, instead of paper or plastic DuraPulp could be used, adding strength and quality to the package.
Headphone packages	These packages have many different designs today and they are often voluminous. Plastic as well as paper is used. DuraPulp could be used to increase the quality of the package and add value.
Jewellery display and jewellery packages	These boxes are often done in plastic, even more exclusive jewelries are sold in plastic boxes, especially from chains like Guldfynd and Smycka. These can be done in DuraPulp, which will add value to the product, since plastic often is associated with low quality products. Bust are also used for displaying jewelries in many cases in plastic, these can be done in DuraPulp for a more exclusive feeling.
Packages for watches	To display watches a lot of plastic details are used as well as when packaging, this could be exchanged to DuraPulp.
Makeup and beauty packages	Packages for beauty and makeup are exclusive, well designed to add value to the product and people are paying for it. DuraPulp could be used in many different ways in this segment.
Praline boxes and cake packages	The inside of praline boxes are usually done in plastic, when the pralines should be kept one by one, these could be done in DuraPulp. Also cake boxes could be made in DuraPulp to add value, to the product and maybe fulfil a second task as tray when serving the cake.
Cutlery packages	The interior in these boxes are done in paper or plastic, plastic is used for the more expensive ones for an exclusive feeling, these can be done in DuraPulp, to reduce plastic and for added value.
Box wine	These are today very similar, the few ones on the market with a different shape gains a lot of attention, many box wine substitutes can also be found on the market, which indicates that there is a market for a new kind of packaging for box wine.

Six pack beer	There are many on the market, but they are often square shaped, not following the shape of the bottle, these can be given more interesting shape, done in DuraPulp.
Calendar and notepad	Front pages or covers in paper do often get worn quick, carrying them back and forth, which makes the notepad or calendar look old or like a low quality item. To increase the durability plastic is sometimes used as front page, here DuraPulp could be used as a cover to increase the durability and design possibilities with its great formability compared to paper or carton.
Lamp-shade	Not really a packaging but a lampshade could take advantage of the marbled pattern and display it instead of that it is seen as a problem.

After discussions with Urban Blomster at Södra [20], it was decided to keep on working with two target areas. One is the lamp-shade segment, this was chosen in order to highlight the unique marbled pattern which occur during the process and use it as a design feature instead of trying to get rid of it. This hopefully in cooperation with Northen lightning. The other target area is box wine, this because the wine packages on the market today are very similar and static. The few ones, which have other shapes than the standard rectangle, gains a lot of attention and adds value to the product. Frontpack will be contacted for this segment, since Urban already introduced DuraPulp for them.

Frontpack did not show any interest therefore Anders Karlsén at Kiviks Musteri [21], was contacted and after a meeting with ideation and brainstorming was the conclusion that the market for box wine is very well explored and the margins are very small. Instead they are interested in buy and get products for campaigns in supermarkets.

Northen lightning showed interest and saw possibilities in this new material but since it is a design product probably carrying a small volume, even though it could display DuraPulp in a new way it was decided not to continue with this concept.

4.3.1 Second immersed marker research

More observation needed to be done, to gain more knowledge about already explored market segments. Where is plastic used, where can DuraPulp be used? How to reduce buy and dispose behaviour regarding plastic? This time the market research was done with focus on a smaller segment.

Packages to do further research on:

- Apple computer packages, see Figure 4.13
- Packages for on–ear headphones, see Figure 4.14
- Packages for smart watches, see Figure 4.15
- Beauty/makeup packages, see Figure 4.16
- Luxury praline boxes, see Figure 4.17

Figure 4.13 Apple computer packages.

Figure 4.14 Packages for on-ear headphones.

Figure 4.15 Packages for smart watches.

Figure 4.16 Beauty/makeup packages.

Figure 4.17 Luxury praline boxes.

The second immersed market research led to a greater insight and more information was gained. See Table 2 for the outcome.

Table 2 outcome from immersed market research

Market segment	**Outcome**
Apple computer packages	The plastic shape inside in the box is injection moulded plastic and could be exchanged to DuraPulp, to decrease plastic and add value.
Packages for on-ear headphones	There are a lot of different packages on the market and a lot of plastic is used, plastic could be exchanged with DuraPulp.
Packages for smart watches	DuraPulp could be used, displaying the watches in a new way and decrease the use of plastic.
Beauty/makeup packages	They often have exclusive boxes to add value to the product here DuraPulp could be used in many different ways.
Praline boxes	Expensive chocolate are often sold in paper boxes to add value but all of these are square for round and individual boxes plastic is used, DuraPulp can add value here and expand possible design options.

All of the areas could be suitable, DuraPulp would add value to the products as well as decrease the use of plastic.

4.3.2 Specify target area

In order to give the possibility to the package to fulfil a second task after being a package, it was decided to focus on headphone packages. There are many different headphone packages on the market, with a lot of different designs and looks. Headphones do often lack a case, there is a lot to be find for smartphones and sunglasses but more or less none for headphones, which often are carried in a bag just like sunglasses or smartphones, tablets and so on.

The goal with the packaging is that it shall not be a buy and through a way packaging, is shall be reused and serve as a protection as well, a second task to fulfil.

Many different technics and materials are used on today's on-ear headphone packages and they are displayed in many different ways in the stores. Either standing on shelves, hanging on a walls or just lying in big buckets, see Figure 4.18. The design of the headphones are clearly mediated, with pictures or with transparent plastic displaying the headphone in the packages. They have a wide range of colours and materials and shapes, see Figure 4.19. There are many different ways to open the packages, in many cases are they sealed with transparent circular stickers but some are laminated together and cannot be reclosed when opened once. Usually there are already opened examples to try in the store.

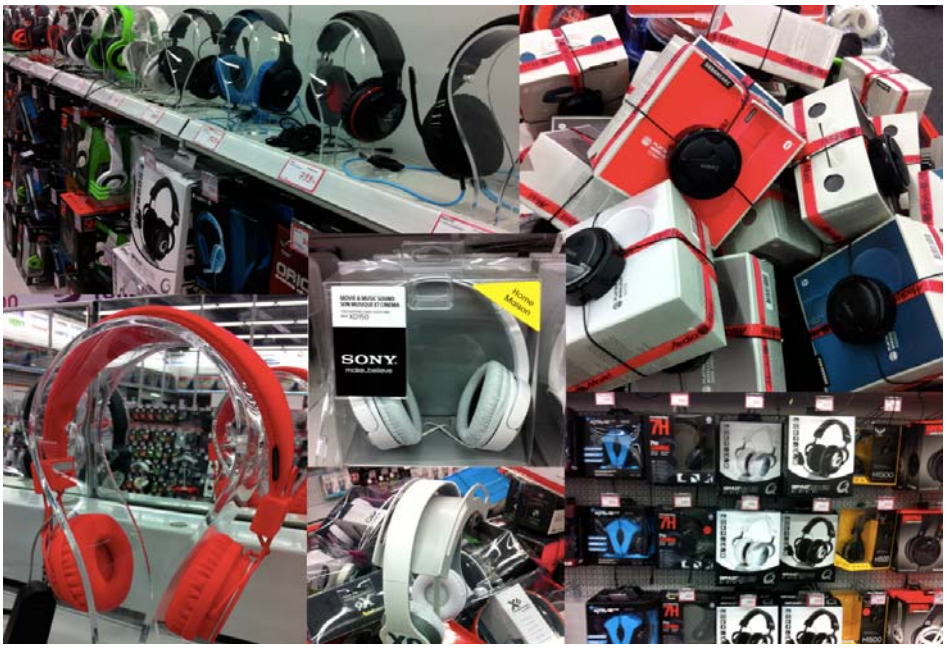


Figure 4.18 Headphones, as they are displayed in stores.

Figure 4.19 A selection of on-ears headphone packages.

More expensive headphones costing around 200 Euro are delivered in packages including a case therefore it was decided to focus on a package for headphones, which costs around 100 Euro, since these are delivered in packages without cases.

4.3.2.1 Specify on-ear headphone

Designing for a specific headphone enables contact with customers and brand owners. With gained knowledge from the market research combined with DuraPulp's properties the headphone Zinken from Urbanears was chosen. Urbanears is owned by Zoundindustries, a Swedish company with headquarter in Stockholm and they are very popular on the Swedish market today. They do colourful headphones, everything is given the same colour, cable, microphone, headphones and packaging. Here DuraPulp's ability to be coloured though has the possibility to be displayed in a beneficial way and will fit with the Urbanear design. The colour Indigo, see Figure 4.18 was chosen since it is one of their bestsellers [22]. One of the goals with the packaging is to gain attention on the market, therefore is it important with a colour people can identify themselves with. Zinken is one of Urbanears biggest on-ear headphone in the right price range, costing 99 Euro. The design and the size of the headphone have the possibility to challenge and highlight DuraPulp's great formability, see Figure 4.20.

Figure 4.20 Urbanears headphone Zinken, with packaging.

Urbanears headphones are today packaged in rectangular paper packages, see Figure 4.18. Designing for Urbanears will not contribute to a smaller consumption of plastic but might inspire other companies to use DuraPulp instead of plastic when choosing packaging material. A packaging for Zinken will be able to highlight many of DuraPulp's unique properties, which is considered to be more important.

Mojdeh Hassani [22], at Urbanears was interviewed for a deeper understanding regarding their packages, chose of material, size and shape and target group.

The main outcome is:

- It is important that the headphone does not get damage or worn during transportation, the headphone need to be safe in place also after being shacked and/or dropped.
- The packages shall embrace and present the headphone.

- It is important that it is easy to spot that it is a headphone from Urbanears. Therefore are front measures set, which all packages need to follow and the headphones need to be designed to fit. They have similar prints on all packages, in order to create an uniform impression, when presented hanging on a wall or standing on a shelf.
- The unpacking experience shall be unique and colourful. The paper is folded different for each model, the folding is following the shape of the headphone, in order to highlight what is unique with exactly this model.
- They are using paper since it is recyclable, which is important for them.
- Each packaging is closed with two transparent stickers, it is important to minimize the amount since they can be annoying to peel away but it is also important to keep them burglar proof. After being peeled of, marks remain on the packaging and can easily be spotted.

