

# Packaging for gear hobs

---

Filip Björkman

DIVISION OF PRODUCT DEVELOPMENT | DEPARTMENT OF DESIGN SCIENCES  
FACULTY OF ENGINEERING LTH | LUND UNIVERSITY  
2019

MASTER THESIS

**VOLVO**  
VOLVO GROUP



# Packaging for gear hobs

Filip Björkman



**LUND**  
UNIVERSITY

# Packaging for gear hobs

Copyright © 2019 Filip Björkman

*Published by*

Department of Design Sciences  
Faculty of Engineering LTH, Lund University  
P.O. Box 118, SE-221 00 Lund, Sweden

Subject: Product Development (MMKM05)  
Division: Product Development  
Supervisor: Per-Erik Andersson  
Co-supervisor: Henrik Pålsson  
Examiner: Giorgos Nikoleris

# Abstract

In this thesis, a new packaging solution has been developed and designed for gear hobs to Volvo Group Truck Operation Powertrain's transmission plant in Köping. There was a need for a new packaging solution since the existing packaging have a number of problems and deficiencies and begins to be obsolete.

The product development began by familiarizing with the current packaging and how it was handled in the production. Thereafter, customer needs were determined through interviews and observations from operators in the factory who are in contact with the packaging. A number of new product concepts were generated for a new packaging solution and from this, the best concepts for further development were chosen. Three concepts were developed further and from this, one concept was chosen to proceed with and develop in detail for a final suggestion for a new packaging solution. A functional, simpler prototype was built in plywood and tested in production and feedback from this was used to further develop the final concept. A 30% scale model was 3D printed of the final concept of a new packaging solution.

The final concept of a new packaging solution solves most of the previous deficiencies and problems. Documentations are made for ordering, manufacturing and implementation of the new packaging solution in the production. The final concept consists of a lower part and a top cover and is developed in three different sizes for different lengths of gear hobs. Complete technical drawings were created for the three different sizes as well as manufacturing and assembly instructions.

**Keywords:** Packaging, Volvo Group, Gear hob, Product development, Prototyping

# Sammanfattning

I det här examensarbetet har en ny förpackningslösning utvecklats och konstruerats för snäckfräsar till Volvo Group Truck Operation Powertrains transmissionsfabrik i Köping. Det fanns ett behov av en ny förpackningslösning då den existerande förpackningen har flertalet problem och brister och börjar bli föråldrad.

Produktutvecklingen började med att bekanta sig med den nuvarande förpackningen och hur den hanteras i produktionen. Därefter så fastställdes kundbehov genom intervjuer och observationer ifrån personal i fabriken som är i kontakt med förpackningen. Ett antal nya produktkoncept genererades till en ny förpackningslösning och ifrån detta valdes de bästa koncepten för vidare utveckling. Tre koncept utvecklades vidare och ifrån detta valdes ett koncept för att gå vidare med och detaljutveckla till ett slutgiltigt förslag till en ny förpackningslösning. En funktionell, enklare prototyp byggdes i plywood och testades i produktion och feedback ifrån detta användes för att vidareutveckla ett slutkoncept. En modell i 30% skala 3D-printades av det slutgiltiga nya konceptet på en förpackningslösning.

Det slutgiltiga konceptet på en ny förpackningslösning löser flertalet av tidigare brister och problem och underlag är framtaget för att beställa, tillverka och implementera den nya förpackningslösningen i produktion. Slutkonceptet består av en underdel samt ett lock och finns utvecklad i tre olika storlekar för olika längder på snäckfräsar. Fullständiga tekniska ritningar skapades för de tre olika storlekarna samt tillverknings- och monteringsinstruktioner.

**Nyckelord:** Förpackning, Volvo Group, Snäckfräs, Produktutveckling, Prototypframtagning

# Acknowledgments

First of all, I would like to say a general thank you to everyone at Volvo in Köping who have been contributing to this thesis with insights and feedback throughout the project. Also, big thanks to the other thesis workers at Volvo in Köping for the discussions and feedback in our common office throughout the spring.

I would like to make a special thanks to the following people at Volvo in Köping and at Lund University:

**Vilhelm Söderberg (Supervisor, Volvo GTO PTP Köping).** Thank you for making me feel welcome at Volvo in Köping and with all the general help throughout the project.

**Mattias Åkerlund (Technical supervisor, Volvo GTO PTP Köping).** Thank you for the guidance and feedback of the designing throughout the project and all the company related feedback.

**Per-Erik Andersson (Supervisor, Product development, Lund University).** Thank you for supervising this project and for all the input, help and feedback throughout the whole project from the start-up of the thesis work to the end.

**Henrik Pålsson (Co-supervisor, Packaging logistics, Lund University).** Thank you for your expert input and feedback about packaging and during the concept development process.

Lund, June 2019

Filip Björkman

# Table of contents

1 Introduction	11
1.1 Company background - Volvo Group	11
1.2 Earlier work	13
1.3 Problem description	13
1.4 Aim	14
1.5 Objectives	15
1.6 Delimitations	15
2 Theory	16
2.1 Packaging	16
3 Methodology	17
3.1 Planning of the thesis work	17
3.2 Product development process	17
3.2.1 U&E's product development process	17
3.2.2 U&E – Phase 1: Concept Development	19
3.2.3 Modified product development process	20
3.2.4 Finite element method analysis	20
3.3 Volvo Group ergonomics standard	21
3.3.1 Small packaging	21
3.3.2 Handles	21
3.3.3 Labels	21
3.4 Data collection	22
3.4.1 Interviews and observations	22
3.4.2 Data analysis	24
4 Research	25
4.1 Gear hobs	25

4.1.1 Properties	26
4.2 Existing solution	28
4.2.1 Existing packaging	28
4.2.2 Space efficiency	30
4.2.3 Advantages and disadvantages	31
4.3 Factory site	35
4.3.1 The packaging's route in the factory	35
4.3.2 Transport and storage	37
4.3.3 Lifting devices	39
4.4 Manufacturing	40
4.4.1 Plastic manufacturing	40
4.4.2 Wood manufacturing	41
4.4.3 Metal manufacturing	41
4.4.4 Water jet cutting	41
4.4.5 3D printing	42
5 Concept development	43
5.1 Customer needs	43
5.1.1 List of customer needs	43
5.2 Target specification	46
5.2.1 Ideal and marginal accepted target specifications	46
5.3 Generate product concept	48
5.3.1 Clarifying the problem	48
5.3.2 External benchmarking	48
5.3.3 Internal product concept generating - Brainstorming	52
5.3.4 Product concept selection – Sub problems	52
5.3.5 Explore the solution space systematic	54
5.4 Product concept selection	58
5.4.1 What is a concept choice?	58
5.4.2 Concept selection	58
5.4.3 Further development	59



5.5 Testing product concept	60
5.5.1 Prototype 1 (Functional prototype)	60
5.5.2 Testing and evaluation	61
6 Detail development	62
6.1 Architecture of the product	62
6.2 Detail development of components	65
6.2.1 Main packaging	65
6.2.2 Top cover	68
6.3 Material selection	70
6.4 Assembly	72
7 Results	73
7.1 Gear hob packaging solution	73
7.1.1 Dimensions and weight	74
7.1.2 Renderings of the new packaging solution	75
7.1.3 Space efficiency	79
7.1.4 Disadvantages of existing packaging solved?	80
7.1.6 Target specification	81
7.2 Finite element method analysis	82
7.2.1 Packaging	82
7.2.2 Top cover	87
7.3 Prototype	90
7.3.1 Solid 3D printed model	90
7.3.2 3D printed components	92
8 Discussion and conclusion	94
8.1 Discussion	94
8.1.1 The product development process	94
8.1.2 Data collection	94
8.1.3 Product concept	95
8.1.4 Target specifications	95
8.1.5 New packaging solution	96

8.1.6 Future work	97
8.2 Conclusion	98
References	99
Appendix A Time plan	101
Appendix B Existing packaging	102
Appendix C Customer needs	104
Appendix D Brainstorming ideas	108
Appendix E Selection matrixes for ideas from brainstorming	117
Appendix F Detailed views of Concept A, Concept B & Concept C	123
Appendix G Technical drawings	135
Appendix H Assembly instructions	150
H.1 Packaging	151
H.2 Top cover	160

# 1 Introduction

*This section gives an introduction to the project. A company background about Volvo Group is presented first to get an overview of the company. Then the problem is described both in a practical and theoretical way. The aim and objectives are then presented for the project and finally the delimitations of the project are described.*

## 1.1 Company background - Volvo Group

Volvo Group is a Swedish company and one of the leading manufacturers of buses, construction equipment, marine and industrial engines and trucks in the world [1]. Volvo Group's vision is "To be the most desired and successful transport solution provider in the world" [2].

Volvo was founded in 1927 by Assar Gabrielsson and Gustaf Larson and the first personal car was produced the same year. The next year the first truck was produced. Volvo has been a pioneer within safety for a long time, for example with early implementation of the 3-point safety belt. In 1999 Volvo Cars was sold to Ford Motor Company and Volvo Group was created with focus on the commercial automotive industry [3].

Volvo Group is nowadays divided into ten different business areas: Volvo Trucks, UD Trucks, Renault Trucks, Mack Trucks, Group Trucks Asia & JV:s, Volvo Construction Equipment, Volvo Buses, Volvo Penta, Arqus and Volvo Financial Services. Volvo Trucks is in its turn divided into three truck divisions: Volvo Group Trucks Technology (GTT), Volvo Group Trucks Operations (GTO) and Volvo Group Trucks Purchasing (GTP) [4], see figure 1.1. This thesis is done at Volvo GTO Powertrain Production (PTP) in Köping and Volvo GTO PTP Köping is subordinate to Volvo GTO.

The site in Köping is mainly producing transmissions and components to transmissions for the whole Volvo Group. All gears to the gearboxes are manufactured and assembled at the production site in Köping, as well as the drives for marine application for Volvo Penta.

# Our organization

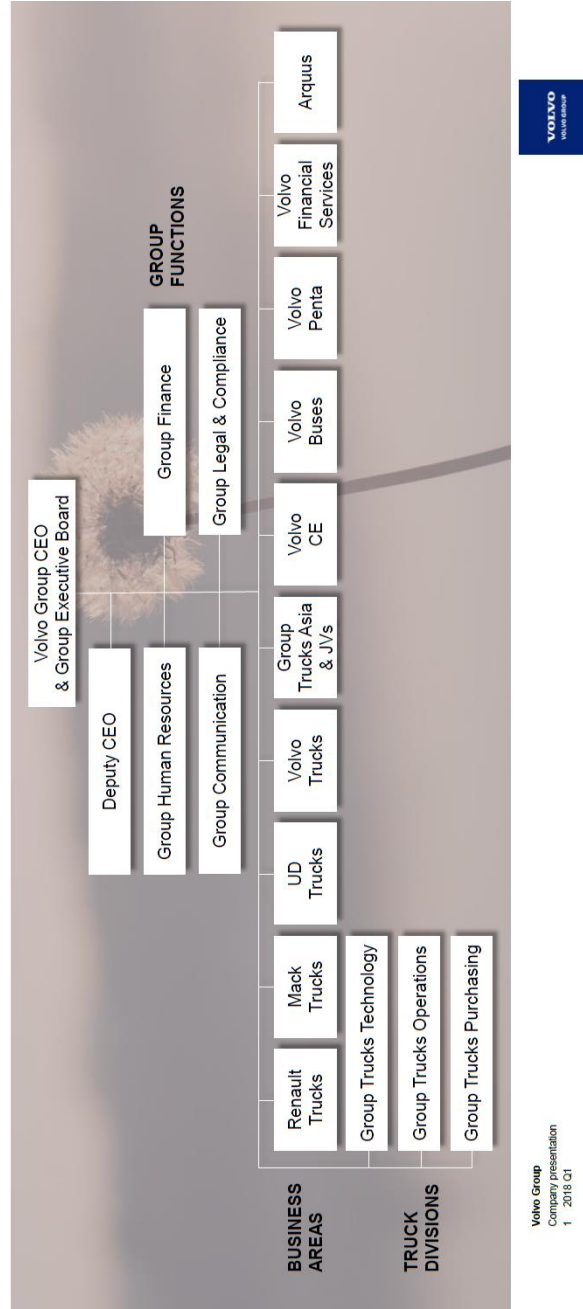


Figure: 1.1 Volvo Group – Our organization.

## 1.2 Earlier work

During the summer 2018, a summer technologist from Mälardalens Högskola, started to work on finding a new packaging solution for gear hobs at Volvo. He worked during six weeks and was able to produce some scaled 3D printed prototypes of three new different solutions. This thesis will continue his work. However, this thesis must not select to continue on working from his prototypes. Rather, it is an advantage to come up with new concepts, to be able to explore more of the space of solutions for the task. He did research of the existing solution and how it is used in the factory today. To avoid inventing the wheel twice, some parts of this thesis are based on work from his report and these parts are mentioned in the report.

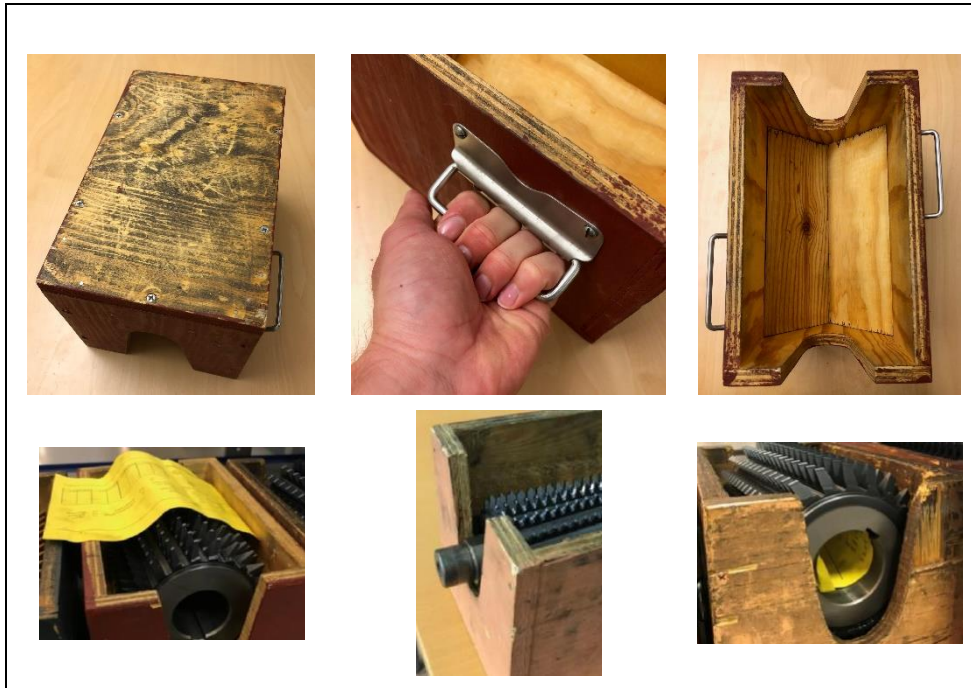
## 1.3 Problem description

At Volvo GTO PTP in Köping, gear hobs, special cutting tools for gears, are transported around in the production at the factory site. The gear hobs are transported between storage, production and sharpening. This transportation is made in a wooden box, which is designed especially for this task. The design of this box is old and different problems have occurred around this packaging in the production on different places over time. See figure 1.2 for an overview of the existing packaging.



**Figure 1.2: Existing solution for packaging for gear hobs.**

Problems with the existing packaging are that the packaging is dirty and hard to clean, there are operational problems around in the production, the packaging has bad ergonomics, lifting devices does not fit with the packaging, there is no placement for the sharpening card, there is different protecting material and no optimized protecting material, some gear hobs protrude in height and/or length and wooden chips are ripped from the packaging. See figure 1.3 for images of the problems with the existing packaging.



**Figure 1.3: Problems with existing packaging.**

There is a need for a new and more modern packaging solution for the gear hobs, which solves as many of the existing problems as possible.

The problem is to develop a packaging solution, which suits as many users as possible who come in contact with the packaging. Each user has its own needs for the packaging and different needs from different users are conflicting. This means that the developed packaging solution needs to satisfy as many needs as possible and try to find a golden way in between. The packaging must also fulfill the primary functions which a packaging should have and these functions are containment, protection, apportionment, unitization, convenience and communication.

## 1.4 Aim

The aim of this thesis is to develop a new packaging solution for gear hobs at Volvo's factory site in Köping. A prototype should be developed, produced and tested in the production to verify its functionality and that it fulfills the customer needs.

## 1.5 Objectives

The objectives of this project to be able to achieve the aim are the following.

- **Concept generating.** To be able to achieve a good final result, it starts with a good base to develop from. A number of different concepts need to be developed, to be able to explore as many solutions as possible.
- **Concept evaluation and selection.** The next important step to take is to evaluate the concepts and select promising concepts and choose the right direction for further development.
- **Design.** The chosen concept(s) should be developed and designed to be able to fulfill the criteria's for the task.
- **Materials selection.** A materials selection process needs to take place to find the optimal material for the product in regards to manufacturing and production.
- **Testing.** The new solution needs to be tested in production to verify its' functionality and to see if it satisfies all customer needs.

## 1.6 Delimitations

The project is a Master Thesis and should be done during 20 weeks of full-time work. The project was given by Volvo GTO PTP in Köping and the task is to develop a new packaging solution. The logistics around the packaging is not supposed to be looked on, if the development of the packaging does not require that. The existing storage solutions around in the production should not either be developed, but the new packaging must fit with the existing storage solutions. It is important to take any future investments in new storage solutions into account.

The goal of the project is to develop a prototype of a new packaging solution and test the prototype in production. This project should be a basis for future investments of a new packaging solution, which means initially that this project is not supposed to push through the implementations of the new packaging solution, but prepare an investment base for a new working packaging solution.

## 2 Theory

*This section describes the theoretical framework used in this thesis regarding the design of the packaging. It describes the functions of a packaging and what needs it should satisfy.*

### 2.1 Packaging

Robertson [5] describes the importance of packaging well: “*without packaging, materials handling would be a messy, inefficient and costly exercise*”. He further on defines the primary functions of a packaging as containment, protection, apportionment, unitization, convenience and communication. How obviously it might seem, one of the most basic function of a packaging is to contain the product and make sure that the function of the product in the packaging maintains. Often, the most important function of a packaging is to protect its content from damages from the outside, but the packaging should also protect the surroundings from the content of the packaging. The importance of apportionment from a packaging varies, depending on its content and could sometimes be essential for the packaging or not. If the packaging should be transported in a standardized transport system, it is important that the packaging is unitization. With an ever evolving society, the convenience of the packaging is an important aspect to take in consideration, to be a successful packaging. Finally, the packaging must communicate with the environment. It could be that it should communicate its content, instructions or similar.

Similar to Robertson, Bowersox [6] points out the following areas connected to packaging to influence efficient materials handling:

- **Communication.** Efficient communication with good content information and handling instructions enhances efficient material handling.
- **Package design.** The design of packaging is an important factor for efficient material handling and working for eliminating air and reducing weight are beneficial.
- **Unitization.** It is important for increasing handling and transport efficiency.