4.4 Finding target group/framing insights

With specified target area and specified on-ear headphone the target group need to be defined, this is done through observations and plenty of interviews (see Appendix B for questionnaire). Insights and pain points are collected in order to understand the user and gain empathy.

Insights and pain points from interviewed users:

- *"The cable is a mess, it is always the connection between the cable and the headphone which stops working. Either the cable get stuck in the bag when you pull out your headphones or you find the cable and pulls it to get your headphones." Malin Nordlund*
- *"No I don't see any need of a case, I don't need it for my headphones, I always buy cheap because they always beak sooner or later but if of course, if I had a protection I would like to have white or bright headphones. I always buy black or dark ones because then you can't see the dirt that easy." Lena Melin*
- *"They always break in the bag, that's why I don't bring them that much anymore." Arturo Petazzi*
- *"They break in my bag so I don't bring them too often, because if I need to put them in my bag they will break, one of the on-ear part of the headphone always fall of, I can put it back and it works again but it doesn't feel good." Malin Kinnander*
- *"Mine are expensive so if I bring them and when I don't listen to music I let them hang around my neck. I got a case with them in the packaging when I bought them but I never use it, it is too big, takes way to much space in my bag." Mattias Uttke*
- *I would never buy a case but it would of course be nice to have one.*
- *"I like the sound and the fitting but they are clunky to transport, when I don't use them. And the cable is unnecessary long."*

- *"We like the square-shaped packages, they are easy to handle and use all the space in the box." Philip employee at Media Markt*
- *"We always have a demo example for customers to try." Philip employee at Media Markt*
- *"You can always return your product even if you had to break the package to open it, we may not be able to sell if for full price after but you can always return if and will have your money back as long as the product is unused." Philip employee at Media Markt*
- *"My on-ear are clunky, do not fit in my pocket like an in-ear"*
- *"But it would be great if I could hang them on the bag"*
- *"It gets worn quickly, especially when traveling with them, taking them up and down from the bag." Justus Melin*
- *"Clumsy I never bring my Zinken if I go in to town, then I always bring my in-ear, which I easily can put in my pocket but I use them a lot at home, in front of the computer or when traveling longer distances." Sebastian Rutgersson*
- *"Ether mic stops to work or one of the headphones, it is always bad connection somewhere. Anja Sandberg*
- *I always push them together and down in the bag and then the cable is a mess and get stock everywhere" Anja Sandberg*

Figure 4.21 Moodboard, problems occurring with on-ear headphones and the cable, as inspiration for further development.

4.5 Product specifications

A function analysis was created, see Table 3, to serve as a base during the ideation and concept selection phase. It ensures that no crucial aspects are overseen and serve as help to evaluate concepts. Needs obtained from interviews, observations and literature were described as a function consisting of a verb and a noun. The functions were classified as main function (MF) needed (N) or desired (D) and the function analysis is divided into the sub categories; package specifications, production and user need [23].

Table 3 Function analysis classifying functions as main function, needed and desired.

Function packaging spec.		**Class**	**Notes**
Protect	Headphones	MF	
Offer	Hanger	N	For display in stores
Offer	Stand	D	For display in stores
Optimize	Transportation space	N	
Own	Reclosability	N	When using as case
Show	DuraPulp properties	N	
Be	Packaging	N	
Own	Stackability	D	
Offer	Protection	N	
Sell	Headphone	N	
Display	Headphone	N	
Express	Headphone shape	D	
Ease	Opening	D	
Ease	Close	D	
Prevent	Theft	D	
Provide	Reclosing	N	
Contain	Brochure	N	
Contain	Cable	N	
Be	Stabil	N	
Own	Innovation	N	
Be	DuraPulp product	N	The packaging shall only consist of DuraPulp
Explore	DuraPulp	N	
Challenge	DuraPulp	N	

Production		**Class**	**Notes**
Allow	Wet moulding and heat pressing	N	

Minimize	Spill	D	
Optimize	Production time	D	
Provide	3D-shape	N	
Minimize	Parts	D	
Optimize	Draft angle	N	
Be	Post processed	N	

User need, as case		**Class**	**Notes**
Protect	Headphone	MF	
Offer	Water resistance	D	
Organize	Cable	D	
Be	Stabile	N	
Offer	Hang construction	D	
Be	Light	N	
Minimize	space	N	
Ease	Opening	N	
Ease	Closing	N	
Own	Re-closability	N	

4.6 Observe discussion

First the focus was set on finding a suitable product/market segment and a brand owner or in order to get a closer connection to converters and customers, for an easier implementation of a DuraPulp packaging. After identifying interesting market segments and brand owners they were contacted, the most of them show interest for this new material. But there are still no converters and in many cases it might be more expensive than existing paper packages, which makes it hard to find a suitable area for DuraPulp without knowing its exact properties or price.

The second immersed market research was limited, because of the very limited time span and in order to explore already identified and interesting market segments. There might be more suitable market segments for packages in DuraPulp but since it is a new material, which has not been tried before it is impossible to say, and need to be tested.

Since there are many possible market segments, less time could have been spent on searching for the perfect one. Already the first should have been more limited. Less time could have been spent trying to get in contact with brand owners and instead have

continued the design process, since it is a long process for companies to change to a new material.

Without doing a very deep and exhaustive market research is it impossible to say, exactly where and when people are trying to avoid plastic and when customers are willing to pay a bit more for the packaging. I had to trust my gut feeling when choosing market segment.

Finally the headphone Zinken from Urbanears was chosen, since they have a big market in Sweden today and have a very significant look on their on-ear headphones. Zinken do only use paper in their packages so plastic will be eliminated designing for them but maybe the amount of material used can be decreased. Many different headphones could have been chosen and maybe it could have been good to choose one, with the on-ear part turning more not only 45° but 90° for a greater freedom when packaging the headphone and designing the packaging.

It is hard to say to set a price on the packaging and it will also depend of the amount of packages that will be produced, if the price factor can concur with the current packaging cannot be told today. Choosing Zinken as the on-ear headphone will not decrease the use of plastic but maybe the amount of material used in total, this need to be further investigated.

5 Define Point of View

In this chapter the target group and a persona will be defined and presented as well as the Point of View with needs and insights.

5.1 Method

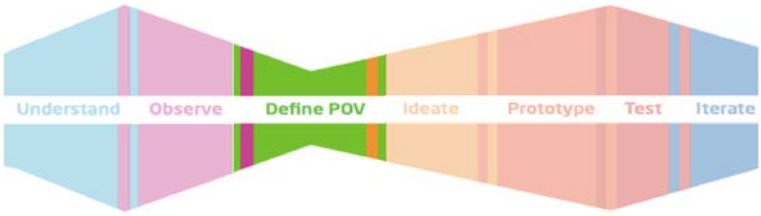


Figure 5.1 Step three, define the Point of View

To be able to design a product the target group need to be known and also a fictive person, the persona, to whom the product will be designed. The point of view, containing a user a need and an insight need to be defined. How to make it world changing?

Areas to define:

- Persona
- Needs
- Point of View

5.2 Target group and persona

The headphones are one size but adjustable to fit everyone, this does not mean that everyone is the target group. The chosen target group for the headphone, defined on earlier done observation and interviewing, are persons interested in music, style and fashion 18-40 years old with low to middle income. To visual the typical user, a persona is created, a fictive person, based on user research, see Figure 5.2. This narrows down the focus to one user with specific needs.

The persona:

Figure 5.2 A Moodboard with the persona for inspiration.

Name: Kajsa Rutgersson

Age: 27 years

Occupation: Concept developer and designer, own company

Income: 22 000 SEK

Living: In a two room apartment in Gothenburg with boyfriend and dog

Lifestyle: Organized, hipster, earthly life

Personality: Humble, curious, social, open minded

Music interest: Like to go to concerts with friends, playing in a band for fun, interested in new music, always up to date.

Other interests: Fashion, to play soccer, cooking, Indian food, interior design, traveling, friends and family.

Defined needs:

- Protect headphones from dirt, so she can buy lighter and brighter ones without that they look worn and get dirty too quick.
- Protect headphones from bumps.
- Want to get hold of the headphones and cables quick, not just headphones and pulling out the cable or pulling in the cable to reach the headphones.
- The protection need to be light and take up as little volume as possible.
- Would never buy one since it is seen as a bit unnecessary

5.3 Point of View

The point of view is constructed with a user, the user's needs and gained insights from the observation and interviews. It is important to keep it narrow, it is not supposed to fit everyone or include all insights.

Point of view:

Kajsa, an engaged multitasking, full time working business woman, prepared on all kind of daily surprises with her well-equipped fjällräven kånken backpack need to protect her Zinken on-ear headphones, keep track of the cable and to keep them clean, transporting them in her backpack in order to extend the feeling of new and "fresh" without extra costs.

5.4 Point of view discussion

It was hard to narrow it down to the persona Kajsa Rutgersson and it is hard to say if she is a suitable persona, this will be showed usually during testing if. If the packaging receive negative feedback it might be because of an incorrect persona and Point of View.

A persona and Poit of View need to be set in order to be able to continue with the process, never design for everyone. It can be changed later if it is needed, more important is to proceed with the process, which was done.

6 Ideation and concept selection

In this chapter ideation and concept selection will occur. Generated ideas will be presented as well as the chosen concept to develop.

6.1 Method

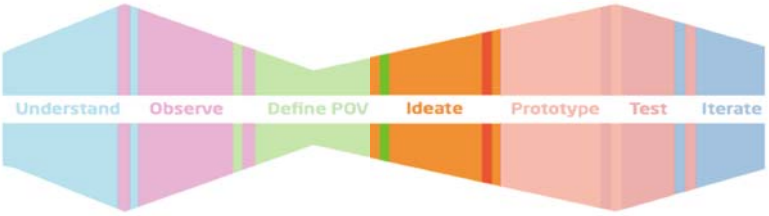


Figure 6.1 Ideation, the fourth step in the *Design Thinking* process.