# 3 Methodology

*This section describes the methodologies used during the project, mainly in the product development process. It also describes methods used by Volvo, which will be implemented in the work process, as well as the methodology for the data collection during the process.*

## 3.1 Planning of the thesis work

The master thesis should be worked on during 20 weeks, from February until June. The predicted time plan is shown in a Gantt chart in appendix A, as well as the finished time schedule. The time plan is updated throughout the working process.

## 3.2 Product development process

The product development process used in this project is based on the method described by Ulrich and Eppinger (U&E) [7]. The product development process is based on this method, since it is one of the most used product development methods, it applies well on this task and helps creating a good structure throughout the report. Since some of the phases will be very small in this project or be delimited, a modified method of U&E's process will be used. U&E's product development process are presented in ch. 3.2.1 & 3.2.2 and in ch. 3.2.3 the modified product development process used in this project is presented.

### 3.2.1 U&E's product development process

U&E divide the product development process into six different phases [7]:

### Phase 0 – Planning

This phase is called “phase zero” because it needs to be done before the product development project has started and is seen as a phase before the project. The planning phase starts with identifying the opportunities and then resources should be allocated and a time frame needs to be set. The outcome of the planning phase is a project mission statement.

### Phase 1 – Concept development

The “Concept development” phase is often in many project the major part of the process. The first step in this phase is to identify customer needs and then translate these into target specifications. From the target specifications as many product concepts as possible is generated and evaluated. The product concepts need to be tested and then final target specification should be set.

### Phase 2 – Development on system-level

The phase when the product should be developed on system-level is mainly focused on develop the product’s architecture. Depending on the product’s complexity, the size of this phase varies. Subsystems and components of the product should be developed. In this phase plans for production system and assembly should start to be developed and the output from this phase could be a geometric layout of the product.

### Phase 3 – Detail developments

The complete specifications of the developed product should be settled in this phase. The geometry, materials and tolerances should be decided and evaluated. If the product shall be produced in-house a process plan for production should be established. The output from this phase should be technical drawings, renderings or similar of each part of the product.

### Phase 4 – Testing and further development

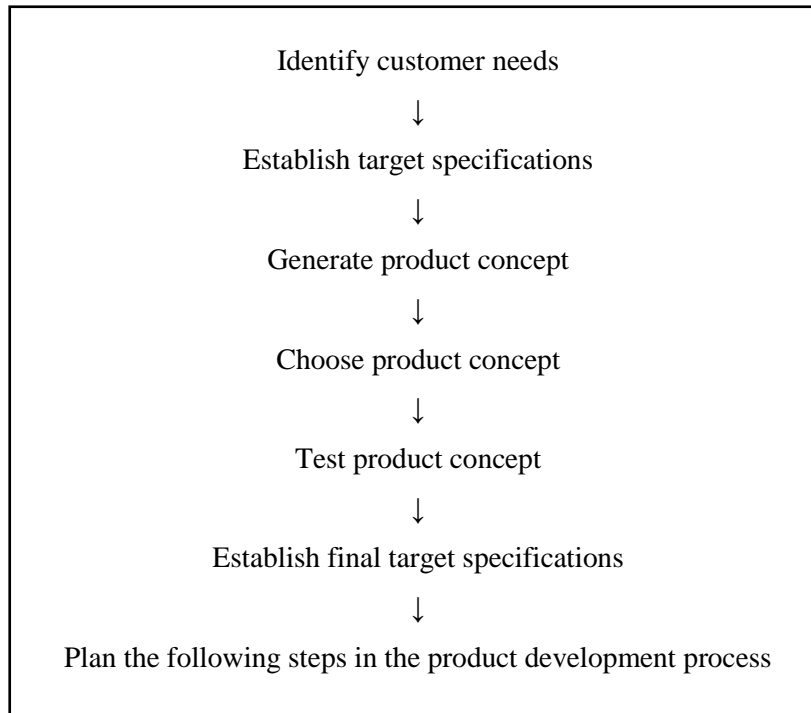
In this phase prototypes or preproduction versions of the product should be tested and be further developed. The first prototypes are made mainly for testing to find out if the concept works as designed and fulfills the customer needs and target specification and later prototypes could be built to test the production and if all production requirements are met.

### Phase 5 – Production start-up

In this last phase of the product development process, the production of the product is ramped up. In this phase the production is tested and eventual problems with production are sorted out. In the beginning of production, the production speed could be lower, since the need of training of operators and fine-tuning of the production process.

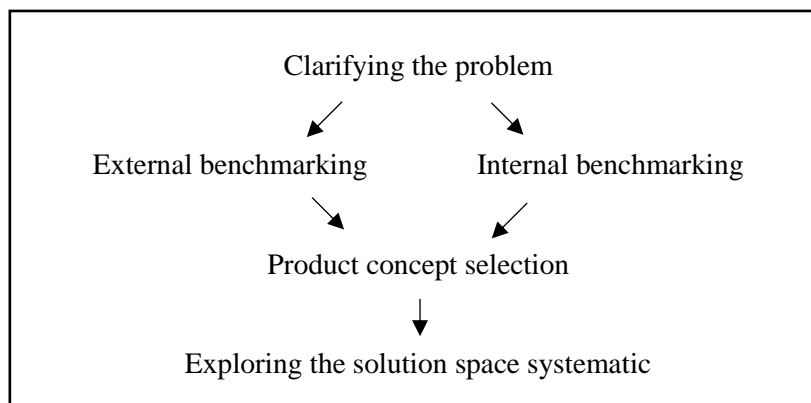
### 3.2.2 U&E – Phase 1: Concept Development

Phase 1, Concept Development, is a large part in U&E’s product development process. U&E divide the concept development into what they call “the front process” [7]. See figure 3.1 for the phases in “the front process”.



**Figure 3.1: “The front process”.**

U&E establishes a process for how to generate product concept, see figure 3.2.



**Figure 3.2: Structure of the concept generation part of “the front process”.**

### 3.2.3 Modified product development process

A modified version of U&E’s product development process will be used in this project. The planning phase (Phase 0) is a bit modified, since a project specification already is made and was given in the beginning of the project. This phase is instead mainly focused on research of the existing solution, the production site and manufacturing possibilities in-house. The next phase, concept development (phase 1) is the biggest phase of this project, since a new concept for a packaging solution should be developed. U&E’s “front process” will be followed during the concept development. After the concept development comes “development on system-level” and thereafter “detail development”. Since the architecture will be relatively simple, the phase with development on system-level does not need to be done. Instead the focus will be on detail development. The last phase in U&E’s development process is “testing and further development”. Digital models and real prototypes should be tested throughout the concept and detail development processes. See figure 3.3 for an overview of the modified product development process used in this project.

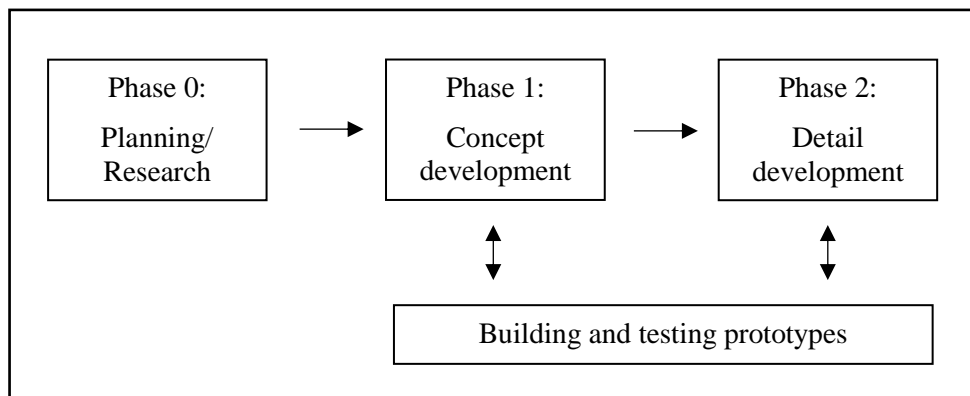


Figure 3.3: Modified product development process.

### 3.2.4 Finite element method analysis

A finite element method analysis will be executed on the new, final developed packaging solution for gear hobs. This is done in the software ANSYS Workbench 18.1 and a stress and deformation analysis will be performed as well as a safety factor analysis. This is done to be able to see if the packaging will withstand the weight of the gear hobs without breaking, as well as the fatigue from usage.

## 3.3 Volvo Group ergonomics standard

In 2017 Volvo Group released a new standard for ergonomics [8]. This standard will be used when considering the ergonomic aspect of the designing process.

### 3.3.1 Small packaging

The standard states the following common guidelines for small packaging:

- The maximum weight is 15 kg (target is 12 kg).
- If the length is above 800 mm the maximum weight is lowered to 10 kg.
- Maximum sizes of packaging which is handled manual is 1200 x 500 mm.
- The surface on the packaging should be smooth and not slippery.
- The content of the packaging must be placed stable.
- The packaging must not have sharp edges.
- The packaging must be easy to grasp even with gloves.

### 3.3.2 Handles

If handles are implemented then the space between left and right hand should be between 400 – 800 mm. The heavier the packaging is, the larger the space between the handles should be. See figure 3.3 for configuration of the handle [8].

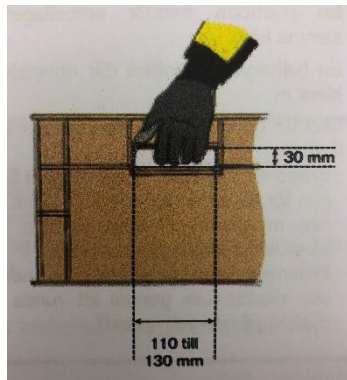


Figure 3.3: Configuration of handles.

### 3.3.3 Labels

Signs and words on labels on a packaging should be as big, high and bold as possible. They should at least be 10 mm high. Labels should be placed horizontal, when placed in its normal position.

## 3.4 Data collection

To be able to develop a new packaging solution, data from current users of the existing packaging solution need to be collected. It is important to collect data from different key persons, which uses the packaging in different ways to be able to cover as many aspects as possible of the usage of the packaging.

### 3.4.1 Interviews and observations

The data in this project is collected either by interviews or by observations. Which type of method, which is selected depends both on what kind of data that should be collected, as well as how the best data is gained from different persons.

#### Interviews

To be able to identify the customer and product needs, interviews with key persons are made. The positions of the interviewed personnel varied and thereby they come in touch with the packaging in different ways and can give feedback from different angles. The interviews will have a semi-structured mode, which means that the interviewer will determine the structure of the interview and agenda through the questions asked, according to Corbin and Morse [9]. This mode is selected to allow the interviewer to be more flexible during the interviews. The questions are formulated based on known problems and limitations. Some questions came up during the meetings and in the discussions with the different personnel. In table 3.1 it is shown where the interviewed personnel work and in the table 3.2 questions asked during the interviews are shown.

**Table 3.1 Interviewed personnel.**

<i>Meeting</i>	<i>Position/workstation</i>
<i>Meeting 1</i>	Meeting with gear technicians
<i>Meeting 2</i>	Meeting with operators from T-storage
<i>Meeting 3</i>	Meeting with ergonomist
<i>Meeting 4</i>	Meeting with warehouse technician
<i>Meeting 5</i>	Meeting with sales person from Binar Quick-lift who sells lifting devices

**Table 3.2 Interview questions.**

<i>Meeting</i>	<i>Questions</i>
<i>All meetings</i>	<ul style="list-style-type: none"> <li>• Advantages and disadvantages of the existing packaging?</li> <li>• Limitations and problems of the existing packaging?</li> </ul>
<i>Meeting 1 (Gear technicians)</i>	<ul style="list-style-type: none"> <li>• Which material is preferred?</li> <li>• What is the preferred protective material between the box and the gear hob?</li> <li>• Which properties should the packaging have in form of inner and outer design, protection and similar?</li> <li>• Which properties should the protection material have?</li> <li>• Optimal placement of the sharpening card?</li> <li>• Where is the best place to place the identification number?</li> <li>• Would it be beneficial to add a top cover to the packaging?</li> <li>• Where and how is the packaging subjected to wear?</li> <li>• Is there any opportunities to wash to packaging internally at the workshops?</li> <li>• Which manufacturing opportunities does exist?</li> </ul>
<i>Meeting 2 (Operator T-storage)</i>	<ul style="list-style-type: none"> <li>• What is the minimum and maximum size for the packaging?</li> <li>• Where is the best place to place the identification number?</li> <li>• Are the packaging stacked on top of each other?</li> <li>• Optimal placement of the sharpening card?</li> </ul>
<i>Meeting 3 (Ergonomist)</i>	<ul style="list-style-type: none"> <li>• What important properties should an optimal handle have?</li> <li>• Is there a preferred material from an ergonomic point of view? (Wood, plastic or some other material?)</li> <li>• Advantages and disadvantages with existing handles?</li> <li>• How does an operator carry the packaging optimal? <ul style="list-style-type: none"> <li>- Top or bottom of packaging?</li> <li>- The long or short side of the packaging against the body?</li> </ul> </li> <li>• How is the gear hobs lifted the best way up and down from the packaging?</li> <li>• What is the internal guidelines for lifting and carrying at Volvo?</li> <li>• How do you pull a box towards you in the best way?</li> </ul>
<i>Meeting 4 (Warehouse technician)</i>	<ul style="list-style-type: none"> <li>• How should a future lifting device be designed?</li> <li>• Is there any future changes planed for the warehouses?</li> <li>• Is there any future changes planed for the logistics?</li> <li>• Where is the best place to place the identification number?</li> </ul>
<i>Meeting 5 (Sales person from Binar Quick-lift)</i>	<ul style="list-style-type: none"> <li>• How should the packaging be designed to fit a lifting device?</li> <li>• Which properties should the packaging have to fit a lifting device?</li> </ul>

## Observations

To obtain a further understanding of the usage of the packaging, observations are made around the factory on different sites for obtaining real-world knowledge of how the packaging is used. In table 3.3 it is shown where the observations were made.

**Table 3.3 Places of observations.**

<i>Observation</i>	<i>Place of observation</i>
<i>Observation 1</i>	Gear production lines
<i>Observation 2</i>	Grinding and coating site
<i>Observation 3</i>	T-storage
<i>Observation 4</i>	Central storage
<i>Observation 5</i>	Places around in the workshops where the packaging is transported.

### 3.4.2 Data analysis

The collected raw data from the interviews and observations needs to be analyzed and then converted to customer needs. According to U&E the following guidelines should be used when the collected raw data from interviews and observations should be interpreted into customer needs:

- “What” and not “how”
- Specific
- Positive, not negative
- The characteristics of the product
- Avoid “must” and should

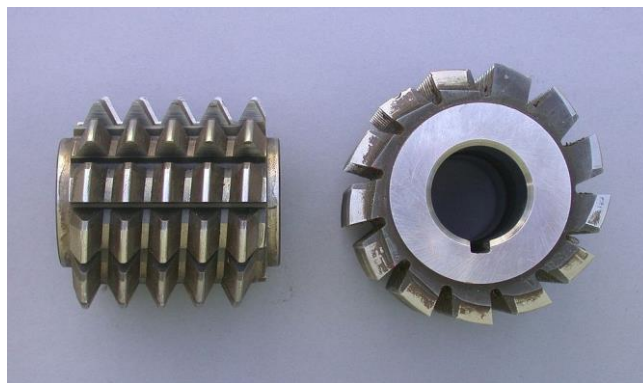


## 4 Research

*This section contains information about the existing packaging solution today at the factory for gear hobs. First information about the gear hobs and properties of used gear hobs in the production are presented. Then the existing packaging solution is presented in detail as well as the production site at Volvo Köping. Manufacturing possibilities are presented at the end of this chapter.*

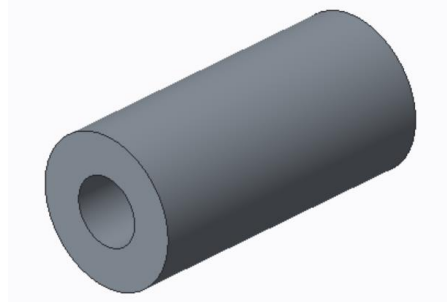
### 4.1 Gear hobs

In the production of gears a cutting tool called gear hob is used, see figure 4.1 [10]. This is a special cutting tool which has a lot of “teeth” with cutting edges. The gears are produced with the gear hobs in a special, mainly automated, cutting machine made for gear cutting. The cutting process is an intermittent cutting process, which means that each cutting edge is not cutting continuously, but goes in and out of engagement for each rotation lap. For every different gear a special gear hob is needed for manufacturing, which means that a lot of different gear hobs are used in the production. All these gear hobs need protection during storage, transportation and usage.

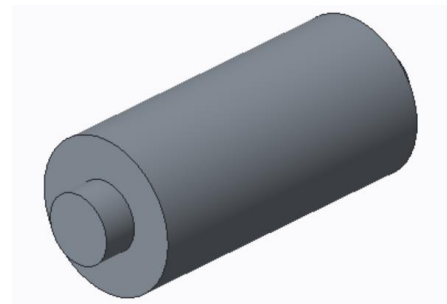


**Figure 4.1: Gear hob.**

There are two different types of gear hobs, either with a hole through the gear hob, see figure 4.2, or with a shaft through the gear hob, see figure 4.3.



**Figure 4.2: Gear hob with hole.**



**Figure 4.3: Gear hob with shaft.**

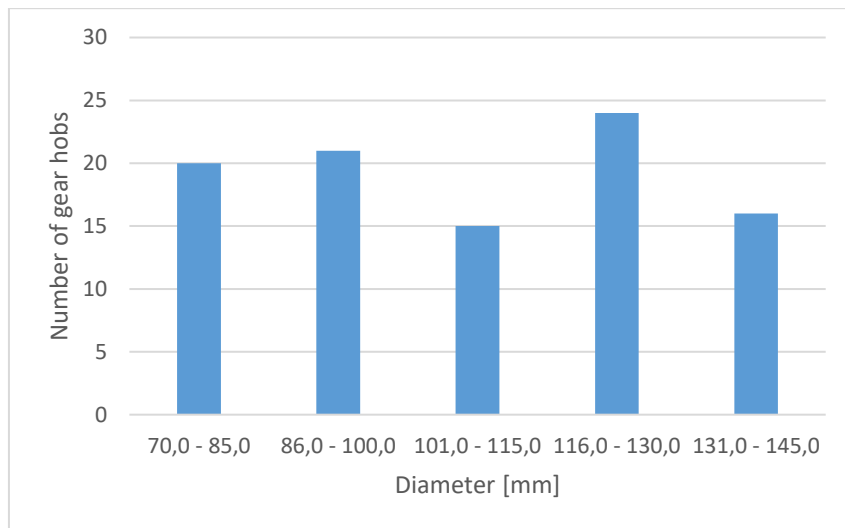
#### 4.1.1 Properties

The packaging should be able to fit as many different models of gear hobs as possible and be a generic solution. In table 4.1 the properties for the gear hobs are listed. This data was given from the supervisor at Volvo in an excel sheet and contained all the gear hobs that are used in production today and properties for respective gear hob. However, this data does not contain information about how many of each gear hob that are used.

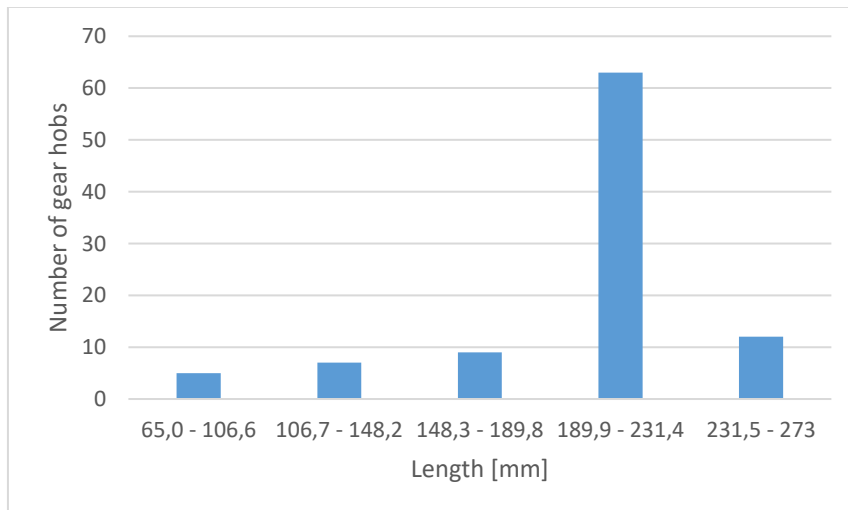
**Table 4.1 Properties of gear hobs.**

	<i>Unit</i>	<i>Interval</i>	<i>Average</i>	<i>Median</i>
<i>Diameter</i>	[mm]	70 - 145	109	110
<i>Length</i>	[mm]	65 - 273	207	225

In figure 4.4 a histogram of the spread in diameter of used gear hobs are shown and in figure 4.5 a histogram of the spread in length of used gear hobs are shown. Since the data which these two histogram builds on does not contain information about the number of used gear hobs for each model, the histogram shows the spread of sizes for the different used models of gear hobs.



**Figure 4.4: Histogram of the spread in diameter.**



**Figure 4.5: Histogram of the spread in length.**

## 4.2 Existing solution

The existing packaging solution has been around at the factory site for a long time and there is a need for a new and modern packaging solution. In this chapter the existing packaging solution will be described.

### 4.2.1 Existing packaging

The existing solution for protecting the gear hobs in the production is a generic box, which fits most of the gear hobs used today, see figure 4.6 & 4.7. See appendix B for illustrations and technical drawings of the existing packaging. The main material which is used in the design is plywood and the sidewalls and the bottom plate are glued and screwed together. The handles and the number badge are made of aluminum and they are attached with screws to the sidewalls. Different types of protection are used between the gear hob and the box for protection of the cutting edges on the gear hub. The protection could either be a piece of foam rubber, a rubber mat or a similar protecting material.



**Figure 4.6: Existing solution for packaging for gear hobs (Side view).**



**Figure 4.7: Existing solution for packaging for gear hobs (Top view).**

There are two different sizes of the existing packaging, where it is the length who varies, see table 4.2 for sizes and weight.

**Table 4.2 Sizes of existing packaging.**

Packaging	Weight [g]	Length [mm]	Width [mm]	Height [mm]
<i>Size 1</i>	1500	205	175	175
<i>Size 2</i>	1960	280	175	175

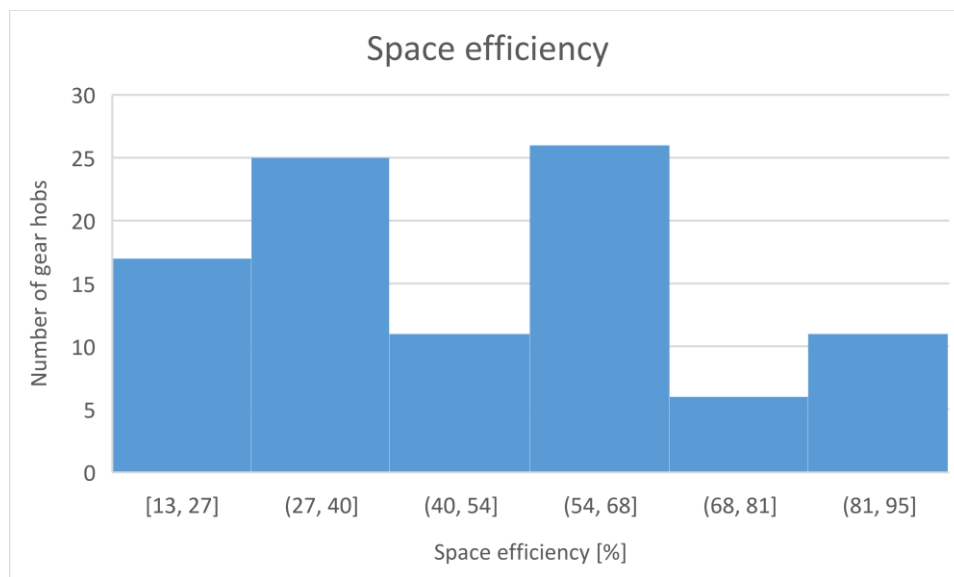
When new gear hobs arrives to the factory, they come in a plastic container. This packaging is more the type of a disposable packaging and is not used in the production handling. Each packaging is made for the size of the gear hob. Gear hobs are stored in this packaging until the gear hobs are needed in production.

#### Sharpening card

With each packaging and gear hob a sharpening card follows with the packaging. The sharpening card contains information about the gear hob and how much and when the gear hob has been used and the sharpening card tells the operator when the gear hob needs to be sharpened. The operator makes a note after each usage. The sharpening card is a normal single A5 copy paper (width: 210 mm x height: 148 mm).

### 4.2.2 Space efficiency

The space efficiency for each model of gear hobs can be calculated. Space efficiency shows how much of the packaging which stores the content and how much air that is stored. Having as high space efficiency as possible means that less storage space is required and thereby costs can be reduced. The percentage of how much the gear hob takes up of the total space in the packaging is calculated. The maximum length of a gear hob that suits in the shorter package is 175 mm. An assumption is made that all gear hobs which are 175 mm or shorter are stored in the smaller packaging and all gear hobs which are longer than 175 mm are stored in the longer packaging. This is a simplification and sometimes gear hobs shorter than 175 mm are stored in the larger packaging in the reality. Since some models of gear hobs are protruding, some numbers could be misleading. Here again the data does not contain information about how many gear hobs of each model that are used today in production. However, if the same method is used when calculating the space efficiency for the new packaging, the results can be compared. In figure 4.8 a histogram of the spread in space efficiency of used gear hobs are shown.



**Figure 4.8: Histogram of the space efficiency.**

In table 4.3 the interval, average and median for space efficiency are shown.

**Table 4.3 Space efficiency.**

	<i>Unit</i>	<i>Interval</i>	<i>Average</i>	<i>Median</i>
<i>Space efficiency</i>	[%]	13 – 95	49	50

### 4.2.3 Advantages and disadvantages

The existing solution has been around for at least 20 years and both advantages and disadvantages have been discovered of the packaging during these years of usages. However, the disadvantages have overshadowed the advantages and a new packaging solution is needed. The advantages and disadvantages are collected from interviews with my supervisors at Volvo, from the previous work by the summer technologist and observations of the packaging in use.

#### Advantages

The experienced advantages of the packaging collected from personnel around at the factory site are shown in table 4.4.



**Table 4.4 Advantages with existing solution.**

<i>Advantage</i>	<i>Description</i>
<i>Fit most of the gear hobs</i>	Almost all different models of gear hobs fit in the existing solution. It is mainly those gear hobs with shafts which are protruding.
<i>Operators are used to the existing packaging</i>	The operators on different workstations are used to the existing packaging and no change in the workflow is required, if keeping the existing packaging.
<i>Stable</i>	The gear hobs are stable when stored in the packaging. The inner supports are designed in a way that keep the gear hobs secure and stable during movement and handling.

### Disadvantages

The experienced disadvantages of the packaging collected from personnel around at the factory site are shown in table 4.5.

**Table 4.5 Disadvantages with existing solution.**

<i>Problem</i>	<i>Description</i>	<i>Image</i>
<b><i>Dirty packaging</i></b>	The existing packaging tends to be dirty after some usage in the production, which is bad for the overall cleanness at the workshops and could impair the gear hob.	
<b><i>Operational problems</i></b>	The overall performance when handling the packaging in production is not optimal and some operators find it hard to lift up and down the gear hob from the packaging. Especially the handles are considered a major problem when handling the packaging.	



***Bad ergonomics***

The packaging does not promote good ergonomics, when working with the packaging. For example, the handles are placed diagonal, which promotes bad ergonomics when lifting the packaging.



***Lifting device does not fit***

The current lifting device in the A-workshop has a grapple which is too big to fit in the packaging.

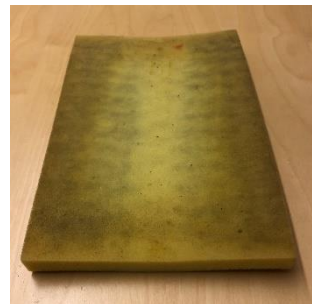
***Placement of the sharpening card***

A sharpening card (a paper with the size of an A5 sheet) needs to be placed in every packaging. It does not exist a place to put the sharpening card in the existing solution.



***Protecting material***

Between the wooden box and the gear hob some kind of protecting material is located to protect the gear hob. Today different materials are used, which is not an optimal solution.



***Protruding tool (diameter)***

During recent years some of the gear hobs have grown in size and this contributes to that some of the gear hobs are protruding.



***Protruding tool (length)***

The gear hobs with shafts are sometimes too long and the shaft is protruding from the packaging, which increases the risk for damages on the gear hobs.



***Wooden chips from the packaging***

Wooden chips are ripped from the packaging and these chips can end up on unwanted places in the workshops.



## 4.3 Factory site

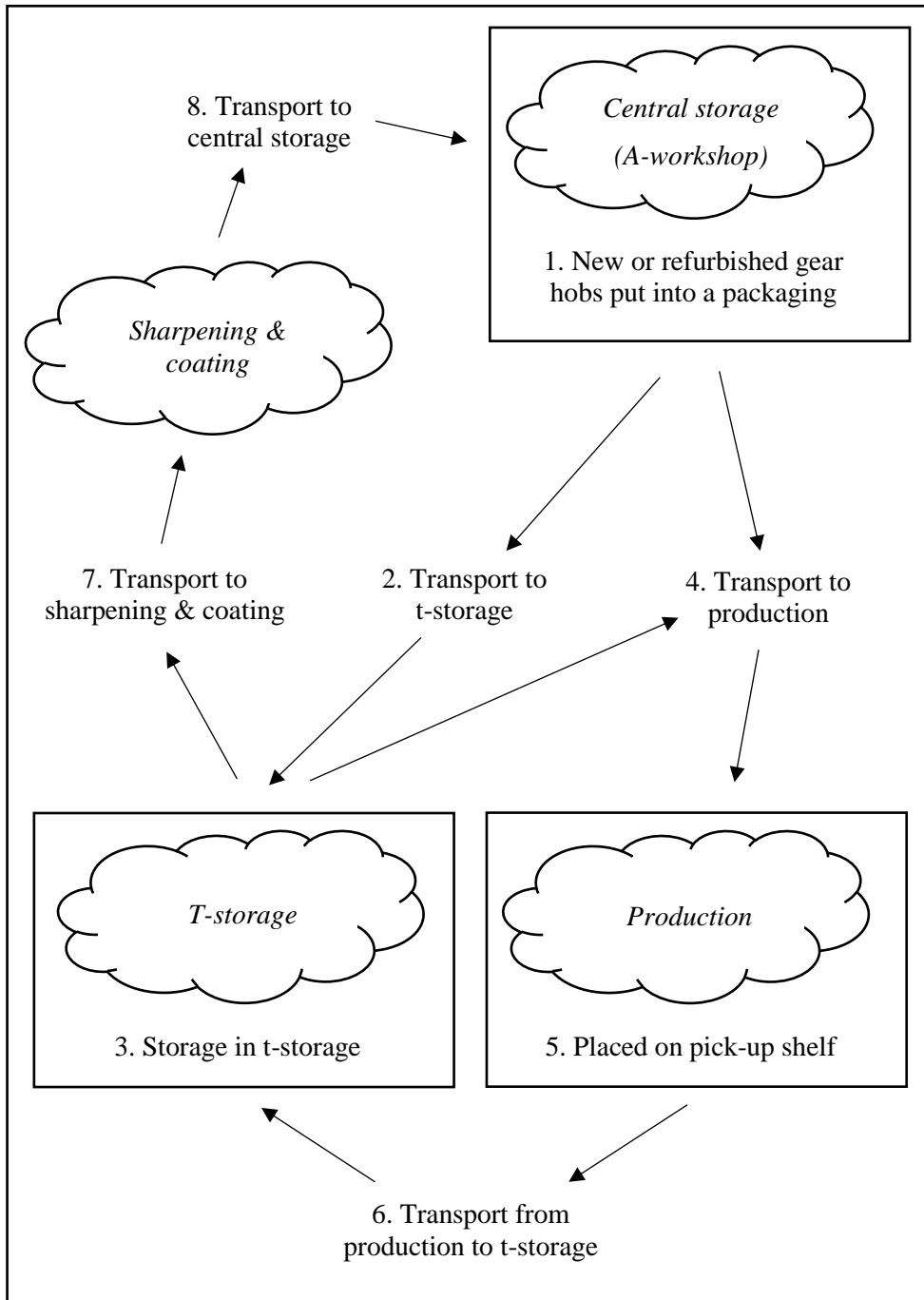
The factory site at Volvo PTP in Köping is divided into different workshops. The packaging is mainly handled in the A-workshop and the T-workshop. In the A-workshop the central storage is located, as well as the grinding and coating section for used gear hobs. In the T-workshop the gear production is located. A smaller storage, called the T-storage, is located in the T-workshop.

### 4.3.1 The packaging's route in the factory

The packaging is continuously transported around in the factory between the different places. Different people at different places are handling the packaging and they all have different needs regarding the packaging. The following list is a description of the packaging's route in the factory:

1. A new gear hob or a used gear hob which has been grinded and coated is packed into a packaging in the central storage in the A-workshop.
2. The packaging is stored in the central storage until it is either transported to the T-storage or an operator picks it up.
3. If the packaging is transported to the T-storage, it is stored there until an operator picks it up.
4. The operator transports the packaging from some of the storages to the cutting machine where it is used in the production.
5. When the gear hob is not needed anymore in the production, the operator puts down the gear hob in the packaging again and a note is made on the sharpening card about the usage. The operator then place the packaging on a shelf for pick-up.
6. Personnel from the storages collect the packaging from the workshops and bring them back to the storages, where they check if the gear hobs need to be sent away for sharpening and coating or can be used again.
7. The gear hobs which needs to be send away for sharpening and coating are placed on a shelf for pick-up for transportation to the grinding and coating section.
8. When the gear hobs are finished from sharpening and coating they are transported to the central storage.

This route of the packaging is visualized in a process map, see figure 4.9.



**Figure 4.9: Process map of the route of the packaging.**

### 4.3.2 Transport and storage

The packaging and gear hobs are continuously transported around in the factory as described in previous chapter. The transportation is carried out on different trolleys and with trucks and the packaging is stored in different storage systems.

#### Transport trolleys

On different places in the A-workshop and the T-workshop transport trolleys pushed or pulled by hand are used by the operators. There are different models of the trolleys used today. Most of them have two storage levels and each level has a width of approximately 500 to 800 mm and a length of approximately 800 to 1200 mm.

#### Operators

Operators around in the production come in contact with the packaging in different ways. In general operators should not carry the packaging longer distances, due to its weight and for safety reasons. In some cases the operator need to carry the packaging shorter distances. The main transportations are carried out on transport trolleys, described above. The main thing the operators need to do is to lift the packaging from a table or desk to the transport trolleys. Since the packaging is heavy when the gear hob is stored within, ergonomic handles are important. The height operators need to handle the packaging are in general from the floor up to one meters height.

#### Storage T-workshop

In the T-workshop the packaging is stored on shelves around at the production lines, see figure 4.10 for examples of shelves. The sizes of these shelves varies, but it is not the limiting factor in the production chain.



**Figure 4.10: Storage shelves in the production.**

In the T-storage in the T-workshop the packaging are stored in different paternoster vertical carousel systems. There is a newly installed paternoster vertical carousel but this is not used today for the packaging, however these measurements could be thought of when developing the packaging for an eventual future use. The used paternoster vertical carousels today are of an older type. See table 4.6 for the measurements of the paternoster vertical carousels and figure 4.11 for an image.

**Table 4.6 Measurements of paternoster vertical carousels.**

Type of paternoster vertical carousel	<i>Depth</i> [mm]	<i>Height per compartment</i> [mm]	<i>Width</i> [mm]
<i>Old type</i> (Existing storage)	500	205	2200
<i>New type</i>	600	450 (Can be divided into sections)	2800



**Figure 4.11: Paternoster vertical carousel in T-storage.**

#### Central storage

In the central storage in the A-workshop the packaging with gear hobs are stored as well. They are stored in a paternoster vertical carousel and on shelves. Like in the T-workshop the packaging is also stored on shelves around at the production lines in the A-workshop. Only one type of paternoster vertical carousel is used, see table 4.7 for the measurements of the paternoster vertical carousels. A lot of the new gear hobs are stored in the packaging which they were delivered new in.

**Table 4.7 Measurements of paternoster vertical carousel.**

Type of paternoster vertical carousel	<i>Depth</i> [mm]	<i>Height per compartment</i> [mm]	<i>Width</i> [mm]
<i>Type</i>	475	340	2900

### 4.3.3 Lifting devices

#### A-workshop

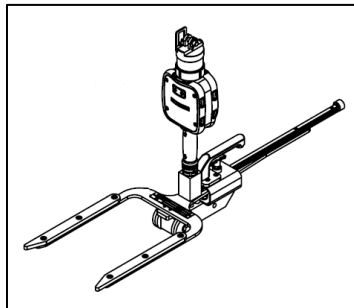
In the A-workshop they use the following lifting devices:

- Lifting device which has a gripping device that grips around a gear hob over the long side.
- Lifting device with a rod that lifts the gear hob through the hole in the middle of the gear hob or on the shaft for gear hobs with shafts.

The problem is that the first lifting device does not fit inside the existing packaging, since it is 205 mm in outer dimension and the inner dimension of the box is 145 mm. They do not have lifts in the central storage.

#### T-storage

In the T-workshop it does not exist any lifting devices. However, it is planned to install a lifting device for the packaging with the gear hobs. The suggested lifting device has a spade or forks which goes underneath the packaging and lifts it, see figure 4.12.



**Figure 4.12: Lifting device.**

Since the process of implementing a lift in the T-workshop and the developing of a new packaging for gear hobs goes on parallel, common consideration must be taken into account during the development.

#### Other places in the factory

Lifting devices exists on other places around in the factory. However, from observations these lifting devices are mainly used when the gear hob is out of the packaging and lays next to the machine on a desk and thereby the design of the packaging does not effect this lift. On some places, a lift is not used or needed, since the operator does not lift the gear hob regularly.