Ideation is about inspire, imagine and innovate, to create unexpected alternatives. It is important to build a wide range of concepts with a great innovation potential. Ideation and concept selection is done through:

- How to questions
- Brainstorming
- Matching with function analysis and Point of View

6.1.1 How to questions

Before brainstorming How to questions are generated, which are going to be used in brainstorming sessions later. These gives the idea generating a focus.

How to questions:

- How to protect headphones?
- How to pack headphones?
- How to travel with headphones?
- How to reuse packages?
- How to open packages?
- How to close packages?
- How to fold headphones?
- How to position the headphones in the packaging?

6.1.2 Brainstorming

Brainstorming is done in order to generate ideas. When brainstorming there are some important rules to follow, for a greater session with high innovation potential:

- Defer judgement
- Encourage wild ideas
- Build on the ideas of others
- Be visual
- One conversation at a time
- Stay focused
- Think user-centred
- Go for quantity
- Fail often and early

There are many different ways to do brainstorming, in this project it was chosen between:

- Negative brainstorming
- Body-storming
- Prototyping brainstorming
- Hot potato
- What would superman do?
- Look for inspiration
- The gallery
- Quiet brainstorming

6.2 Ideation

Brainstorming sessions have been done in small groups, with help from volunteers in order to broaden the perspective, create a wide range of concepts and built up a great innovation potential. Designing a packaging is complex and many decisions need to be taken, therefore the ideation was divided into three smaller sub tasks:

- Positioning of headphones in packaging
- Shape of packaging
- Open and close function

With How to questions and different brainstorming techniques the ideation got started.

6.2.1 Positioning of headphones in packaging

First the focus was on finding a way to position the headphones in the packaging, displaying the headphone and highlighting DuraPulp’s formability. Fold them when packaging them, as small as possible, see Figure 6.2 or leave them in the open start position, see Figure 6.3.

Source: www.urbanears.com

Figure 6.2 Folded Zinken on-ear headphone.

Source: www.urbanears.com

Figure 6.3 Unfolded Zinken, on-ear parts in starting position.

There are also different possibilities to place the on-ear part of the headphone, since the on-ear part can turn 45º, see Figure 6.4. The headphones can be placed in the packaging like in Figure 6.4 or with one turned 45º in and one 45º out. The on-ear part can also be left unturned, in start position, see Figure 6.3, when being packed.

Source: www.urbanears.com

Figure 6.4 Zinken headphones with the he on-ear part turned 45º in.

The two kind of brainstorming techniques, which have been used, for this sub problem are quiet brainstorming and look for inspiration. The brainstorming have been done in smaller groups with the How to questions; How to fold headphones and How to position headphones in packaging, see Figure 6.5 for the outcome.

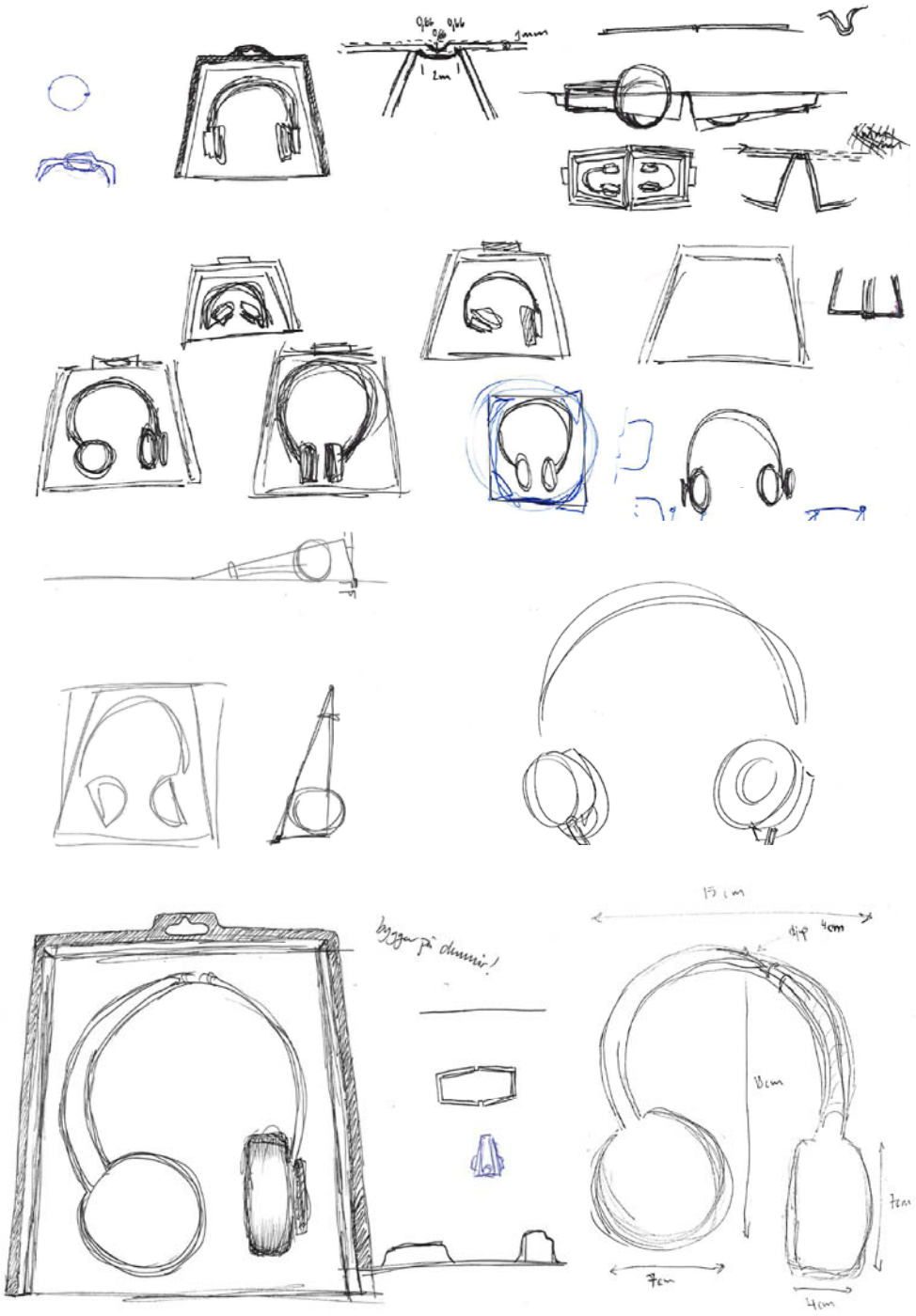


Figure 6.5 Outcome from quiet brainstorming and look for inspiration when searching for a positioning of the headphone in the packaging.

6.2.2 Shape of packaging

There are many different technics which can be used when designing a packaging. Since this packaging is supposed to explore DuraPulp's possibilities, ideas which were similar to earlier packages, see Figure 6.6, will be avoided as far as possible.

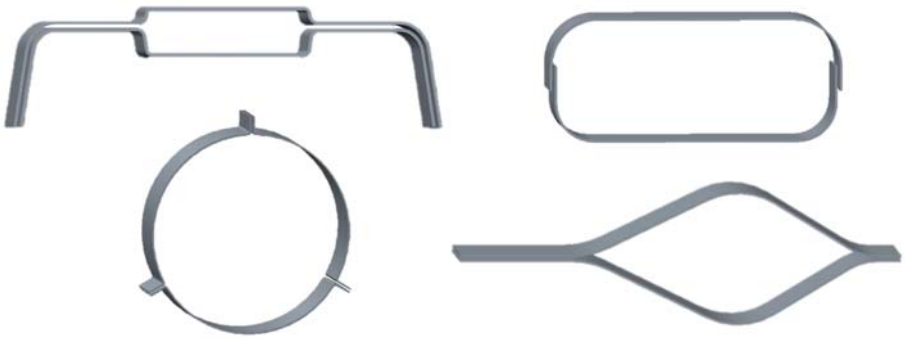


Figure 6.6 Cross cut from packages produced in DuraPulp.

All produced packages so far consists of two parts or more. There have been discussions about producing activated DuraPulp products containing inactivated parts in order to maintain soft and bendable areas. This have never been carried out and neither have foldings been tried. Focus was therefore set on a packaging consisting of only one part, which need to be folded in order to be closed, since techniques allowing this is not yet explored. Quiet brainstorming, build on the ideas of others and prototyping brainstorming was carried out with the How to questions; How to protect headphones and How to package headphones, see Figure 6.7 and Figure 6.8 for the outcome.

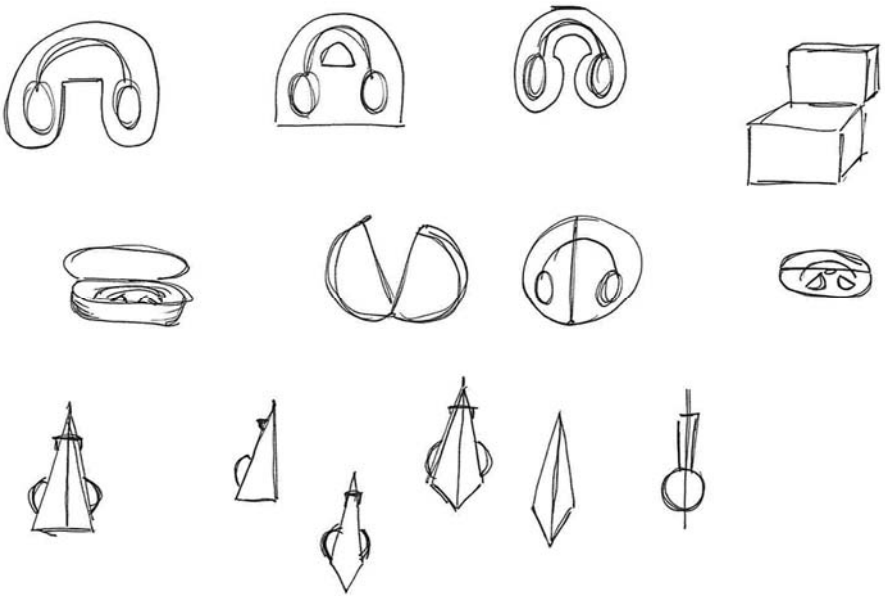


Figure 6.7 Ideas after Quiet brainstorming and build on the ideas of others, exploring how to do a packaging, exploring new techniques and DuraPulp's properties.

Figure 6.8 Outcome after prototyping brainstorming-thinking with your hands.

6.2.3 Open and close function

The open and close function have an essential role in the package when it is going to be used as a case. Brainstorming sessions took place, the How to questions; How to reuse packaging, How to open packaging and How to close packaging. Many ideas were generated, see Figure 6.9 for the outcome.

Figure 6.9 Open and close functions, outcome after brainstorming. Starting from first row, left to right 1. Overlap, 2. Egg box, 3. Snap fasteners, 4. Purse closing, 5. Groove, 6. Magnet, 7. U-cut and 8. Glue fold and tear.

6.3 Selection

The packaging is not only supposed to protect the headphone and serve as a case when the headphone is sold, it is also supposed to highlight DuraPulp's unique properties. There is a lot to take into account when selecting the concept. In order to not forget or miss any important needs or functions the function analysis is used as a check list. To ensure sure that main function and needed needs are fulfilled and preferable as many of the desired ones as possible.

6.3.1 Selection of positioning and shape of packaging

After matching the ideas with the functional analysis a packaging, consisting of one part, with a folding for an easy bending from 180º to 0º, when closing was chosen. The packaging will be produced in an open, flat position, with 180º between the two sides, see Figure 6.10. This will decrease the volume of the packaging when closed, facilitate the access of the tools and strain the folding as little as possible. The packaging will be done as thin as possible, like a skin not adding more volume than necessary, see Figure 6.11.

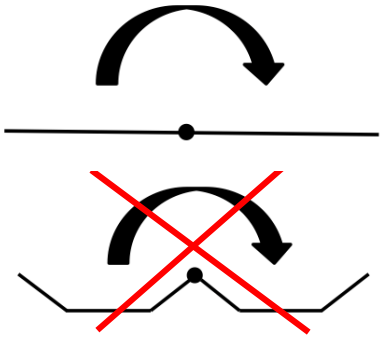


Figure 6.10 The selected packaging concept, allowing a flat thin packaging adding as little volume as possible.

Figure 6.11 The packaging from the side, only covering the headphone, adding as little volume as possible.

In order to take advantage of DuraPulp's great formability and be able to display the shape of the headphone as much as possible on the packaging, it was chosen to pack them in an open position, see Figure 6.3.

The on-ear part of the headphone can turn 45º, turning both in will give the packaging a natural front and the packaging will be a few millimetre thinner then with unturned headphones. If you turn one in and one out the two sides will be identically. Not turning the headphones, letting them be perpendicular to the surface of the packaging, will result in a bit thicker packaging but the outer shape of the packaging can be done smaller then with turned on-ear parts. Leaving the on-ear part in starting position also imply the sides to be mirror images.

In order to expose the shape of the headphone as much as possible and to be able to highlight DuraPulp's formability it was decided to keep the on-ear part in a starting position. This will also allow more rounded corners then with turned on-ear parts. Designing the packaging with the on-ear part in starting position also allows the packaging concept to be applied on other Urbanear headphones, which on-ear parts cannot be turned.

6.3.2 Selection of open and close function

In order to select the open and close concept a concept-Screening was done [5], see Table 4. The eight different options was evaluated, number five, with the highest score was chosen to be further developed in combination with number one and eight.

Table 4 Concept-Screening with generated opening and closing concepts.

	Open and close concepts							
Selection Criteria	1. Overlap	2. Egg box	3. Snap fastener	4. Purse closing	5. Groove	6. Magnet	7. U-cut	8. Glue, fold and tear
Only use DuraPulp	+	0	-	+	+	-	+	+
Able to produce with wet molding and heat pressing	+	-	-	+	+	-	+	0
Re open and closable	+	+	+	+	+	+	0	-
Easy opening and closing	0	0	+	+	+	+	0	-
Long lasting	+	0	+	-	+	+	-	-
When closed no gap between parts	+	0	+	0	+	+	0	-
New on DuraPulp	-	+	+	+	+	+	+	+
Score	+4	+1	+3	+4	+7	+3	+3	-2
Rank	2	4	3	2	1	3	3	5
Continue	Combine				Yes			Combine

6.4 Ideation and concept discussion

For rewarding brainstorming sessions it is recommended to be a group of five to six persons, therefore people have been invited to take part in these. Most of the times the groups were smaller since it was hard to find enough with volunteers to the numerous brainstorming sessions. The people taking part have not had as varied background as desired, which does not open up as much as possible for new innovative ideas. I generated the How to questions, which should have been done by more people to be optimal and because of limited time only a few brainstorming techniques was used when brainstorming.

In this project is it chosen to only work with DuraPulp in the packaging otherwise it could be possible to exchange parts in the packaging to plastic, in order to visible the headphone. To inform the customers about the look a picture can instead be placed on the packaging, which is also common on today's packages.

No exact matching with function analysis have been done but it have always been a base when deciding between ideas, in combination with gain knowledge and the gut feeling.

With the chosen position of the headphones, in "starting position" the two sides are identical except for the opening and closing mechanism. If the front and back side are identical one tool could be produced with half of the size doing one side at the time and the two sides will be attached external. This could decrease the tool cost maybe to half of the price but the essential and important folding which have not been tried on DuraPulp before will not be explored, therefore it was decided to continue with the packaging as one part, since it is going to be a demonstrator. Otherwise one tool is preferable since it keeps the productions time down only producing one part per packaging.

The chosen shape, see Figure 6.11, will be done as thin as possible to add as little volume as possible. This results in a packaging without base, it will not be able to stand by itself but probably on a shelf if they have support from a wall behind. This is not optimal for a packaging. It have been compromised on this before, on other packages on the market and in this case it was more important to facilitate the access for the tools and strain the bending as little as possible then focus on enable standing.

7 Prototype and concept development

In this chapter different critical functions will be identified and developed. Prototypes will be created and 3D-models will be presented.

7.1 Method

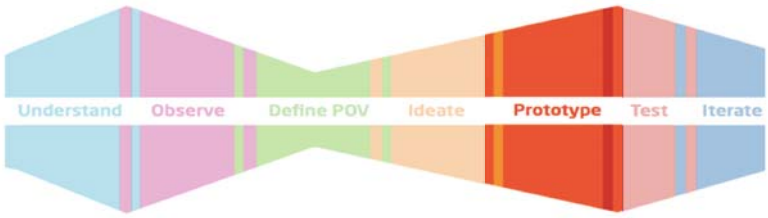


Figure 7.1 Prototype, the fifth step in the *Design Thinking* process.

Thinking via doing for a common understanding. Do a tangible prototype and bring the idea to life, through:

- Think with your hands
- Specify details
- Identify critical functions
- Do 3D-models

Questions to answer:

- Which function is vital to the idea?
- Which is the main underlying assumption about the user?
- Which needs are being addressing and how?

7.2 Prototyping

Prototyping is done in order to be able to mediate the idea. There are many different ways to do prototypes and many different techniques to use. First quick and dirty mock-ups was build, see Figure 7.2, for a tangible prototype then 3D-models with the program Creo Parametric 2.0

Figure 7.2 Quick and dirty mock-up bringing the idea to life.

7.2.1 Feedback on mock-up

In order to make sure that the right needs are being addressed and to be able to meet the needs of the target group as good as possible, when 3D-modelling the concept and specifying critical functions, the paper mock-up was showed during an exhibition at IKDC, Lunds University.

The people testing matched the target group very well, meaning that all feedback is meaningful. Focus was on gathering information about interactions and behaviors when people interacted with the prototype. Observations and interviews was carried out and the visitors could also write feedback on post-it and put them on the wall under the areas; What worked? What can be improved? New ideas and Problems today? See Figure 7.3

Figure 7.3 Testing and feedback on cardboard prototype, at IKDC, Lunds University.

Main gained insights from testing, to take into account when specifying critical functions and designing the concept:

- Take away corners and as much extra material as possible
- It need to be light
- The cable is a big problem

7.2.2 Identify critical functions

Which functions are vital to the idea?

There are several critical functions and they are therefore divided into smaller sub problems:

- Folding
- Open close function
- Cable storage
- Display and safety in stores
- Brochure storage

7.2.2.1 Folding technics

When working with foldings or joints in plastic, the elastic polypropeen is used. The plastic detail is designed to be thinner where it is going to be bend, see Figure 7.4. The thickness is usually decreased from both sides, which can be done in many different ways, see Figure 7.5. This allows both sides to end up close to each other when closed. These products are usually injection moulded, a manufacturing method allowing this appearance [24].

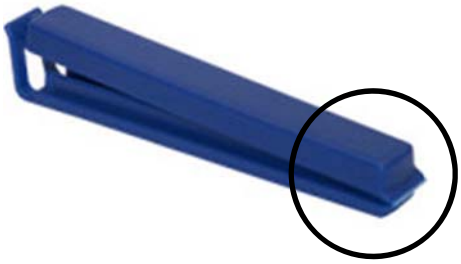


Figure 7.4 Plastic detail made in polypropeen with decreased thickness for an easy bending.

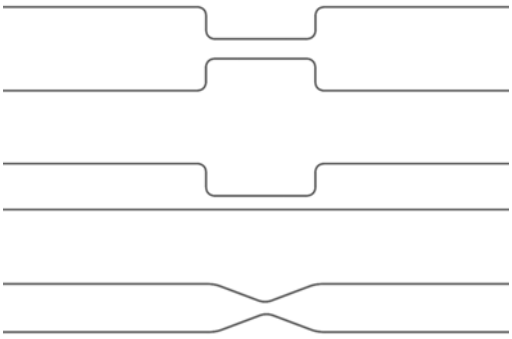


Figure 7.5 Possible rarefactions allowing in plastic details, allowing the detail to be bend over and over.