## 4.4 Manufacturing

In the A-workshop the workshop for in-house manufacturing is located. They have possibilities to manufacture a lot of different components and products for the production. These different manufacturing possibilities are described in ch. 4.4.1 – 4.4.3. It is possible to use water jet cutting and this is done by an external company and this manufacturing possibility is described in ch. 4.4.4. There is a possibility to use the 3D-printer located at Volvo, this is described in ch. 4.4.5.

### 4.4.1 Plastic manufacturing

For manufacturing of plastic components and products, they work in a couple of different materials. They recommended to use acetalplastic POM or polyethylene with high molecular weight. Acetalplastic POM, also known as polyacetal, polyformaldehyde or polyoxymethylene is an engineering polymer with high strength, modulus and resistance to impact and fatigue [11]. Polyethylene is a versatile material with lot of applications. For technical applications, high density polyethylene is mainly used, since the durability enhanced with higher density [12].

The workshop buys acetalplastic POM and polyethylene from the company Christian Berner AB. The trade name of the specific material for acetalplastic POM is POM and for polyethylene it is HD 1000 SBF. They buy sheets of acetalplastic POM, ranging from 3 – 100 mm and polyethylene, ranging from 8 – 50 mm. If the sheets should be screwed together, they should at least be 5 mm thick and they prefer to work in sheets with a thickness between 10 – 20mm. Sheets of acetalplastic POM are either 1000 or 2000 mm long, has a width of 1000 mm and the following different heights are possible to buy: 3, 5, 8, 10, 12, 16, 20, 25, 30, 40, 50, 60, 80 and 100 mm [13]. Sheets of polyethylene are 2000 mm long, has a width of 1000 mm and the following different heights are possible to buy: 8, 10, 12, 15, 20, 25, 30, 40 and 50 mm [14].

In table 4.8 properties for acetalplastic POM and polyethylene are listed [12], [15].

**Table 4.8 Properties acetalplastic POM and Polyethylene.**

Property	<i>HD 1000 SBF</i>	<i>POM</i>	<i>Unit</i>
<i>Density</i>	0.94	1.41	g/cm <sup>3</sup>
<i>Tensile strength</i>	20	70	N/mm <sup>2</sup>

For manufacturing in plastic materials, the most common manufacturing methods can be used. The workshop at Volvo is large and is equipped with the most common machines, like drilling machines, milling machines and different saws.



#### 4.4.2 Wood manufacturing

For manufacturing in wood, they mainly work with construction plywood. In table 4.9 properties for construction plywood is listed [16], [17]. Since there is different types of plywood, properties varies. The listed properties is a general trade-off and thereby medium values.

**Table 4.9 Properties “construction plywood”.**

<i>Property</i>	<i>Value</i>	<i>Unit</i>
<i>Density</i>	0.6	g/cm <sup>3</sup>
<i>Tensile strength</i>	30	N/mm <sup>2</sup>

#### 4.4.3 Metal manufacturing

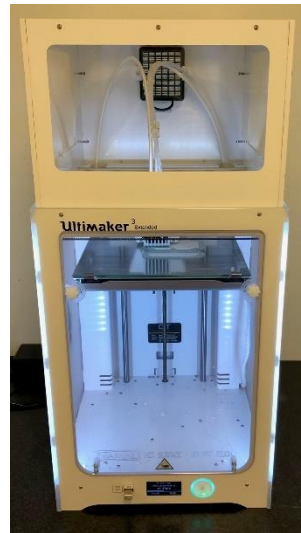
For manufacturing of metallic components and products, they can work in all kind of the most common metals and do the most common manufacturing methods.

#### 4.4.4 Water jet cutting

There is possibilities to use water jet cutting for manufacturing. This is done by an external company. It is possible to cut sheets of different materials and in different thickness. The thicker the material is, the worse the tolerances become. For a plastic sheet with a thickness of 10 mm, the tolerance is +/- 0.35 mm.

#### 4.4.5 3D printing

Volvo has a 3D printer available for use for printing prototypes and concepts. The model is an Ultimaker 3 Extended, see figure 4.13.



**Figure 4.13: Ultimaker 3 Extended, 3D printer.**

The printer can print details with a dimension up to 215 x 215 x 300 mm. It has two print heads and can print two different materials [18]. The main material is PLA which is a plastic material. This is an affordable material suited for printing prototypes in 3D. The printer can also print in the material PVA, which is a material who dissolves in water and is therefore used for printing support materials.

# 5 Concept development

*This section contains the process where product concepts are generated, from customer and product needs to the final concepts which goes on to further development and testing. This chapter follows the “front process”, which is described in the method chapter.*

## 5.1 Customer needs

The first step in the process of generating product concepts is to determine customer needs. The final product will only be used internally in the production, so there is no external interests from customers or suppliers. The customers in this case are the internal personnel which uses the packaging on a daily basis. However, different personnel which works at different stations around in the factory have different customer needs and it is important to gather all these customer needs.

### 5.1.1 List of customer needs

Data is collected according to the method described in chapter 3.4. The collected data from interviews and observations are interpreted and converted into customer needs, see appendix C for all data converted into customer needs.

Since the packaging is used by operators on different workstations, their customer needs are different and the hierarchy of importance of the customer needs vary between operators and a general hierarchy of importance of the customer needs is hard to establish. The customer needs are instead organized in categories where similar customer needs are placed, see table 5.1. These customer needs come from the converted raw data in appendix C. Similar customer needs are put together to one customer need.

**Table 5.1 Customer needs.**

<i>Need no.</i>	<i>Customer needs</i>
1	The packaging works for the size of existing gear hobs.
2	The packaging is suitable for different sizes of the gear hobs.
3	The packaging takes up as little space as possible.
4	The packaging works with gear hobs with shafts.
5	The packaging can be produced of any material.
6	The packaging is made of an optimized material.
7	The packaging has low weight and is durable.
8	The packaging is oil repellent and washable from oil.
9	The packaging is washable with water.
10	The packaging has user-friendly and ergonomic handles.
11	The packaging can be carried with the long side against a person.
12	The packaging has optimized handles.
13	The packaging enables to be pulled with the arms close to the operator's body.
14	The packaging works for transportation on trolleys and are optimized for lifting.
15	The packaging facilitates lifting of the gear hob from the packaging.
16	The packaging is well balanced and can be lifted from the bottom.
17	The packaging is lifted in an ergonomic way into the paternoster vertical carousel.
18	The packaging makes lifting the gear hob by hand accessible.

19	The packaging is durable against damages.
20	The packaging has good protection between the gear hob and the packaging.
21	The packaging minimizes damages on the gear hob during the transfer from the packaging to the cutting machine.
22	The packaging has good protection from the top.
23	The packaging shows the sharpening card.
24	The packaging stores the sharpening card.
25	The packaging keeps the identify badge safely.
26	The packaging shows the sides of the gear hob.
27	The packaging works with lifting devices.
28	The packaging works with existing lifting devices.
29	The packaging works with future lifting machines.
30	The packaging is lifted with a lifting device with a spade or forks.
31	The packaging is well balanced when lifted on the long side.
32	The packaging is lifted from both the short and long side.
33	The packaging works with future storage implements.
34	The packaging works with a bar-code system or similar.
35	The packaging has a low price.
36	The packaging can be stacked.

## 5.2 Target specification

The second step in the process of generating product concepts is to establish target specifications. These specifications reflect the anticipations and ambitions for the project. The target specifications are written before the limitations of the product are known and are based on the customer needs. Some customer needs are not possible to measure and need instead to be measured binary and some customer needs cannot be transformed into target specifications.

### 5.2.1 Ideal and marginal accepted target specifications

Before the target specifications can be settled, measurable properties need to be settled. These properties are established from customer needs. In table 5.2, the measurable properties are listed with marginal and ideal target specifications for each property. The marginal and ideal properties are based on the customer needs and research from the factory and existing solution. Binary values can either be “No” or “Yes”.

**Table 5.2 Measureable properties with marginal and ideal values.**

<i>Metric no.</i>	<i>Need no.</i>	<i>Metric</i>	<i>Unit</i>	<i>Marginal value</i>	<i>Ideal value</i>
1	1,2,18	Inside size of the packaging (Largest size)	mm	> W:145 > L: 273 > H: 145	> W:155 > L: 283 > H: 155
2	3	Outside size of the packaging (Largest size)	mm	< W:200 < L: 320 < H: 200	< W: 180 < L: 300 < H: 180
3	3	Space efficiency	%	> 50	> 70
4	4	Works with gear hobs with shafts	Binary	Yes	Yes
5	6,7	Total weight	kg	< 2	< 1.5
6	8	Oil repellent	Binary	Yes	Yes
7	9	Water resistant	Binary	Yes	Yes
8	10,11,12, 13,14,15, 16,17	Ergonomic handles <sup>1</sup>	Binary	Yes	Yes
9	19	Durable	N	≥ Heaviest gear hob	> Heaviest gear hob
10	20,21,22	Protection for the gear hob	-	Bottom and sides are protected	Bottom, sides and top are protected
11	26,27	Works with lifting devices	Binary	Yes	Yes
13	31	Stackable	No.	≥ 2	> 2

<sup>1</sup> According to Volvo Group: Ergonomiska Riktlinjer – Produktion 2017 [6].

## 5.3 Generate product concept

A good starting point in the process of generating product concept are the task description, customer needs and target specification. With these three components, the process of generating product concept has a solid foundation to build from and making sure that the concept development goes in the right direction. It is important to spend a lot of time in this part of the project and try to generate as many ideas as possible, to be sure to exploring the whole space of solutions for the task. It is also important to not exclude any ideas in this stage of the development phase and also welcome “impossible” ideas.

### 5.3.1 Clarifying the problem

The first step in the process of generating product concept is to clarifying the problem. By doing this it facilitates the idea generation and ideas and concepts of parts of the product can be developed. In table 5.3 the problem is divided into sub problems. This division is based on the customer needs and target specifications and which areas they covered. They cover the main part of problems that have arisen so far in the project.

**Table 5.3 Problem divided into sub problems.**

<i>Sub problem</i>	<i>Description</i>
Sub problem 1	Outer design of the packaging
Sub problem 2	Inner design/support of the packaging
Sub problem 3	Placement of sharpening card
Sub problem 4	Design of handles
Sub problem 5	Integration of possibilities for lifting devices

### 5.3.2 External benchmarking

The packaging developed for the gear hobs used in the production at the factory in Köping is a special product especially developed for this application. However, it is important in the concept generation process to do a benchmark of existing solution from other companies to get ideas and inspiration. Some packaging solutions are mainly used as a packaging for delivery and transportation and not for usage in production. A lot of gear hob manufacturer does not sell or are not marketing a special packaging solution for gear hobs. The most common case is that newly produced gear hobs are delivered in a disposal packaging and then stored in a custom packaging solution.



The external benchmarking is divided into two groups. The first group to benchmark is manufacturer of gear hobs and see what packaging solution system they offer. The second group to benchmark is manufacturer of general industrial packaging solutions.

#### External benchmarking – Gear hobs manufacturer

Gear Technology [19] lists a large number of manufacturers of gear hobs. The list does not rank manufacturers in some way, so this list works as a frame to find manufacturers to benchmark. It was only Saazor and Samputensili who had interesting packaging solutions worth mentioning from this list. A search outside of this list was also done and did not result in finding other manufacturers with interesting packaging solutions.

#### **Saazor**

Saazor is one of the leading manufacturers of solid steel and solid carbide hobs. In figure 5.1 Saazor's transportation system for multiple gear hobs is shown [20]. This model seems to be mainly developed for transportation.



**Figure 5.1: Packaging solution from Saazor for multiple gear hobs.**

#### **Samputensili**

Samputensili is a manufacturer of gear hobs and other cutting tools. They have a packaging solution for gears, see figure 5.2 and they have a solution for storing documentation which is interesting for this application [21].



**Figure 5.2: Packaging solution from Samputensili.**

### External benchmarking – Manufacturer of general industrial packaging

There is a jungle of manufacturer of general industrial packaging. Schoeller Allibert will be benchmarked since one of the supervisor from the university recommended to benchmark them, as well as they are the largest manufacturer of plastic containers and reusable transit packaging [22] in Europe.

#### **Schoeller Allibert**

Schoeller Allibert is a manufacturer of plastic containers and reusable transit packaging [23], which they are inventing, developing, designing and manufacturing. They produce packaging solutions for different markets, where “Industrial manufacturing” is one market. Their products are standard products and ideas for solutions for the sub problems will be benchmarked from these products.

#### *Handles*

The product “Tellus 300 x 200 x 150mm – solid base and walls” has integrated handles in under the top part of the packaging, see figure 5.3 [23].



**Figure 5.3: Schoeller Allibert: “Tellus 300 x 200 x 150mm – solid base and walls”.**

The product “180° SN 600 x 400 x 300MM – solid base and walls – 2 open handholes” has two integrated handholes on the long sides, see figure 5.4 [24].



**Figure 5.4: Schoeller Allibert: “180° SN 600 x 400 x 300MM – solid base and walls – 2 open handholes”.**

### *Labels*

The product “Stack-nest – 800 x 600 x 350mm – solid base and walls – 4 open handholes” has label holders on top of each side and barcodes on the middle of each side, see figure 5.5 [25].



**Figure 5.5: Schoeller Allibert: “Stack-nest – 800 x 600 x 350mm – solid base and walls – 4 open handholes”.**

### *Top cover*

The product “Euro ALC – 600 x 400 x 385mm – solid base and walls” has a top cover divided into two parts and each part is fixed along the long side of the packaging, see figure 5.6 [26].



**Figure 5.6: Schoeller Allibert: “Euro ALC – 600 x 400 x 385mm – solid base and walls”.**

### 5.3.3 Internal product concept generating - Brainstorming

To be able to generate as many ideas as possible “Brainstorming” will be used. According to U&E the following points should be taken into consideration during the “Brainstorming” process:

- Ideas are not allowed to be criticized until a formal evaluation is done
- Spontaneity is encouraged
- All ideas are good ideas
- An idea which does not seem promising in the beginning could be brilliant in the end
- The number of ideas is important since quantity generates quality

To be able to generate as many relevant ideas as possible, one week was dedicated for this stage of the development process and did not continue before that week was over, to make sure to find time to come up with new concepts. During this period as many ideas as possible were generated, see Appendix D. Each idea is numbered and a shorter description describes the idea. A sketch for each idea is presented as well as advantages and disadvantages for each idea.

### 5.3.4 Product concept selection – Sub problems

In the phase of product concept selection the different produced concepts are evaluated in relationship to customer needs and other criteria's. The strengths and weaknesses of each concept is weighted to be able to select which concept or concepts that should be further developed and tested. According to U&E methods to select product concept could be:

- External decision
- Favorite product
- Intuition
- Advantages and disadvantages
- Build prototypes and test
- Matrix for decision

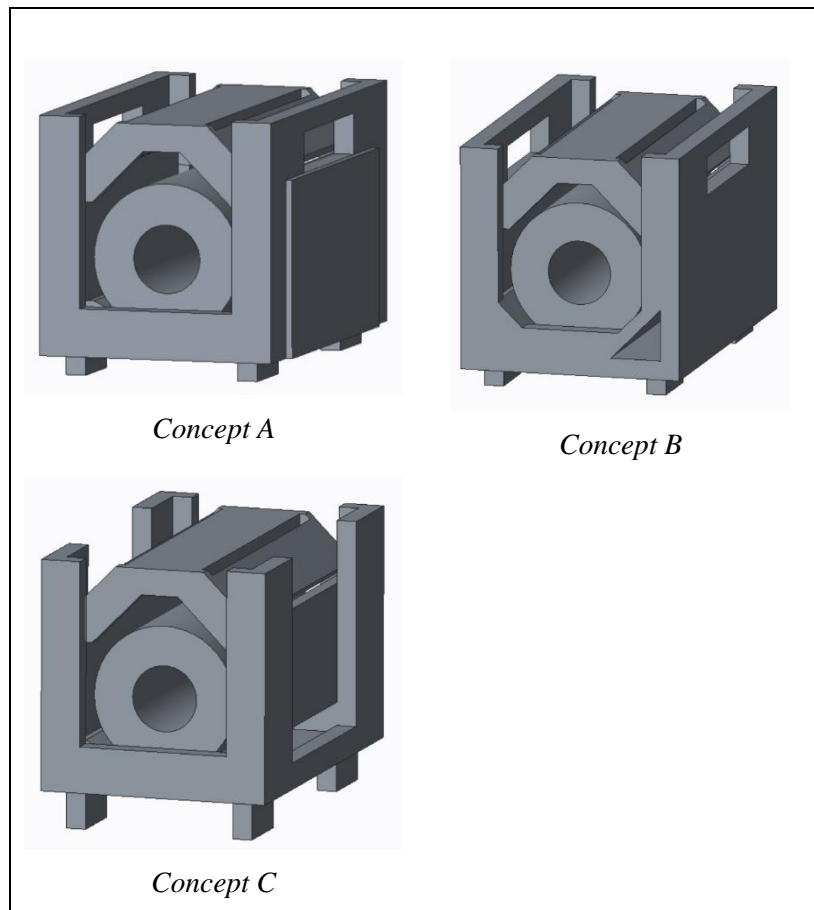
In this first product concept selection, the selection is made for the ideas and concepts for each sub problem. The chosen selection method for this stage is “Matrix for decision”, since it is a methodical way to select ideas, when a lot of ideas has been generated. Matrixes for decision for each sub problem are made and the ratings in the matrix are based on advantages and disadvantages, external decision and favorite product. These variables are based on input from the supervisors at Volvo as well as my own thoughts of the concepts. See Appendix E for the idea selection matrixes for each sub problem. Sub problem 1 is divided into three groups with solutions for three different areas within sub problem 1. See table 5.4 for rankings on ideas for each sub problem.

**Table 5.4 Rankings on ideas for each sub problem.**

<i>Sub problem</i>	<i>Description</i>	<i>Rankings</i>
Sub problem 1 (Short sides)	Outer design of the packaging	1: 1.1, 1.2, 1.4, 1.5 5: 1.3
Sub problem 1 (Top cover integration)	Outer design of the packaging	1: 1.8, 1.9 3: 1.6 4: 1.10 5: 1.7
Sub problem 1 (Top cover design)	Outer design of the packaging	1: 1.11 2: 1.16 3: 1.15 4: 1.12, 1.13 6: 1.14
Sub problem 2	Inner design/support of the packaging	1: (2.1), 2.2, 2.6 3: 2.3, 2.4, 2.5 6: 2.7, 2.8 8: 2.9, 2.10
Sub problem 3	Placement of sharpening card	1: 3.1 2: 3.2
Sub problem 4	Design of handles	-
Sub problem 5	Integration of possibilities for lifting devices	1: 5.3 2: 5.2, 5.4 4: 5.1

### 5.3.5 Explore the solution space systematic

After that the concepts for each sub problem have been ranked, the next step is to explore the solution space systematic based on this ranking and create concepts which are combination of concepts for each sub problem. It is important to still generate as many concepts as possible to be able to explore the whole solution space. However, concepts and ideas for each sub problems which does not seem promising should not be considered when developing concepts. For each concept, ideas for solutions to the sub problems are stated if they are used. When developing the following concepts, the goal is to produce concepts, which solves the task in different ways, but with the same results and fulfills the customer needs. This is done to be able to explore as much of the solution space as possible. See figure 5.7 for an overview over the three generated concepts.