Foldings used in plastic, like in Figure 7.5 could be interesting to try on DuraPulp in order to make the two parts closing up close to each other but making the material thinner also increases the fragility. In paper, working with paper sheets an even thickness is wanted, therefore a notch is created which allows and even thickness, see Figure 7.6 and Figure 7.7.

Figure 7.6 Foldings in a paper container for an easy bending.

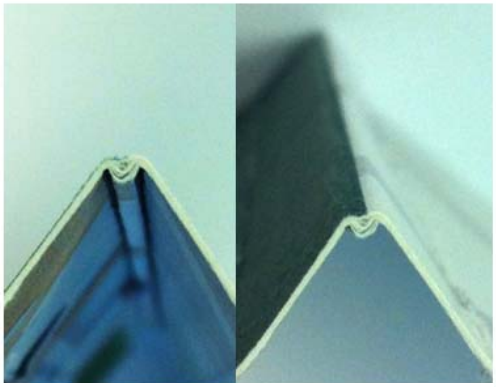


Figure 7.7 Foldings in a paper brochure for an easy bending.

Working with wet moulded products both technics occur, either it is the same thickness or it is decreased for an easier bending. In egg boxes and take away boxes, see Figure 7.8 and Figure 7.9, a thinner area is created for an easy folding. None of these boxes need to withstand pressure or tension and are not supposed to last long.

Figure 7.8 Folding in egg box.

Figure 7.9 Folding in take away box for burgers.

When bending in carton a common way to make a nice bending is to make a shallow cut in the paper. This was tested in DuraPulp but the outcome was not appreciated see Figure 7.10. The shiny and tacitly nice layer, which had to be cut, opened up more than preferred and it was easy to peel it off.

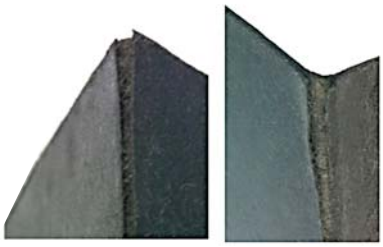


Figure 7.10 DuraPulp after cutting and bending, the shiny tacitly nice layer started to peel off and exposed more sensitive fibers underneath.

One possibility could be to design the tool with a wider part over the folding, to decrease the pressure over this area, in order to activate it less. Then DuraPulp's soft and bendable properties as inactivated will be maintained.

The main function is being a packaging, when being used as a case it shall protect the headphones and extend the feeling of "new and fresh". Therefore the folding need to be able to be bent multiple times without breaking.

After discussion with Urban Blomster [20] at Södra and Katarina Elner-Haglund [24], at LTH it was chosen to continue with the folding technique using an even thickness, see Figure 7.11. This was seen as the most reliable one, it is well proven on paper and cardboard, the packaging will not be thinner, adding fragile segments and no fibres will be cut.

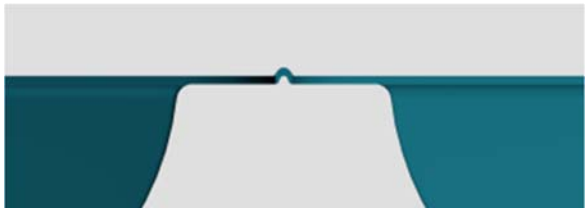


Figure 7.11 An even thickness, the chosen folding technique for the packaging.

7.2.2.2 Open and close functions

Opening and closing concept number five, the groove was chosen to be further develop in combination with one and nine. Different combinations was carried out and 3D-modelled. After discussions with Teodor Johnsson at Trifilon [10], Södra's toolmaker the opening and closing concept to be seen in Figure 7.12 was chosen. This kind of mechanism have not been produced in DuraPulp before but is considered to be manufacturable and an appropriate challenge to try in DuraPulp. It consists of two U-profiles with the depth 6 mm, one on the front side and one on the backside, in order to close the packaging these two will be pressed into each other for closing. For opening they will simply be pulled apart.

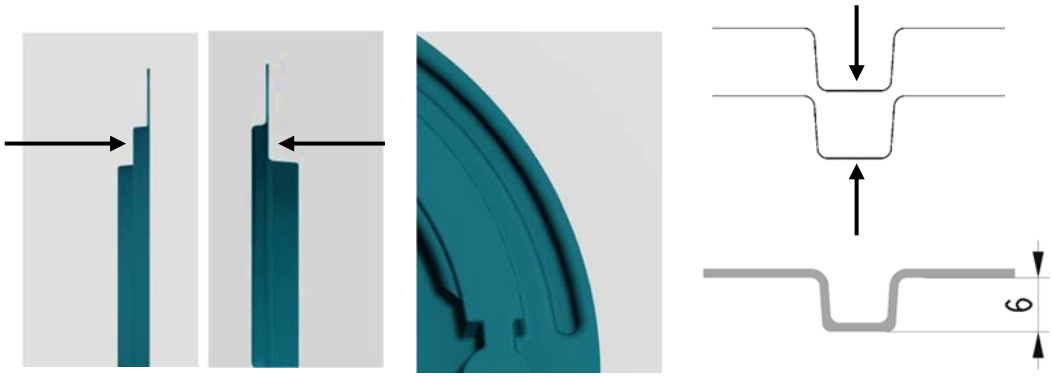


Figure 7.12 The two U-profiles, allowing re-closing of the packaging, measurements in mm.

7.2.2.3 Cable storage

The packaging need to store a cable. The headphone can either be packaged with the cable attach to the headphone or detached. With a detached cable it could easier be stored in between the headphones, but it also leads to when putting the headphone in the case the cable need to be detached. This it is not preferable since it adds one step before the case can be closed. One advantage with this is that the cable will not be bend and worn where it connects to the headphone, which is a sensitive point, in the same extension, see Figure 7.13.

It is chosen to package the headphones with the cable detached since there is a possibility to do the packaging smaller, the cable is standing out 30 mm before it can be bend, see Figure 7.13.

A prototyping brainstorming, was done in order to understand how much space the cable need and how to store it as easy as possible. In order to promote the material DuraPulp's logo should be included in the packaging. Therefore was it chosen to shape the cable storage like the DuraPulp logo. Then the cavity will then be able to store the cable and promote the material. Three prototypes came out from the brainstorming, see Figure 7.14. The first one with just one cavity, the second one with an attachment for

Figure 7.13 The cable attached to the headphone and detached.

the cable in the centre in order to keep the ends stuck and fold the rest of the cable around it. The third one have an elevation in the middle of the cavity, which the cable can be twisted around.

Figure 7.14 Outcome after prototyping brainstorming about how to store the detached cable in the package. From left to right; prototype with only one cavity, prototype with attachment for cable and prototype with an elevation in the middle.

Test where done and it was shown that the one with only a cavity was easiest to use. The cavity can preferable be placed in the centre of the packaging, preferable on the back side then the risk is smaller that it will fell out when opening specially when being used as a case. See Figure 7.15 for dimensions.

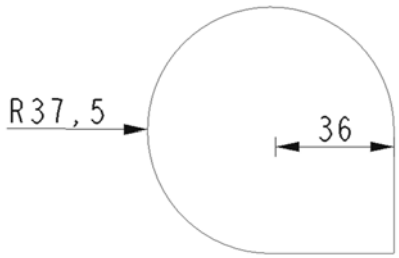


Figure 7.15 The dimensions on the cavity for cable storage, in mm

7.2.2.4 Display and safety in stores

To increase the safety in stores and in order to ensure a new product, it is important to use safety stickers. After the safety stickers have been removed, marks are left on the packaging indicating that this packaging have been opened, see Figure 7.16. The stickers are usually transparent with a circular shape but can be designed in many different ways. Many stickers increases the security but are also annoying when the customer wants to open the packaging. It is important to find a fine balance between the security and the time it takes to open it, a too long opening process can lead to frustration, when opening.

Figure 7.16 Safety stickers on one of Urbanears headphone packaging for Zinken.

The packaging need to be able to be displayed hanging in stores, there are standards for display hangers, which should be followed in order to fit all different kinds of hangers, see Figure 7.17.

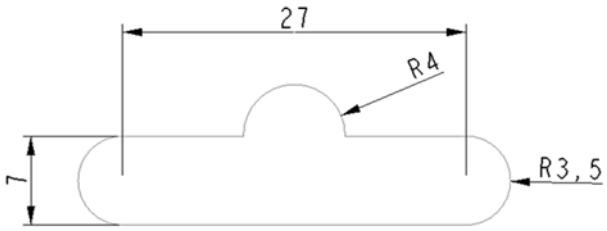


Figure 7.8 Standard shape for display hangers, dimensions in mm.

Since the packaging shall be a case too and then not look like a packaging, the display hanger need to be removed when opening the packaging, transforming the packaging into a case. In order to explore the material further and try new techniques it was decided to use the opening and close technique number 8. Glue fold and tear, when designing the display hanger. The hanger will be placed at the top of the packaging, one on the frontside and one on the backside, which will end up on top of each other when the packaging is closed. To secure safety in stores these will be glued together, instead of using safety stickers. Where the hanger is connected to the case a fold and tear technique will be designed, see Figure 7.18 which will be folded and stripped away when opening the packaging and transforming it into a case.

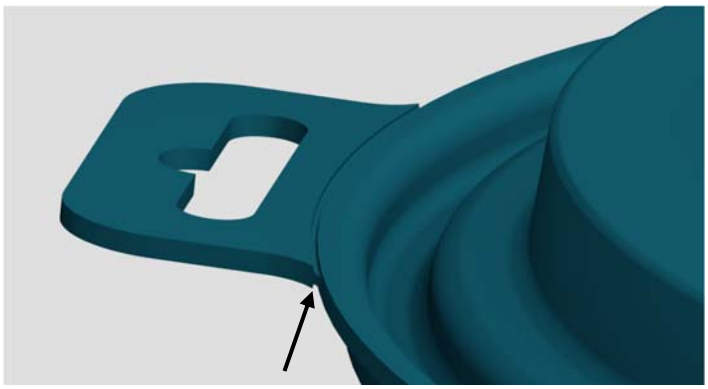


Figure 7.18 A fold and tear indication between display hanger and case.