**Figure 5.7: Concept A, Concept B and Concept C.**

## Concept A

Concept A is an evolution of the existing packaging, based on the customer needs and target specifications. See figure 5.8 for an overview of the concept and see Appendix F for more detailed views.

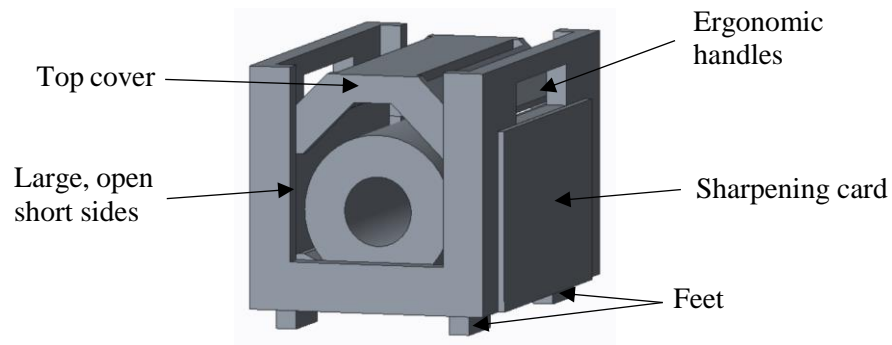


Figure 5.8: Rendering of Concept A.

### Key points

- Large, open short sides which enables easy access to the gear hob for lifting, as well as possibility to read the information on the short sides.
- The feet on the packaging enables to lift the packaging with a lifting device.
- Lower inner supports enables the gear hob to be stored lower in the packaging.
- No exterior handles, which make it possible to place packaging close next to each other.
- Handles designed according to ergonomic guidelines from Volvo Group.
- Top cover protects the operator's hands, as well as protecting the gear hob.
- Sharpening card on the side of the packaging

See table 5.5 for the chosen ideas from Appendix D from the brainstorming for each sub problem for concept A.

Table 5.5 Concept A.

<i>Sub problem</i>	<i>Description</i>	<i>Chosen idea(s) from brainstorming</i>
Sub problem 1	Outer design of the packaging	1.4, 1.9 & 1.16
Sub problem 2	Inner design/supports of the packaging	2.7
Sub problem 3	Placement of sharpening card	3.2
Sub problem 4	Design of handles	4.6
Sub problem 5	Integration of possibilities for lifting devices	5.1

## Concept B

Concept B is similar to Concept A. The differences are how the sharpening card is stored, as well as the inner supports. See figure 5.9 for an overview of the concept and see Appendix F for more detailed views.

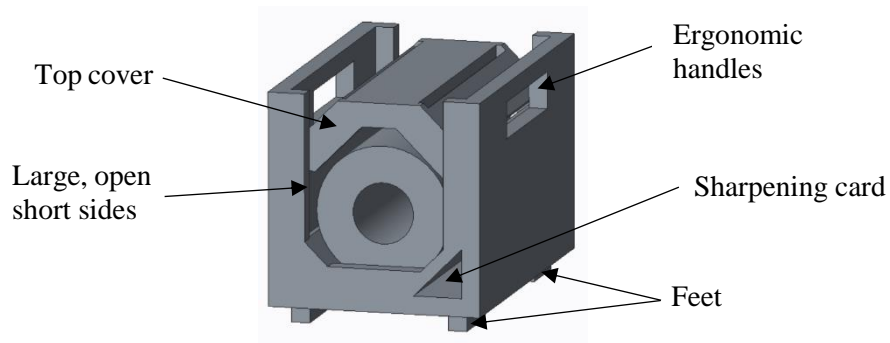


Figure 5.9: Rendering of Concept B.

### Key points

- Large, open short sides which enables easy access to the gear hob for lifting, as well as possibility to read the information on the short sides.
- The feet on the packaging enables to lift the packaging with a lifting device.
- Lower inner supports enables the gear hob to be stored lower in the packaging.
- No exterior handles, which make it possible to place packaging close next to each other.
- Handles designed according to ergonomic guidelines from Volvo Group.
- Top cover protects the operator's hands, as well as protecting the gear hob.
- The sharpening card is stored in separate protected pocket.

See table 5.6 for the chosen ideas from Appendix D from the brainstorming for each sub problem for concept B.

Table 5.6 Concept B.

<i>Sub problem</i>	<i>Description</i>	<i>Chosen idea(s) from brainstorming</i>
Sub problem 1	Outer design of the packaging	1.4, 1.9 & 1.16
Sub problem 2	Inner design/supports of the packaging	2.2
Sub problem 3	Placement of sharpening card	-
Sub problem 4	Design of handles	4.6
Sub problem 5	Integration of possibilities for lifting devices	5.1



### Concept C

Concept C is partly an evolution of the existing packaging, but it also features new outer design details. See figure 5.10 for an overview of the concept and see Appendix F for more detailed views.

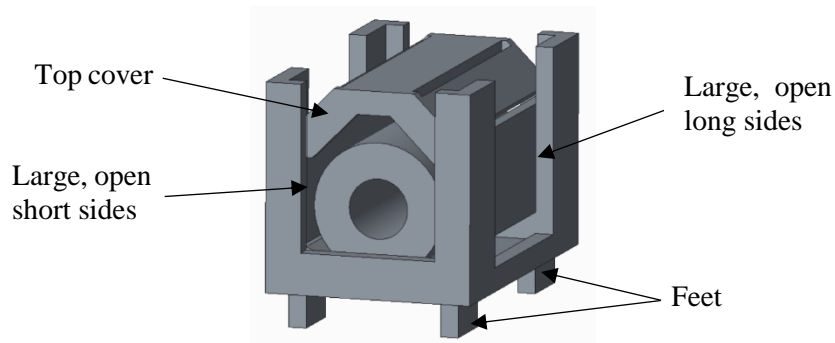


Figure 5.10: Rendering of Concept C.

#### Key points

- All sides have large openings, which enables easy access to the gear hob for lifting, as well as possibility to read the information on the short sides.
- The feet on the packaging enables to lift the packaging with a lifting device.
- Lower inner supports enables the gear hob to be stored lower in the packaging.
- No exterior handles, which make it possible to place packaging close next to each other.
- Possibility to carry the packaging from both the long and short sides.
- Top cover protects the operator's hands, as well as protecting the gear hob.

See table 5.7 for the chosen ideas from Appendix D from the brainstorming for each sub problem for concept C.

Table 5.7 Concept C.

<i>Sub problem</i>	<i>Description</i>	<i>Chosen idea(s) from brainstorming</i>
Sub problem 1	Outer design of the packaging	1.4, 1.9 & 1.16
Sub problem 2	Inner design/supports of the packaging	2.7
Sub problem 3	Placement of sharpening card	-
Sub problem 4	Design of handles	-
Sub problem 5	Integration of possibilities for lifting devices	5.1 & 5.4

## 5.4 Product concept selection

The final product concept selection is between “Concept A”, “Concept B” and “Concept C”. All concepts manage to solve most of the customer needs, which means that none of them can be sorted out due to this. A more accurate selection process needs to be done in this chapter.

### 5.4.1 What is a concept choice?

In chapter 5.3.4 “Product concept selection – Sub problems” it is accounted for how a product concept selection can be done. The important thing when doing a concept choice is to evaluate each concept in relationship to the customer needs and other criteria’s. Relative strengths and weaknesses for concepts should be compared to be able to select one or more concept for further development.

### 5.4.2 Concept selection

The concept selection process will start with listing each concepts relative weaknesses and strengths compared to each other. The next step is to discuss the concepts with the supervisors and get their opinions on the concepts and then a final selection of the concepts will be performed.

Weaknesses and strengths of each concept will be presented. These weaknesses and strengths were found during the development of the concepts and weaknesses and strengths for each concept were discussed during an evaluation meeting with supervisors from Volvo.

#### *Concept A*

- + Simple construction
- + Sharpening card visible from the outside
- + Ergonomic handles
- + Inner supports are easily mounted
- Sharpening card could be in the way for the handles
- Inner supports need to be wide enough to hold all sizes of gear hobs stable

### *Concept B*

- + Sharpening card is placed secured in its pocket
- + Good inner support for gear hobs with different sizes
- Sharpening card is not visible from the outside
- Inner supports are harder to mount

### *Concept C*

- + Good access to the gear hob from all sides
- + Low weight
- + Can be lifted from both the long and short side
- Weaker construction
- Bad support for shorter models
- No handles on the packaging, just underneath

### **5.4.3 Further development**

The decision to decide which concept that should be developed further, is based on an external decision, favorite product and advantages and disadvantages. The supervisors' favorite concept were "Concept A" and they suggested to proceed with this concept. Based on relative strengths and weaknesses "Concept A" seems to be one of the better concepts as well, beside the recommendation from the supervisors.

The product concept development phase is almost finished. Concepts for each of the sub problems have been developed, as well as three complete concepts. "Concept A" has been selected for further developing. A functional prototype will be developed and tested before continuing on to develop the product on detail level. The reason to develop a functional prototype is to make sure that the chosen concept works and to find out which areas of the concept that need to be changed or be further developed. Exact dimensions and materials will be developed in a later stage of the development process, which mean that this does not have to be taken into account.

## 5.5 Testing product concept

A prototype is manufactured based on “Concept A”. The prototype in this stage of the process is a functional prototype. This type of a prototype will make it possible to test and verify if the selected concept works and if it solves the customer needs. This first real prototype is manufactured out of plywood, to be able to manufacture it in a short timeframe, since the project is limited in time.

### 5.5.1 Prototype 1 (Functional prototype)

Some minor modification of Concept A is made based on input from supervisors from the meeting where different concepts were discussed and some designs needed to be changed in order to be able to be manufactured. The prototype is produced out of construction plywood with a thickness of 15 mm. Each piece is sawn out from a sheet of plywood with a jigsaw and are then glued and screwed together. The tolerances and fit of the construction are limited, but good enough for a functional prototype. This method is selected to be able to rapidly cut the time from drawings to a finished prototype. See figure 5.11 for photos of prototype 1.

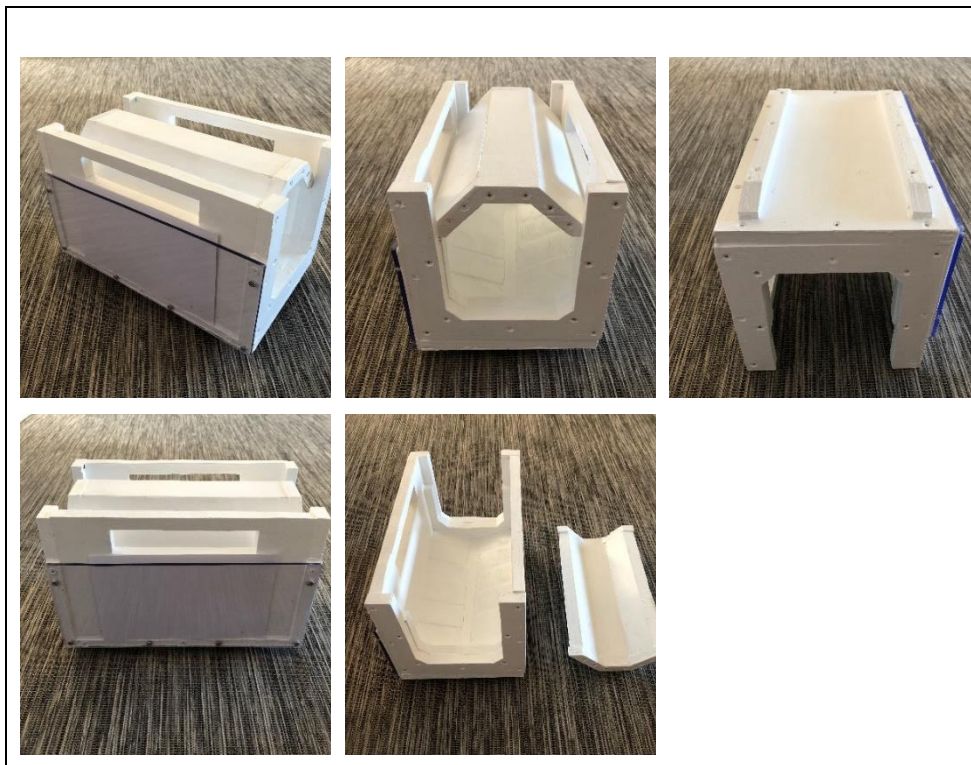


Figure 5.11: Prototype 1.

## 5.5.2 Testing and evaluation

Prototype 1 is a functional prototype and its' functionality is tested for feedback to further development. The testing and evaluation of the prototype is done with different users. See table 5.8 for the results from the different meetings. This feedback will be used for further development of the packaging.

**Table 5.8 Testing and evaluation.**

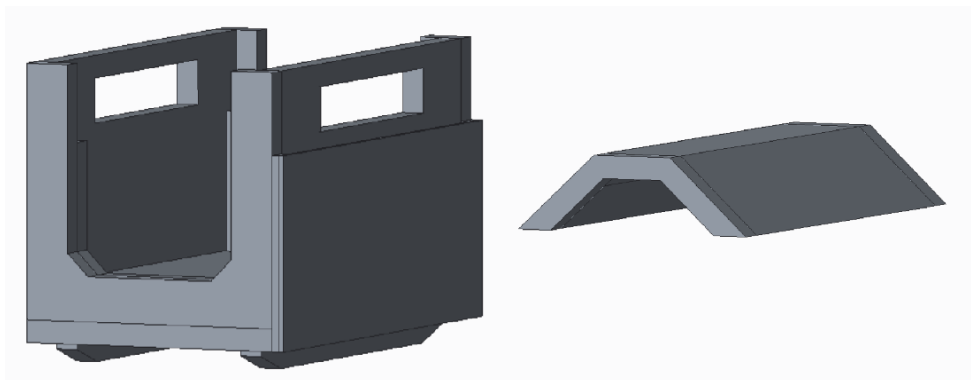
<i>Meeting</i>	<i>User</i>	<i>Outcome</i>
<i>Meeting 1</i>	Gear technicians (Supervisor at Volvo)	<ul style="list-style-type: none"> <li>• Good solution overall.</li> <li>• Inner supports need to be modified for different sizes of gear hobs.</li> <li>• There must be a hole or similar at the top of the plastic sheet which holds the sharpening card, to be able to get it easily out.</li> </ul>
<i>Meeting 2</i>	Operators in production	<ul style="list-style-type: none"> <li>• Good solution overall, risk of losing the top cover.</li> <li>• If the gear hob is used and then stored in the production, operators leave the sharpening card protruding out of existing packaging to mark for next operator to use the same gear hob.</li> <li>• A drain hole inside the packaging would be good to be able to drain water and oil.</li> <li>• The existing identification plate solution is good, except from that it quite easily falls out. A solution with identification sticker was not beneficial for them.</li> <li>• Good to be able to see the gear hob more from the short sides with new solution.</li> </ul>
<i>Meeting 3</i>	Operators in T-storage	<ul style="list-style-type: none"> <li>• Good solution overall and the development is in the right way.</li> <li>• The handles were placed high, would be good to place them lower down on the side. The width of the handles would also be good to increase.</li> <li>• The top cover is good and a necessary protection. Must be easy and simple to take on and off the top cover from the packaging.</li> <li>• The separate pocket for sharpening card was a good solution, but it does not need to be so high. It would also be great to be able to place the identification card in this pocket.</li> <li>• It would be great to have a similar pocket as the pocket for the sharpening card on the short side to place the identification card.</li> </ul>

## 6 Detail development

*This section contains the process where the generated product concept is developed in detail. First the architecture of the product is presented and then the detail development for all the components. The material selection process is described and finally the assembly process is described.*

### 6.1 Architecture of the product

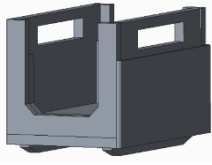

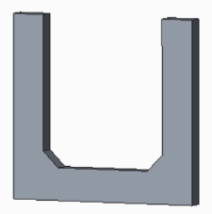
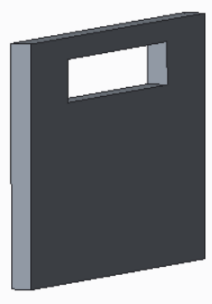


The product consist of two parts, which are the main packaging and the top cover, see figure 6.1. This architecture of the product comes from the concept development stage of the product development process. It is possible to change the architecture of the product if needed during the latter part of the detail development process.

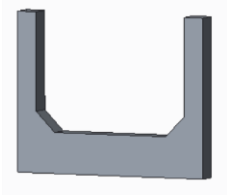
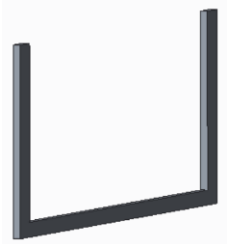
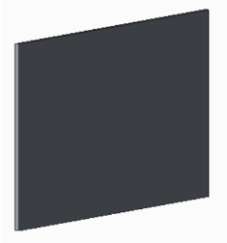
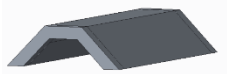





**Figure 6.1: Architecture of the product.**

Both the main packaging and the top cover consists of different components which make up the whole construction of each part. Each component of the parts need to be developed in detail in the next stage of the development phase. In table 6.1 all components for both parts are listed.

**Table 6.1 Components of each part.**

<i>Part</i>	<i>Description</i>	<i>Number of components per part</i>	<i>Figure</i>
<i>Main packaging</i>			
1.1	Bottom plate	1	
1.2	Short side	2	
1.3	Long side	2	
1.4	Foot	2	
1.5	Inner support	2	

1.6	Top cover support	2	
1.7*	Sharpening card frame	1	
1.8	Sharpening card front	1	
<i>2. Top cover</i>			
2.1	Side plate	2	
2.2	Top side	1	
2.3	Side	2	

\*The sharpening card frame should be implemented on the bottom plate and on the short sides instead of being its own part.



## 6.2 Detail development of components

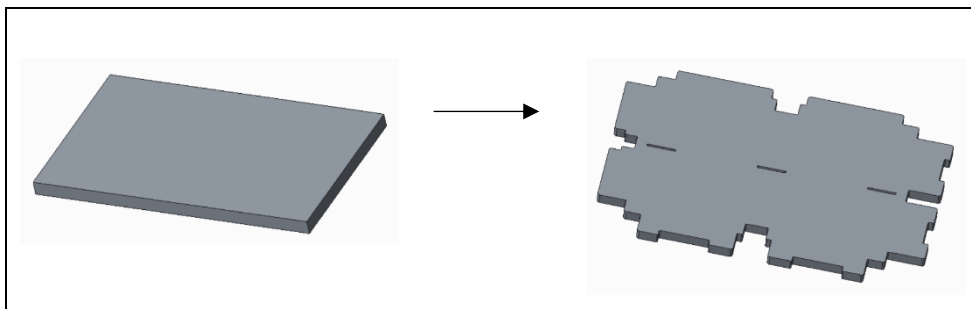
Each component of the main packaging and the top cover are further developed. The idea is to develop the packaging with the style of a “Lego-assembly”. This idea came up during a discussion with another thesis student at Volvo. Each component is developed parallel with each other to be able to fit into each other. Each component is designed with a sheet with a thickness of 10 mm. This thickness is chosen because it is a standard thickness and the workshop wished to work in sheets with a thickness of at least 10 mm to be able to assemble the components with screws. In the following chapter the development of each component is described with a comparison of each part before and after the detail development. See appendix G for technical drawings for each component.