7.2.2.5 Brochure

The packaging do also need to store a brochure, this will be done in the frontside since the cable is stored in the backside. For un uniform look and in order to promote the material further, will this cavity also be designed with the same shape as the logo. To clarify that it is the front side and to mediate that it is made from DuraPulp the text of the logo will be engraved, see Figure 7.19. This cavity will not be done as deep as the one on the back side in order to be able to grab the brochure easy and to give the packaging a neat appearance.

Figure 7.19 Cavity with logo on the front side, where the brochure can be stored.

7.2.3 3D-modeling the concept

With specified critical functions and a tangible paper mock-up the general concept could be build see Figure 7.20, this was done with the 3D-modelling program Creo Parametrics 2.0.

The headphone was measured with a slide caliper part by part and then 3D-modeled. After modelling the packaging in 3D with measurements from the headphone the draft angel 5º where added. A draft angle is needed in order, to facilitate the manufacturing process. The draft angle also facilitates an easy sliding of the headphone into the packaging.

All corners on the packaging have been rounded, with the radius 1, 2 or 3 mm depending on the position, for an easier manufacturing process but also for a better match with the corner on the headphone.

For sufficient stability without being too heavy the thickness on the packaging was set to 1 mm. Therefore the 3D-model will be given the thickness 1mm, which will be the final thickness on the DuraPulp packaging, after wet moulding and heat pressing.

The 3D-model is modelled as the final packaging will look like, see Figure 7.20 in reality there will be a margin around the packaging after manufacturing and these need to be post processed with knife or laser before it achieves its final apparance.

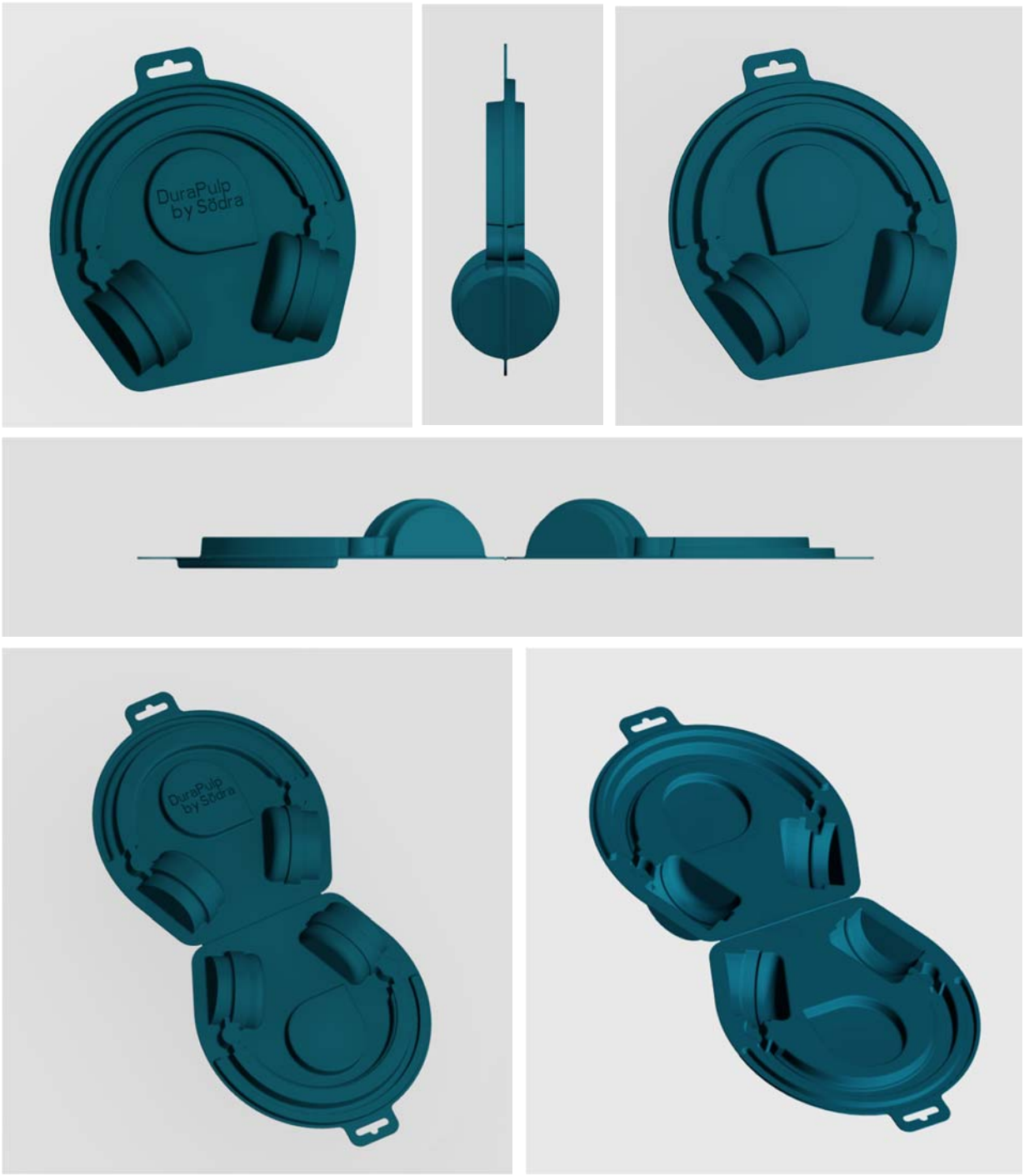


Figure 7.20 The selected concept 3D-modelled.

7.2.4 3D-printing the concept

The prototype will be printed in nylon which is strong and durable and can be done very thin. It is printed in order to have a tangible and detailed prototype when testing.

The 3D-printer can print objects with the maximum length 200 mm and width 187 mm. Therefore the packaging had to be split in two parts. The U-profile for opening and closing as well as the hanger had to be removed, in order to make the prototype fit the 3D-printer, see Figure 7.21 and see Figure 7.22 for the printed 3D-model.

Figure 7.21 The Outside, front-and backside, of the 3D-model to be printed.

Figure 7.22 The outside, front-and backside, of the 3D-printed model.

7.3 Prototype- concept development discussion

The prototyping and concept development have been presented as a linear process but in the reality is it was an iterative process. Separating the critical functions into smaller subtask was vital in order to do progress, in the same time as they had to be done parallel for an uniform look.

The chosen designed communicates the shape well but it is not optimal regarding communing written information about the product, there is very limited space for written information, a compromise was done and focus was set on promoting the material.

Instead of the more common transparent safety sticker it was chosen to glue the two display hangers together and to construct a fold and tear mechanism in order to open the packaging. This results in that an opened packaged cannot be resealed, which is not optimal if you want to return the headphone but similar techniques occur on packages in stores today. Therefore is was considered to be an acceptable solution. When buying headphones in the stores you can try display items, which facilities the choice and decreases returned items. How deep the notch shall be and if it can be designed in the tool in order to partly cut the material when heat pressing or if or if it is more efficient to do it during finishing work need to be further investigated and experimented in DuraPulp.

It was essential that the shape of the display hanger was designed to fit all hangers since it cannot stand and is depending on being displayed on a wall or stand for an organized and clean presentation. This it is not optimal for a packaging but was compromised in order to do a thin packaging, which takes up as little space as possible and for an easy access of the tools.

Space for the cable and brochure are designed in the packaging but there will be no further investigation about how to attach these.

The packaging is now modeled as the final product shall be, when producing the packaging there need to be a margin around. This will be communicated to toolmaker and set by the toolmaker. The product will then be completed when the finishing work is done, the extra material is cut away, with laser or knife.

8 Test and iteration

In this chapter testing and iteration will occur, critical functions will be tested, in order to get feedback and to iterate.

8.1 Method

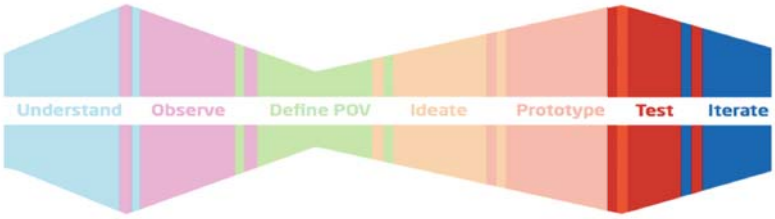


Figure 8.1 Test and iteration the last steps in the *Design Thinking* process, before a final concept.

Testing is done in order to gain input and feedback. For a meaningful test and in order to get the feedback right some decisions need to be made:

- What is going to be tested?
  - Function
  - Usability
  - Aspects
  - Principles
- How do you test?
  - Interactions
  - Behaviours
  - Attitudes
- Why is it relevant for you?
  - Empathy
  - Constraints
  - Feedback

8.2 Testing

Testing have partly occurred during the process. For progress and to make sure that the need are being addressed, a paper prototype was showed during an exhibition at IKDC, Lunds University at an early stage.

When testing the 3D-printed model, focus was set on function and usability. This is important in order to explore the models constraints for further iteration and later a final concept.

Early in the testing it was discovered that it is not possible to close the box. One part of the diadem on the headphone, see Figure 8.2, is broader than the packaging. Overall the packaging fits very well, see Figure 8.3 and Figure 8.4. Since the 3D-printed model had to be reduced to fit the printer and 3D-printed nylon have different properties than a wet moulded and heat pressed DuraPulp product, not all of the critical functions could be tested.

Figure 8.2 The 3D-model is done a bit too small over one part of the diadem, see the arrows in the figure to the right, and it is therefore not possible to close the packaging all the way.

Figure 8.3 The packaging is closing tight and nice over the on-ear part.

Figure 8.4 The headphone in the packaging, fitting well.

The cavity for the cable is not optimal it is a bit to small and the draft angles complicates the packaging, the cable is sometimes jumping up or standing out from the cavity, if it is not folded very carefully, see Figure 8.5. This complicates the closing of the packaging and is time demanding when being packaged. Since the cavity is as deep as the case for the headphones diadem and this need to be deeper, the cable storage will be done deeper too and hopefully allow an easier packaging.

Figure 8.5 The cable packaged in the cavity on the backside.