### 6.2.1 Main packaging

The main packaging consists of seven different components (total 12 components). The components are presented in assembly order.

#### Bottom plate

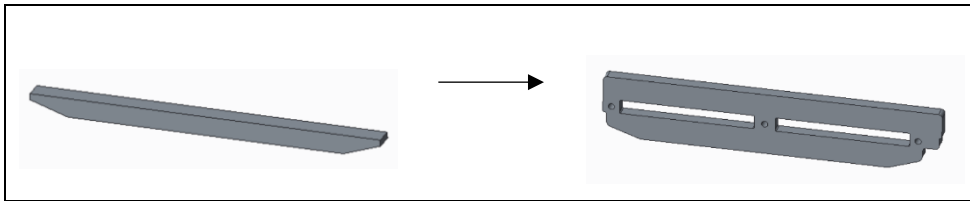
The bottom plate is used as a base for the design and assembly of the main packaging. A number of different cavities from all sides of the bottom plate are used to be able to attach other components to the bottom plate. From the long sides of the bottom plate, the feet and the long sides are attached. From the short sides of the bottom plate the inner and outer short sides are attached. See figure 6.2 for the development of the bottom plate in this development phase.



**Figure 6.2: Before and after detail development – bottom plate.**

### Foot

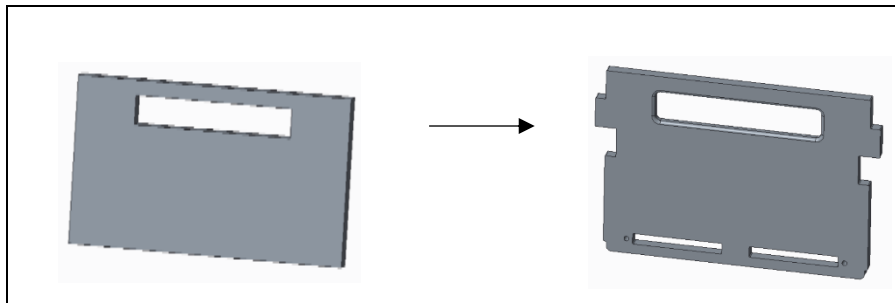
The foot is similar on the lower part of the design, except that the edges on the bottom part of the component are rounded. The whole foot is higher to be able to attach to the side of the bottom plate through the two holes. The part above the holes acts as a part of the inner support along the side walls, as well as making the component more rigid to be able to transfer the weight from the gear hob through the design. On one of the sides there is also an extension to attach the identification plate. See figure 6.3 for the development of the foot in this development phase.



**Figure 6.3: Before and after detail development – foot.**

### Long side

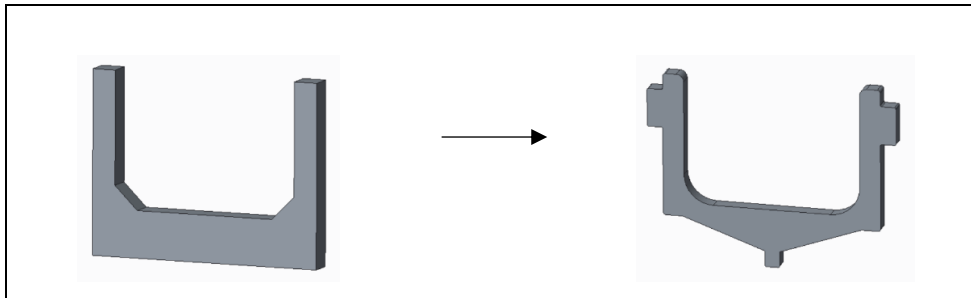
The long side is mainly developed to be able to attach to the bottom plate at the bottom of the long side and at the sides to be able to attach to both the inner and outer short side. The handle is developed to be able to fulfill the Volvo ergonomic guidelines. Some edges around the design are rounded as well. Two holes is placed on the edges, where screws will be screwed into the bottom plate. See figure 6.4 for the development of the long side in this development phase.



**Figure 6.4: Before and after detail development – long side.**

### Inner short side

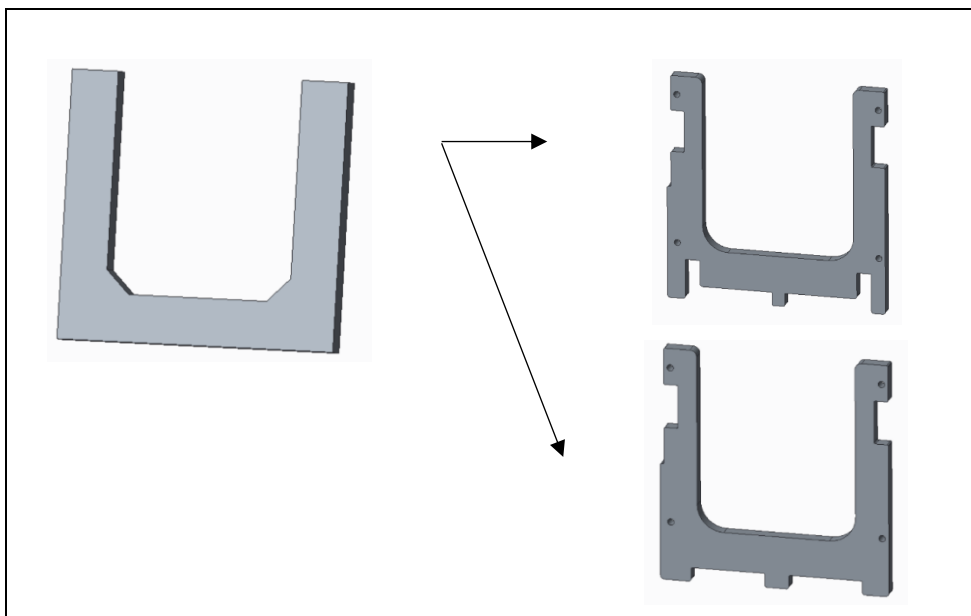
The inner short side is developed to be able to attach to the bottom plate as well as the long sides. Edges on the inside are rounded for better user-friendliness. At the bottom of the inner short side, the design is adjusted so that the inner support goes underneath and are hold in place by the inner short sides. See figure 6.5 for the development of the inner short side in this development phase.



**Figure 6.5: Before and after detail development – inner short side.**

### Outer short side

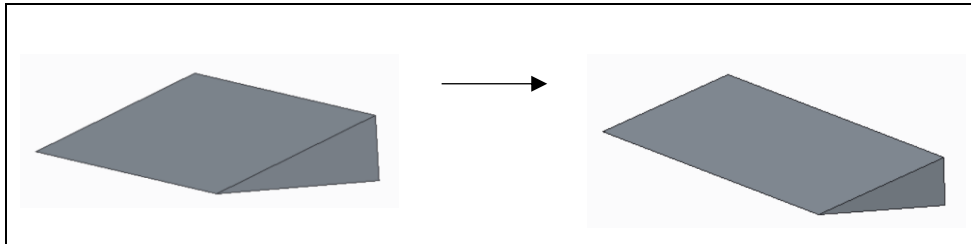
The outer short side is developed to be able to attach to the bottom plate as well as the long sides. Edges on the inside are rounded for better user-friendliness. Four holes are placed on the edges, where screws will be screwed into the long side. The outer short sides are of different design on each side. See figure 6.6 for the development of the outer short side in this development phase.



**Figure 6.6: Before and after detail development – outer short side.**

### Inner support

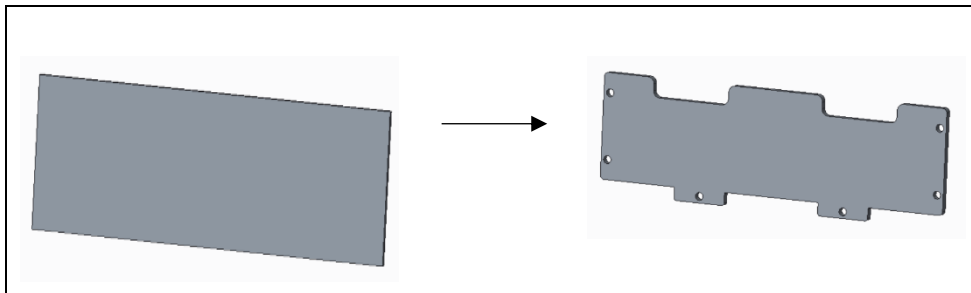
The inner support is not changed that much. The width and height of the triangular profile are slightly changed as well as the length of the support. See figure 6.7 for the development of the inner support in this development phase.



**Figure 6.7: Before and after detail development – inner support.**

### Sharpening card front

Two gravities are placed at the top of the sharpening card front to be able to easily access the grinding card. Each corner are designed to be able to fit on the long side of the packaging. Six holes are placed on the edges, where screws will be screwed into the long side. See figure 6.8 for the development of the grinding card front in this development phase.



**Figure 6.8: Before and after detail development – grinding card front.**

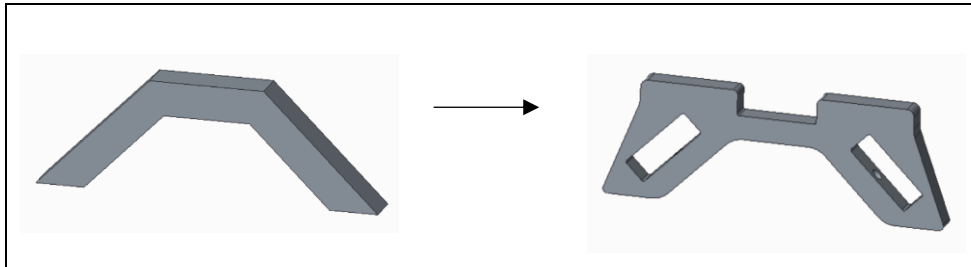
## 6.2.2 Top cover

The top cover consists of three different components (total five components). The components will be presented in the assembly order.

### Side plate

The side plate of the top cover is developed to be able to attach to the long sides. Edges on the inside are rounded for better user-friendliness. The top side is extended to make it possible to place the top cover upside down, which enables the top cover to be used as a container for the gear hob when it is placed outside of the box.

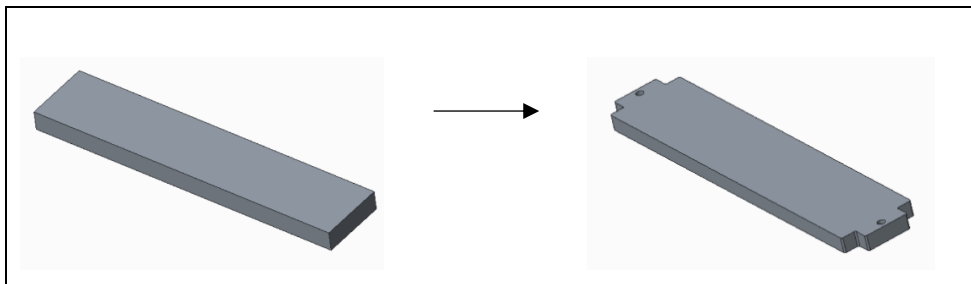
Two holes are placed on the inside, where screws will be screwed into the sides. See figure 6.9 for the development of the side plate in this development phase.



**Figure 6.9: Before and after detail development – side plate.**

### Top side

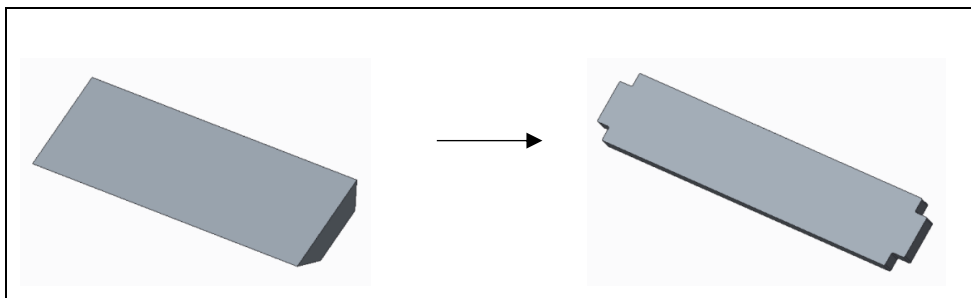
The top side is not changed that much. The ends of the top side are modified to be able to be attached to the side plates. Two holes are placed at end of each side, where screws will be screwed into the side plates See figure 6.10 for the development of the top side in this development phase.



**Figure 6.10: Before and after detail development – top side.**

### Side

The side is not changed that much. The width and height of the profile of short side are slightly changed. The ends of the side are modified to be able to be attached to the side plates. See figure 6.11 for the development of the side in this development phase.



**Figure 6.11: Before and after detail development – side.**

## 6.3 Material selection

There is no general restriction or limitations in the material selection. However, it is recommended from Volvo to use an already used material in the workshop at Volvo for the packaging. See table 6.2 for the available materials which suits for the packaging.

**Table 6.2 Available materials.**

<i>Material</i>	<i>Category</i>
POM (Acetalplastic POM)	Polymer
HD 1000 SBF (High-density polyethylene)	Polymer
Construction plywood	Wood

From the customer needs the criteria's in table 6.3 should be fulfilled:

**Table 6.3 Material criteria's.**

<i>Material criteria</i>	<i>Unit</i>
Low density	kg
Durable	N/mm <sup>2</sup>
High fatigue strength	MPa
Oil repellent	-
Washable	-
Low cost	kr/kg

To be able to compare materials and select an optimal material, a comparison of materials are made with the software CES 2018. See table 6.4 for data for each material. All data are collected from CES 2018 and some data, for example the price, are approximate data used for ranking purposes.

**Table 6.4 Data for available materials.**

<i>Property</i>	<i>POM</i>	<i>HD 1000 SBF</i>	<i>Construction plywood</i>
Price [SEK/kg]	20	14	5
Density [kg]	1.41	0.94	0.6
Tensile strength [MPa]	70	20	30
Fracture toughness [MPa·m <sup>1/2</sup> ]	4	1.5	0.75
Fatigue strength at 10 <sup>7</sup> cycles [MPa]	24	9.5	28
Durability: Water	Excellent	Excellent	Limited use
Durability: Organic solvents	Acceptable	Limited use	Acceptable
CO <sup>2</sup> footprint [kg/kg]	3	1.8	1.3

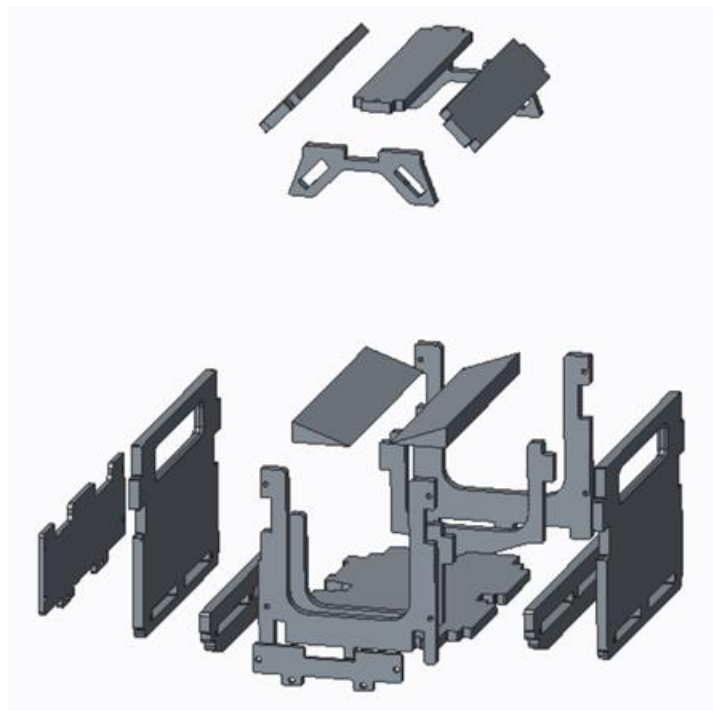
### Material selection

The final material selection is based on the available data in table 6.4, discussions with supervisors, customer needs and target specifications. Quite early in the development process a number of parties opted to change material from the existing construction plywood to some kind of polymer. The main reasons for this were to be able clean the packaging easier, reduce wear, get rid of ripped wooden chips and get a more “industrial” material for the production. These arguments reduced the material choice to select between POM and HD 1000 SBF.

HD 1000 SBF is both lighter and cheaper than POM and has a lower CO<sup>2</sup> footprint. However, POM has higher tensile strength, fracture toughness and fatigue strength, which could open opportunities to design with smaller dimensions. However, HD 1000 SBF is selected due to mainly the lower density.

## 6.4 Assembly

To be able to mass-produce the packaging and get good tolerance and fit, the assembly must be accurate, efficient and fast. This is achievable thanks to that each component can be attached to each other and the design holds each component in the correct place without the need of measuring and securing components. Moreover, the design minimizes the need for screws and glue joints. The assembly instructions are presented in Appendix H. See figure 6.12 for an exploded view of the packaging.



**Figure 6.12: Exploded view of the packaging.**



# 7 Results

*This section contains the results from the product development process of a new packaging solution. First, the new packaging solution will be presented, the properties of the packaging and the sizes of which the packaging will be available in. The results from a Finite Element Method analysis will be presented and then the prototypes of the packaging.*

## 7.1 Gear hob packaging solution

The new packaging solution is an evolution of the existing packaging solution. Different customer needs have been taken into account during the development process and as many of these needs as possible have been tried to be fulfilled. The packaging is produced out of sheets of polyethylene, which is a durable material suited for this application and the density is relative low for a plastic material. The new main features of the new packaging solution is:

- Larger and more open short sides for better access to the gear hob
- Top cover for protection from outer debris and protection of hands during lifts
- Integrated handles designed according to Volvo ergonomic guidelines
- Possibilities to use lifting devices, which is lifting from underneath of the packaging
- Lower inner support, which enables storage in a lower position in the packaging
- Separate transparent pocket for the sharpening card on one of the long sides
- Pocket on one of the short side for identification number
- Secure design for stacking the packaging
- Optimized sizes of packaging for current used gear hobs in the production
- Designed for an effective manufacturing and assembly process

### 7.1.1 Dimensions and weight

An important customer need was to reduce the size of the total area and volume which each packaging takes up, since storage space and space in general is limited at the factory site. The existing packaging have two sizes and the new packaging solution will have three sizes of the packaging. The dimensions of these new three sizes of the packaging are based on the spread of sizes of the gear hobs. The longest gear hob used today in production is 273 mm long and thereby the size “Large” should fit this length. The main part of the gear hobs are 225 mm long and the size “Medium” is designed for this length to optimize the size for as many gear hobs as possible. The size “Small” is small enough to be able to reduce the size of the packaging but at the same time be long enough to fit enough of gear hobs with lower lengths. All sizes have the same height and width for easy storage. All packaging can be stacked on top of each other if they are of the same size or if the upper packaging is of a smaller size. A larger packaging cannot be stacked on a smaller packaging. See table 7.1 for external dimensions of the three sizes of the packaging.

**Table 7.1 Sizes of the new packaging solution.**

<i>Packaging</i>	<i>Unit</i>	<i>Small</i>	<i>Medium</i>	<i>Large</i>
Width	[mm]	178	178	178
Length	[mm]	217	282	327
Height	[mm]	200	200	200

To avoid loss of space efficiency, the length of gear hobs decides which size of the packaging that should be used, see table 7.2 for which sizes of gear hobs that suits in which packaging.

**Table 7.2 Length of gear hob for each size of the packaging.**

<i>Packaging</i>	<i>Length of gear hob [mm]</i>
Small	0 – 160
Medium	160 – 230
Large	230 - 275

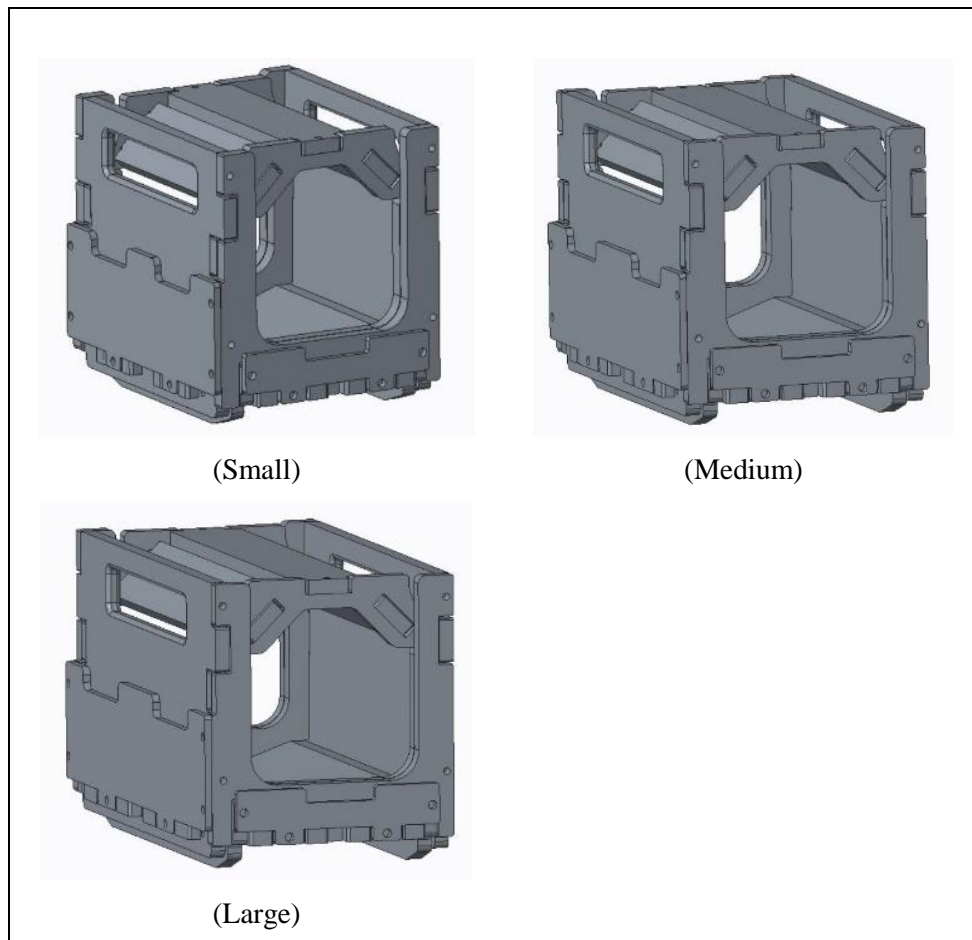
The weight of the new packaging solution for the three different sizes are shown in table 7.3. The weights are shown for the packaging and the top cover separate, as well as the total weight for them both.

**Table 7.3 Weights of the new packaging solution.**

<i>Packaging</i>	<i>Packaging [g]</i>	<i>Top cover [g]</i>	<i>Total [g]</i>
Small	1649	311	1960
Medium	2097	403	2500
Large	2407	466	2873

### 7.1.2 Renderings of the new packaging solution

Since the different sizes have the same width and height, it is the length who varies and thereby the design of the long side. See figure 7.1 – 7.5 for renderings of the new packaging in the different sizes.



**Figure 7.1: Illustrations of the new packaging (Overview).**

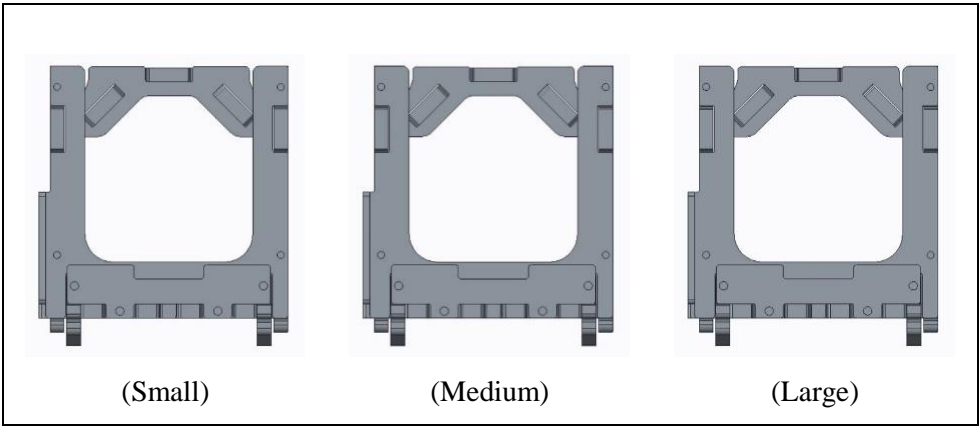


Figure 7.2: Illustrations of the new packaging (View of short side).

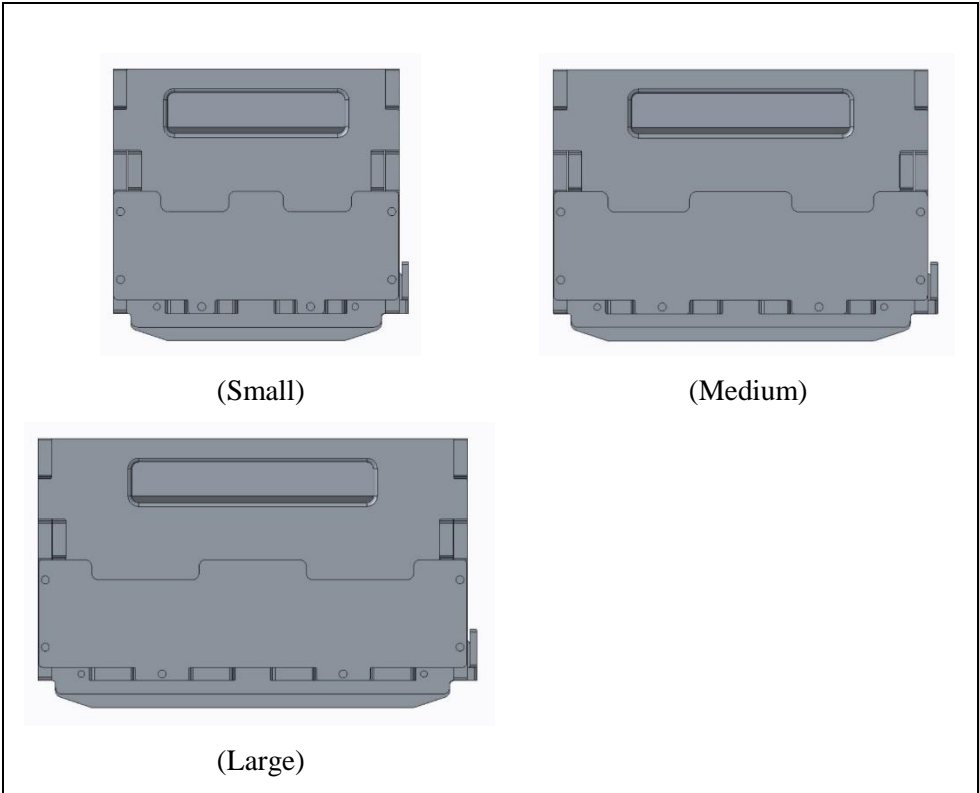
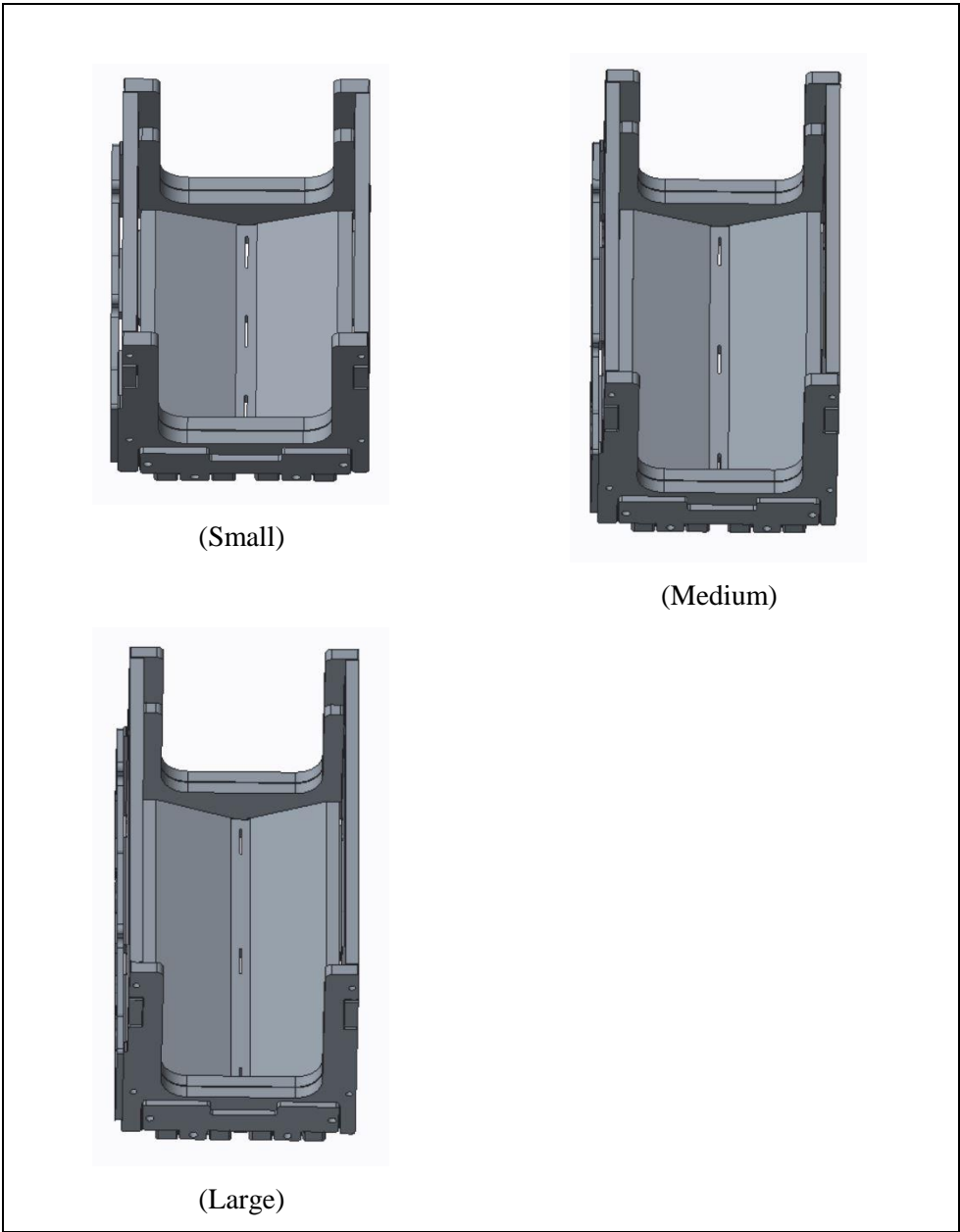


Figure 7.3: Illustrations of the new packaging (View of long side).



**Figure 7.4: Illustrations of the new packaging (Top view).**

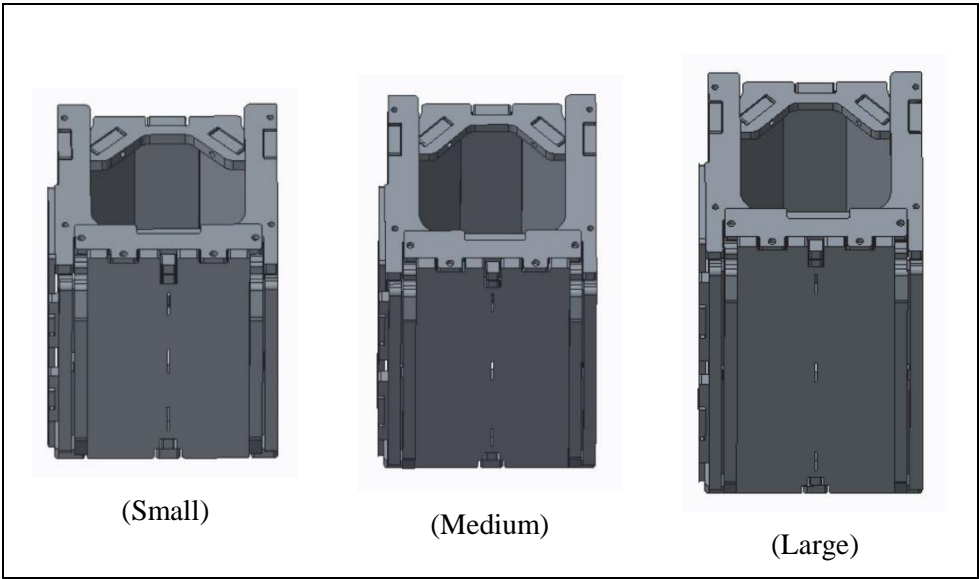


Figure 7.5: Illustrations of the new packaging (Bottom view).

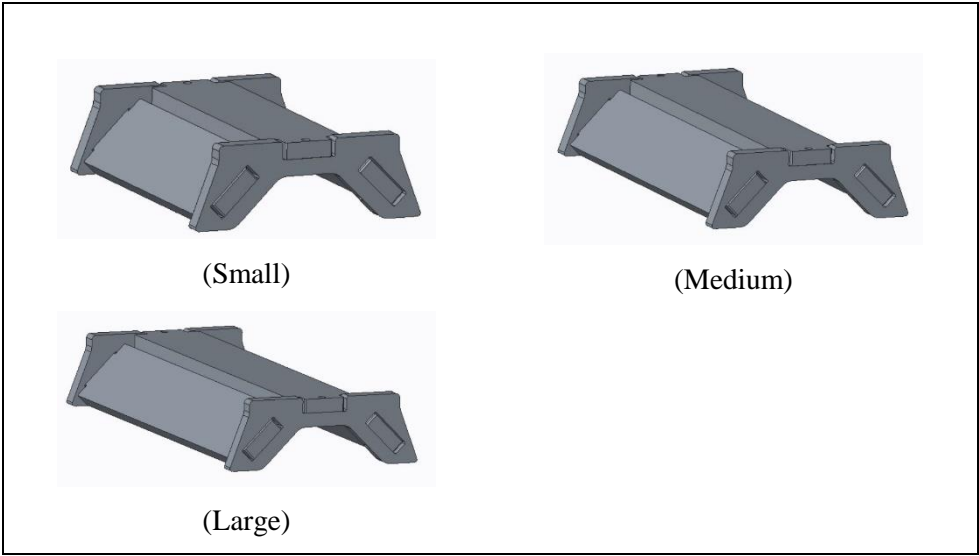
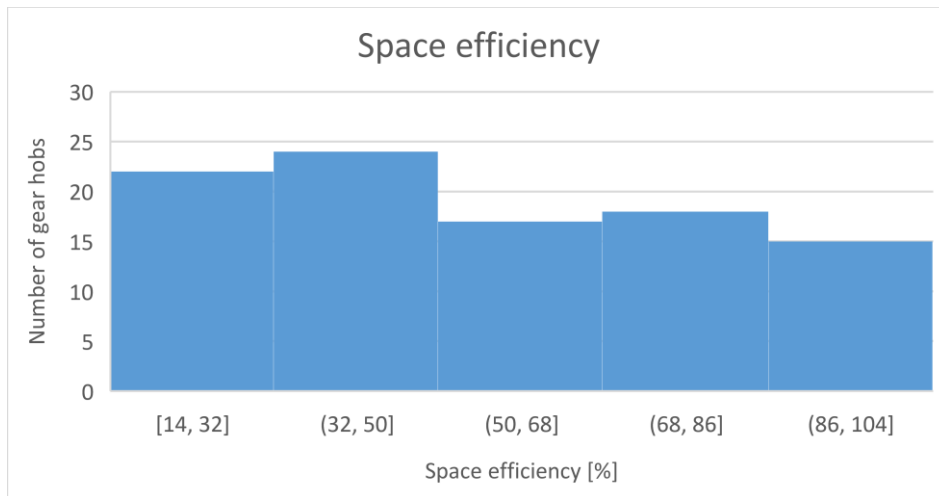


Figure 7.6: Illustrations of the new packaging (Top cover).

### 7.1.3 Space efficiency

The space efficiency was calculated for the existing packaging solution. The space efficiency is calculated for the new packaging solution. The same method is used to calculate the space efficiency for the new packaging solution as for the existing packaging solution and gear hobs are placed in the right size according to table 7.2. In figure 7.7 a histogram of the spread in space efficiency of used gear hobs are shown.



**Figure 7.7: Histogram of the space efficiency.**

In table 4.3 the interval, average and median for space efficiency are shown both for the existing packaging and the new packaging.

**Table 7.4 Space efficiency.**

<i>Space efficiency [%]</i>	<i>Interval</i>	<i>Average</i>	<i>Median</i>
<i>Existing packaging</i>	13 – 95	49	50
<i>New packaging</i>	14 – 91	53	53

#### 7.1.4 Disadvantages of existing packaging solved?

During research about the existing packaging solution, disadvantages were collected. In table 7.5 it is discussed if the new packaging solution solves or at least improves the disadvantages of the existing packaging.

**Table 7.5 Disadvantages of existing packaging solved?**

<i>Problem</i>	<i>Description</i>
<i>Dirty packaging</i>	The new packaging is manufactured in a plastic material which is water repellent and is possible to clean in laundry machines in the factory.
<i>Operational problems</i>	The new packaging has redesigned handles for improved handling and it has larger and more open sides for better access to the gear hob.
<i>Bad ergonomics</i>	The new packaging is designed according the latest ergonomic guidelines from Volvo and an ergonomist has given input to the development.
<i>Lifting device does not fit</i>	The new packaging does not fit the lifting device in the A-workshop, however it is easier to use lifting device which grips the gear hob from the short side. The new packaging is also prepared for future use of a new lifting device which can lift the whole packaging from underneath.
<i>Placement of the sharpening card</i>	The new packaging has a separate pocket for placement of the sharpening card.
<i>Protecting material</i>	The protecting material has not been developed and the same protecting material needs to be used. However the plastic material the new packaging is manufactured of should protect the gear hobs better.
<i>Protruding tool (diameter)</i>	With the new packaging none of the size of gear hobs are protruding as long as the right size of packaging is used.
<i>Protruding tool (length)</i>	With the new packaging none of the size of gear hobs are protruding as long as the right size of packaging is used.
<i>Wooden chips from the packaging</i>	The new packaging is manufactured in a plastic material which is durable and no chips will be torn from the packaging.