The critical functions; U-profile for opening and closing, the folding for an easy bending of the packaging and the fold and tear technique under the hanger, could not be tested on the 3D-model. First of all because they had to be removed to fit the 3D-printer but also because nylon have different properties then DuraPulp. The U-profile could maybe have been tested to some extent but not fully since the elasticity and the surface finish are different. The folding for an easy bending and the fold and tear technique for the hanger need to be tested in DuraPulp.

8.3 Test and iteration discussion

After 3D-printing the prototype it was showed that the packaging could not be closed, it is too small on the part covering the diadem. To be able to 3D-print the prototype was essential, errors in the packaging was detected and could be corrected before production.

The cable is not practical to store when the packaging is used as a case. When it is packaged at the factory it can be attached with glue or packaged in a small bag holding it together, for a nice presentation. This is a compromise which had to be done, the packaging should be a demonstrator for DuraPulp and highlight its properties first of all, which it do very well. The cable storage is therefore left as it is.

The most critical functions were not able to be tested since this could not be printed in the 3D-printer but even if they could have been printed it is not sure it would be helpful since 3D-printed nylon and DuraPulp have different properties. A ruff idea about how

the U-profile for the opening and closing function, fit to each other could have been gained. The most discussed function, the folding, allowing the packaging to bend and close, would not be able to be tested even if 3D-printed. Printed nylon is much harder than DuraPulp and would not allow to be bend without cracking, neither could the fold and tear technique be tested. This need to be tested in DuraPulp.

The packaging is designed to explore DuraPulp and challenge it, some techniques have not been used when producing products in DuraPulp before. Therefore, it is recommended to test these functions first; the folding, the U-profile for opening and closing as well as the fold and tear technique next to the hanger, on a separate tool. Trying it on a separate tool allows a smaller and less expensive tool, different depth and dimensions can be tried in order to find the best solution and this can then be applied it on the headphone packaging. The process will take a bit longer but with less risks, it might be discovered that foldings are impossible to do in DuraPulp, then a lot of money will be saved or some fine tuning can be done to improve the design before producing the final product.

9 Final concept

In this chapter will the adjustments, the final prototype and the final concept be presented.

9.1 Refinements and final concept

Not all critical functions could be tested but some feedback was collected during testing, the packaging need to be done broader over the diadem, see Figure 9.1. A few other small adjustments were done to minimize scruff on headphones, before the 3D-model was printed a second time, see Figure 9.2 – 9.5.

Figure 9.1 Final concept to be 3D-printed.

Figure 9.2 Iterated and 3D-printed final concept.

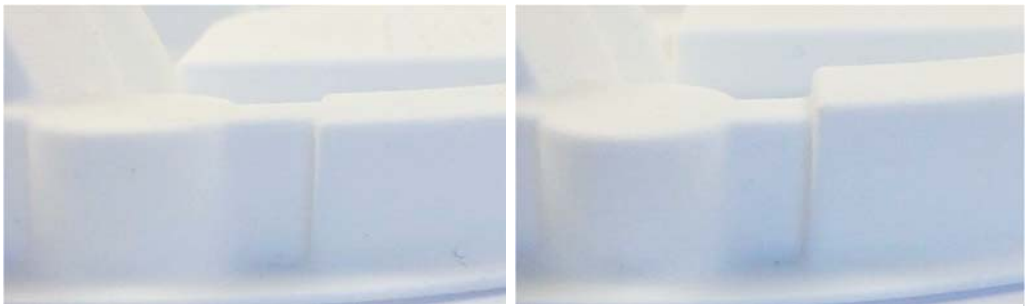


Figure 9.3 Before (left) and after (right) rectification.

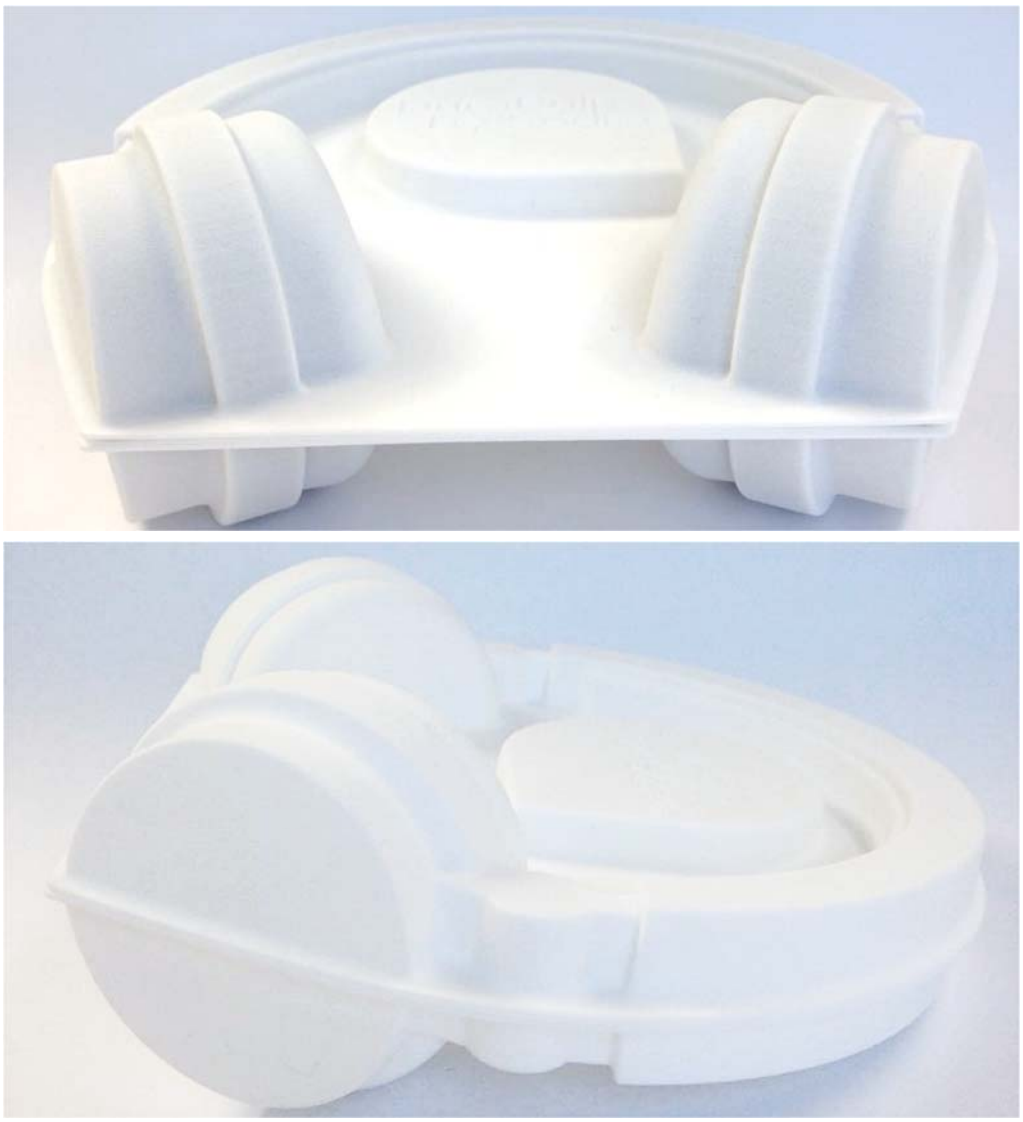


Figure 9.4 The headphone fits well and, the packaging is closing properly.

Figure 9.5 The final concept 3D-printed.

Figure 9.6 3D-printed and spray painted final concept,
for an as realistic prototype as possible.

The headphone fits very well and the packaging closes smooth. With a deeper cavity it is easier to package the cable but it is still not optimal.

9.2 Final concept and manufacturing

The designed packaging will be sent as a stl file or similar to Södras toolmaker, which will produce the tool. The tools will be milled out from aluminium blocks, four tools is needed, two for the cold press and two for the hot press. The packaging will be produced with the earlier presented manufacturing method wet moulding and heat pressing. The thickness is decided to be 1 mm, after discussions with Urban Blomster [20], for a light and stabile packaging.

Before a completed packaging the margins need to be removed and the hanger need to be cut. The choice of finishing work will be discussed with Södra. See Figure 9.6 and Figure 9.7, for the final concept.

Figure 9.7 The outside of the final concept in an open position

When closed the packaging have the length 235 mm with hanger and without hanger, as a case 209 mm, the width is 223mm. The maximum depth, over the on-ear part is 76 mm.

Figure 9.8 The final concept and open and closed with the headphone Zinken.

9.3 Final concept discussion

Some adjustments where done to make the headphone fit better and the cavity for the cable was done a bit deeper, but no other adjustments to facilitate the packaging of the cable. More tests and improvements could have been done on the cable and brochure storage and but it was decided not to because it is first of all a demonstrator for DuraPulp and because of time limitation.

10 Discussion

In this chapter the used method, the process and the final concept will be discussed as well as recommendations for further development.

10.1 Method and process

DuraPulp is a new material, it is not on the market and there is no defined marked segment today. This complicated the limitation for this project and it was hard to estimate the time required for different phases. In the beginning without a clear focus the market research was done too broad and the questions where numerous.

The chosen method *Design Thinking*, with six different phases dividing the project in six different steps, allowing iteration within phases but also between phases, suited very well for this project. The *Design Thinking* process is initially done for groups of five to six persons, therefore have volunteers been invited, in order to do ideations and brainstorming sessions. It was hard to find enough volunteers and their background was not as various as desired for optimal sessions. The initial project plan was almost followed, since it is an iterative process it is hard to keep the steps strictly apart and then also the amount of time spent on each step.

In the first phase *understand* a lot of time was spent in Södras workshop in Varberg, where they have been producing some of the first products in DuraPulp. During this time was it showed that the process window was not set, there was still many question to be answered regarding the manufacturing process and optimal settings, for example temperature, pressure and thickness of the product. What occurred on many produced parts was an unidentified marbled pattern. This specially complicated the understanding phase and the market research.

For a better understanding about DuraPulp, its properties and the matrix occurring during activation, pulp and then PLA was investigated separately. Wet moulding with pulp was investigated and compared with wet moulding and heat pressing with DuraPulp, in order to understand the differences converters might face, for a better understanding and guidelines, since wet moulding with pure pulp is a well-known and explored manufacturing process. A good knowledge about wet moulding with pure pulp also increased the comprehension in how material can be saved.

Literature studies was carried out and many interviews were held for a better understanding about how DuraPulp can be used. It was important to gain a solid understanding for the material, special regarding possibilities and limitations, in order to find a suitable market segment and target group. It was hard to know where to find

this information, who to interview and which questions to ask, many times important information was gain by coincidences and later in the process than optimally. This complicated the observing phase and led to that more time was spent there than planned.

During *observation* market research was done, the first one was done very broad. It would have been good to narrow it down and to focus on a smaller segment in order to be able to immerse it. It was showed that it was complicated to find companies, which have interest and whom produces products, which can be suitable for DuraPulp. Many of the contacted companies showed interest for a new renewable and biodegradable material but could not find any use of it in their own companies or had not enough time to take it further. Therefore it was decided not to focus on finding a company to cooperate with. This phase was very hard and time demanding a narrower focus should have been set and less time should have been spent on trying to find a company with interesting products to cooperate with.

The chosen market segment was on-ear headphones and the chosen product is the headphone Zinken, from Urbanears. The shape of the headphone was very suitable for the project and also the matter that the whole headphone is given the same colour. This goes very well with DuraPulp's ability to be coloured though out. For a thinner packaging and to facilitate the placement of a picture on the final concept it could have been better to have chosen an on ear headphone which can be turned 90º and not only 45º. The packaging would have been thinner and a photo of the headphone could have been placed on the turned on-ear part. On the other hand keeping them in the "starting position" facilitates the concept to be applied on their other headphones, which on-ear part cannot be turned.

Point of View was created after interviews with Urbanear and Urbanears users. It is hard to determine if it was the optimal procedure, but it is important to have one in order to give the ideation and prototyping a focus. This had to be done more rapid then planed since I was behind schedule.

Ideation and *prototyping* was more or less executed parallel even though they are presented as one step following the other. It was not possible to keep the processes apart since the different subtasks were depending on each other and for an uniform design they could not be done one by one but had to be performed parallel.

Feedback have been collected during the process in order to proceed and eliminate as many problems as possible as early as possible in the process and for an intuitive packaging, which appeals the target group.

When *testing and iteration* the ability to 3D-print the model was facilitating and crucial, in order to obtain rewarding feedback. It appeared that the packaging was done to narrow over the diadem of the headphone and could therefore not be closed properly. This would not have been detected without a 3D-printed prototype. The failure was corrected and a new 3D-model was printed to secure a good fitting. Not all critical functions have been tested since some of them need to be tested in DuraPulp. Therefore it is recommended to do a smaller tool and try these functions before producing the tool for the headphone packaging in order to use workable and refined techniques on the

final concept. The final 3D-model, done with Creo paremetrics 2.0 was transformed to a suitable format and delivered to Södra's toolmaker.

10.2 The final concept and suggestions for further development

It was difficult to find a good balance between designing an optimal packaging, presenting the headphone and a being a demonstrator for DuraPulp, highlighting its properties. One goal with the project was to arouse interest along brand owners and converters for a cooperation, when designing and producing the product. This was more difficult than thought and in the end a market segment was chosen without having a company to cooperate with, the goal was instead set on gaining interest with the final product.

The final concept is challenging and exploring DuraPulp more than what's have been done before. In order to be able to approach the industry and specially the packaging industry all properties of a new material need to be known. Therefore the packaging have been designed whit techniques never used on DuraPulp before in order to explore new potentials with the material.

3D-printed models have been done, which affirm a good fitting for the headphone. Three main critical functions have still not been tested since these need to be produced and tested in DuraPulp for reliable results.

The cavity for the brochure have not been tested and the cavity for the cable is not optimal when using it as a case. These two functions will be left for further development, the packaging will be able to promote DuraPulp consummately anyway. The fitting between the primary packaging and the secondary packaging is not evaluated and left for further development.

The limitations of DuraPulp is partly unknown and there are still many techniques to try on DuraPulp. Therefore it could have been seen as favourable to only focus on designing a tool which tries these techniques, before applying them on products. Another possibility could be to design small demonstrator products, which tries these techniques out, but then without the goal to gain attention on the market or designing for a special product.

The main goal, to develop a packaging, highlighting and exploring DuraPulp's unique properties, when activated is achieved. This for a certain marked segment with the possibility to gain attention from brand owners and customers.

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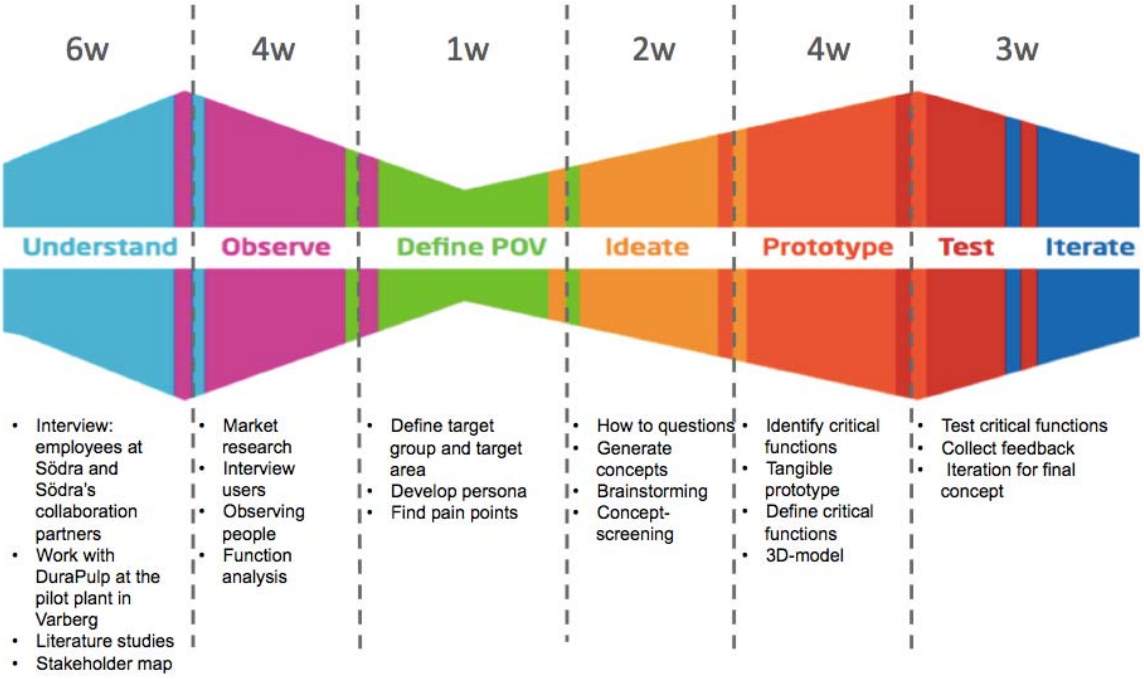
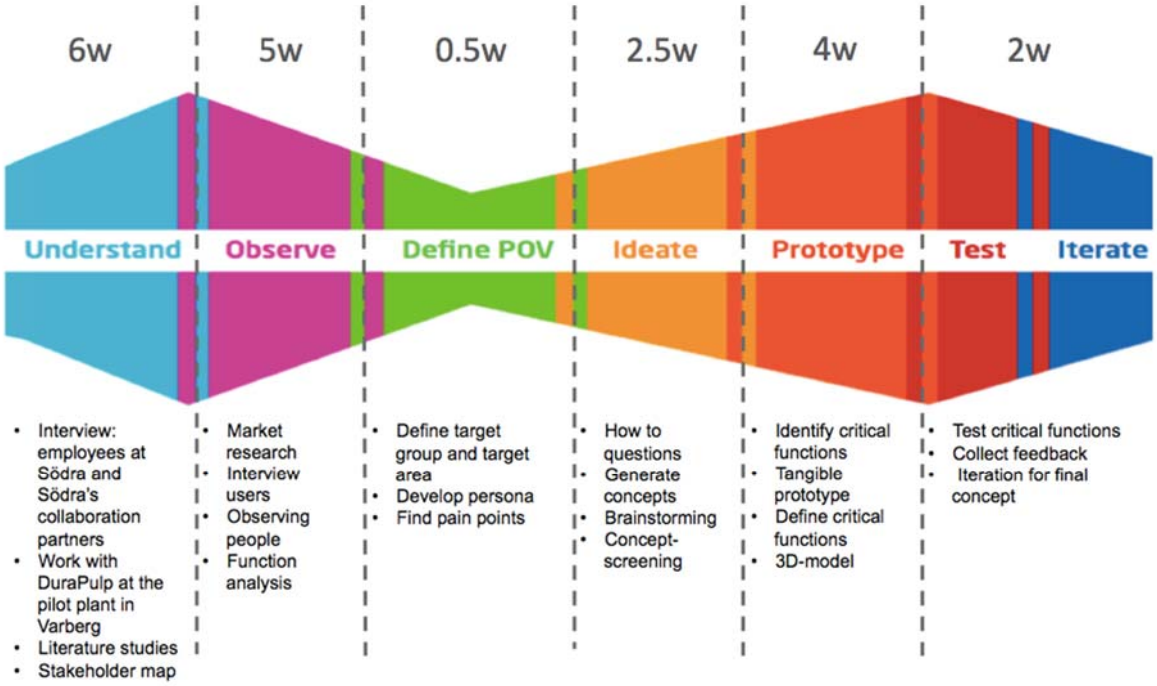
Appendix A: Project plan

A.1 Planed project plan



A.2 Actual outcome



Appendix B: Questionnaire

How do you use your headphones today?
When do you use your headphones?
Which kind of headphones do you have and why have you got this model?
Do you have any problems which your headphones?
What kind of problems do you have?
How do you pack or bring your headphones?
Have you any need for a protection or case?
Would you spend money buying a case for your headphone?
If you had one would you use it?
What do a case first of all need to protect your headphones from?