### 7.1.6 Target specification

In the early part of the product development process target specification were stated. In table 7.6 the set marginal and ideal value are shown as well as the real value from the new packaging is shown.

**Table 7.6 Target specification.**

<i>Metric no.</i>	<i>Metric</i>	<i>Unit</i>	<i>Marginal value</i>	<i>Ideal value</i>	<i>Real value</i>
1	Inside size of the packaging (Largest size)	mm	> W:145 > L: 273 > H: 145	> W:155 > L: 283 > H: 155	W: 150 L: 280 H: 160
2	Outside size of the packaging (Largest size)	mm	< W:200 < L: 320 < H: 200	< W: 180 < L: 300 < H: 180	W: 180 L: 328 H: 200
3	Space efficiency	%	> 50	> 70	53
4	Works with gear hobs with shafts	Binary	Yes	Yes	Yes
5	Total weight	kg	< 2	< 1,5	2,5
6	Oil repellent	Binary	Yes	Yes	Yes
7	Water resistant	Binary	Yes	Yes	Yes
8	Ergonomic handles <sup>2</sup>	Binary	Yes	Yes	Yes
9	Durable	N	≥ Heaviest gear hob	> Heaviest gear hob	> Heaviest gear hob
10	Protection for the gear hob	-	Bottom and sides are protected	Bottom, sides and top are protected	Bottom, sides and top are protected
11	Works with lifting devices	Binary	Yes	Yes	Yes
13	Stackable	No.	≥ 2	> 2	No limit

#### Color guide

**Green** = Reached ideal value

**Yellow** = Reached marginal value

**Red** = Does not reach marginal or ideal value

<sup>2</sup> According to Volvo Group: Ergonomiska Riktlinjer – Produktion 2017 [6].

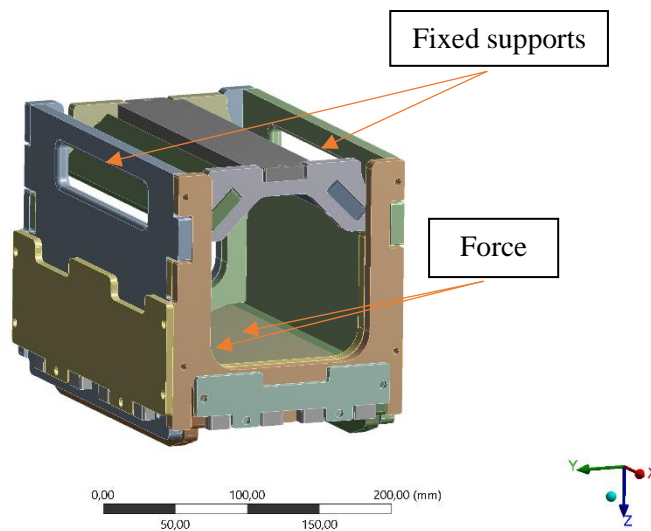
## 7.2 Finite element method analysis

To verify that the design withstands the weight of the gear hob a finite element method analysis (FEA) is performed. In the following chapter, results from the FEA of the medium sized packaging are shown. The results from the FEA of the small and large sized packaging were very similar and thereby, only results from the medium sized packaging are selected to be presented.

In the FEA the material HD 1000 SBF was selected and if the safety factor is large enough, this material can be used for manufacturing the packaging.

### 7.2.1 Packaging

In the FEA, it simulates an operator holding the packaging in the handles with the largest gear hob used in production today inside the packaging. Fixed supports are put at the top of the handles and a force corresponding to the weight of the gear hob are put on the inner supports, see figure 7.8.



**Figure 7.8: Supports and forces in the FEA.**

## Stresses

The highest levels of stress were at the top corners of the handles and at the holes on the bottom plate with approximately a top level of 4 MPa. An overview of the stresses of the packaging are shown in figure 7.9, details of the stresses on the handles of the packaging are shown in figure 7.10 and 7.11.

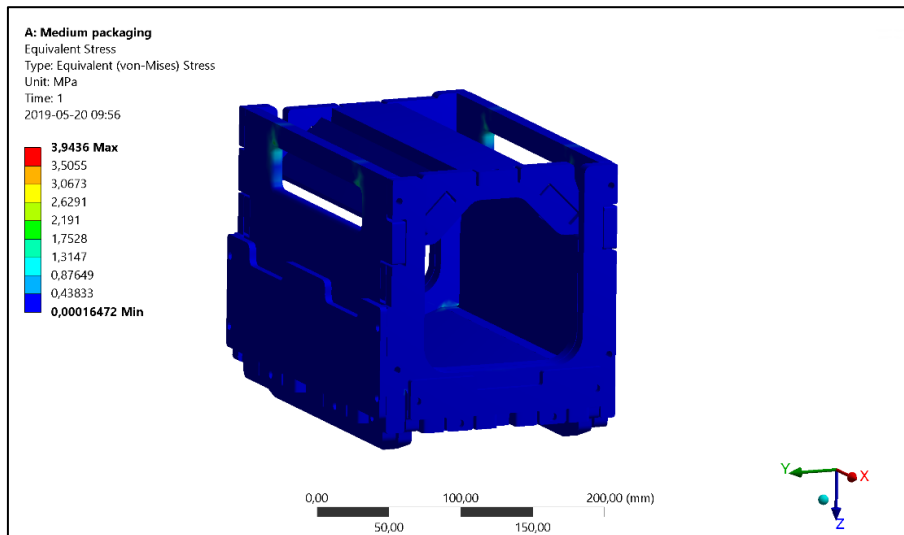


Figure 7.9: Overview of the stresses in the packaging.

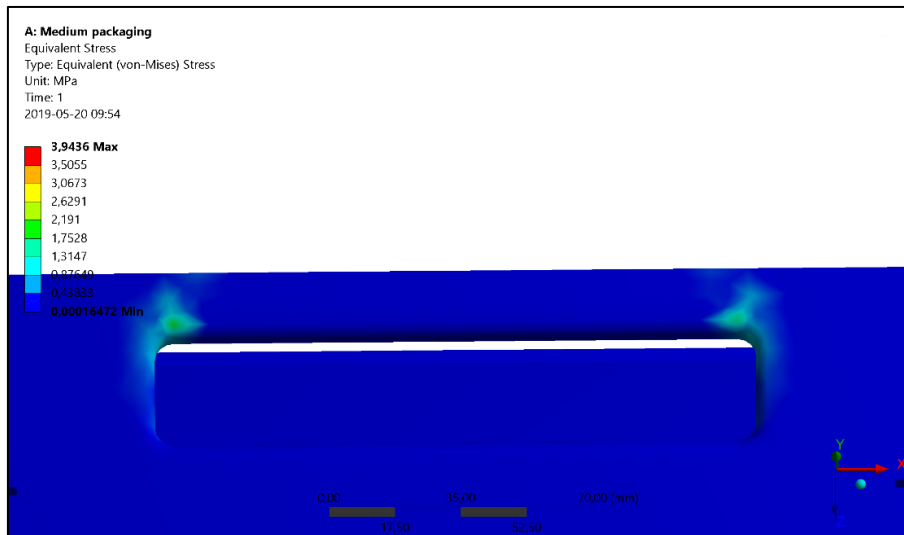
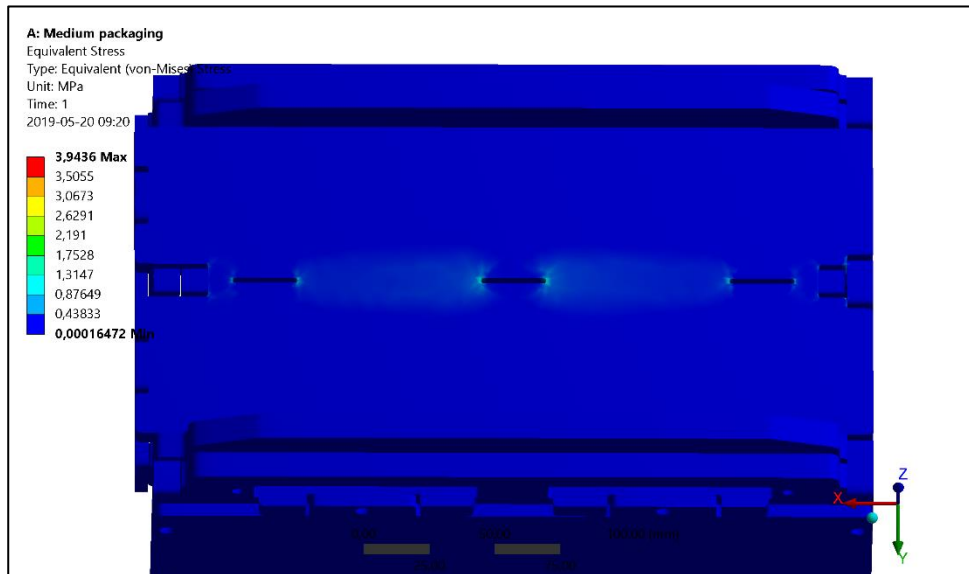


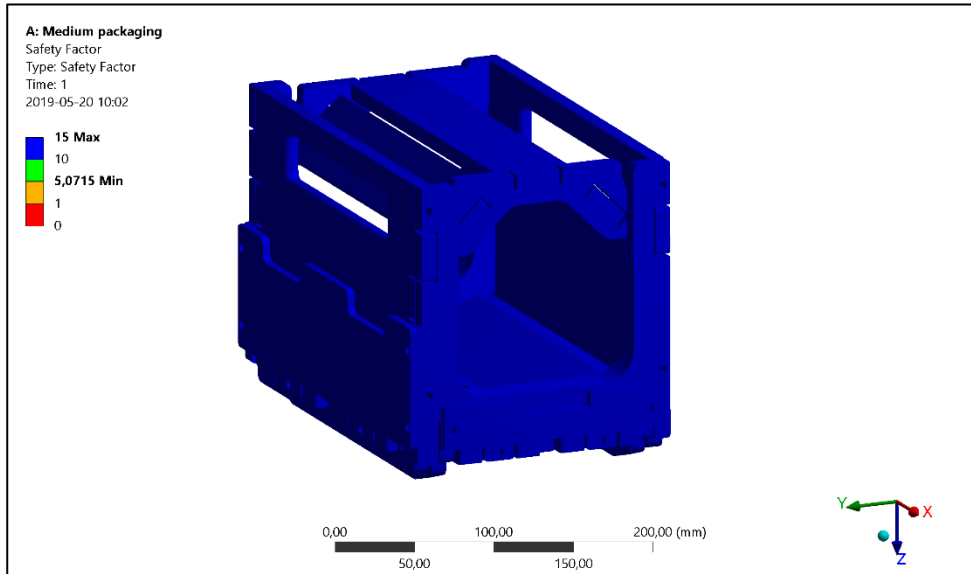
Figure 7.10: Details of the stresses in the packaging.



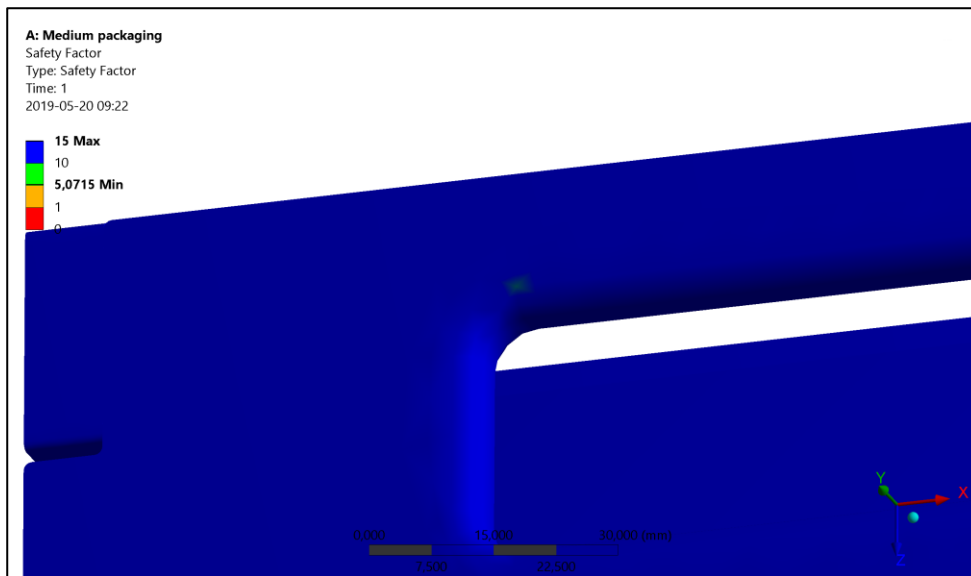
**Figure 7.11: Details of the stresses in the packaging.**

### Safety factor

The lowest safety factor against failure is five and is on the same spot where the highest stresses were found. An overview of the safety factor of the packaging are shown in figure 7.12 and details of the safety factor on the handles of the packaging are shown in figure 7.13. Even though the lowest safety factor is around 5, it is that low only on a very small spot and it is hard to see that in the figures. This could indicate on singularities and that the real lowest safety factor is higher. This means that it seems for sure that the packaging will manage the weight from the heaviest gear hob.



**Figure 7.12: Overview of the safety factor in the packaging.**



**Figure 7.13: Overview of the safety factor in the packaging.**

## Deformation

The largest deformations happens at the bottom of the packaging in the middle of the bottom plate, where the maximum deformation was 0.12 mm. An overview of the deformations of the packaging are shown in figure 7.14 and details of the deformations of the packaging are shown in figure 7.15.

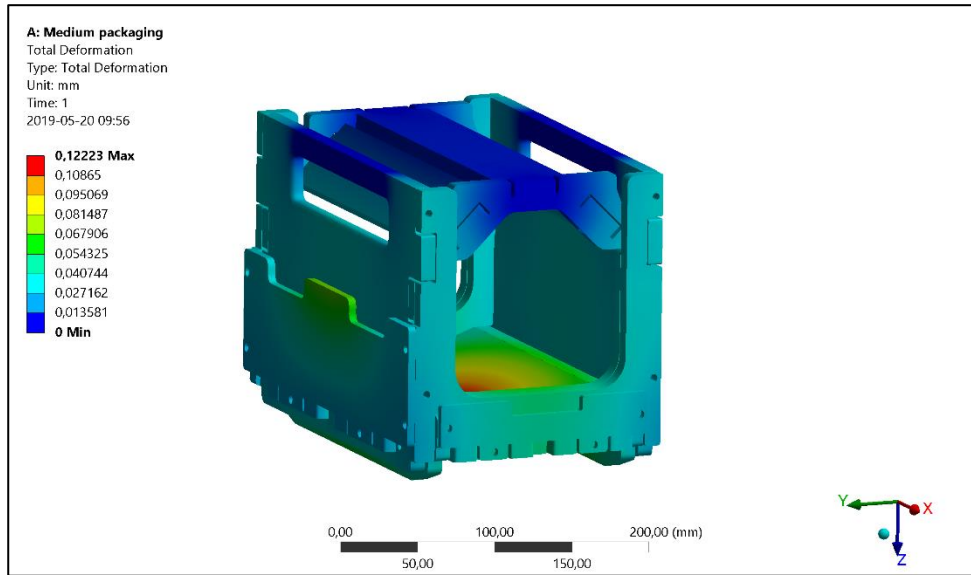


Figure 7.14: Overview of the deformations of the packaging.

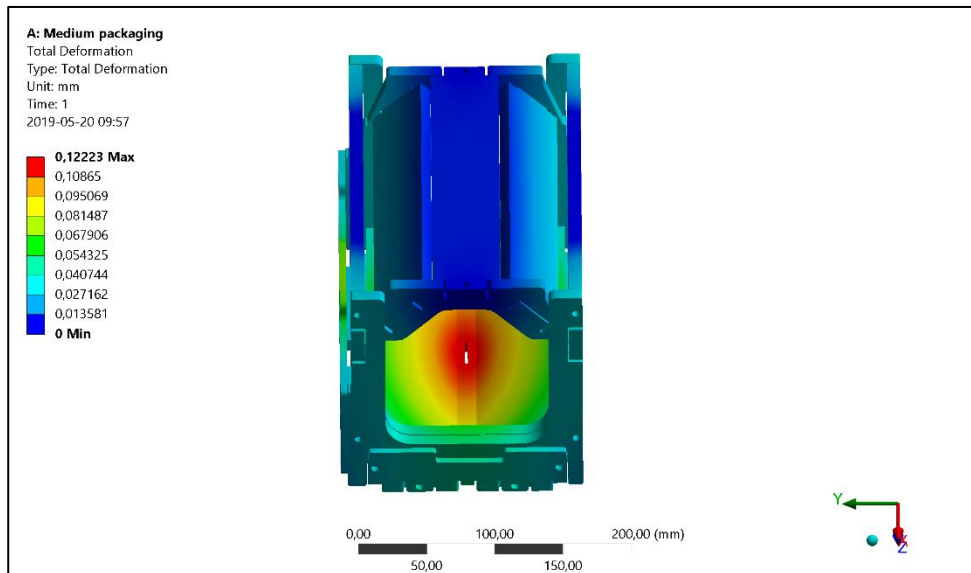


Figure 7.15: Details of the deformations of the packaging.

## 7.2.2 Top cover

A FEA was also done when the top cover lay upside down on a bench and with the largest gear hob put on the top cover. Fixed supports are put at the bottom of the short sides and forces corresponding to the weight of the gear hob are put on the inside of the long sides, see figure 7.16.

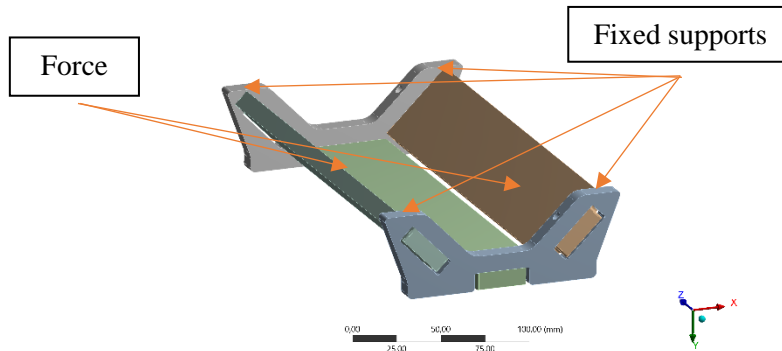


Figure 7.16: Supports and forces in the FEA.

### Stresses

The highest levels of stress were at the bottom of the top cover with approximately a top level of 2.6 MPa. An overview of the stresses of the top cover are shown in figure 7.17.

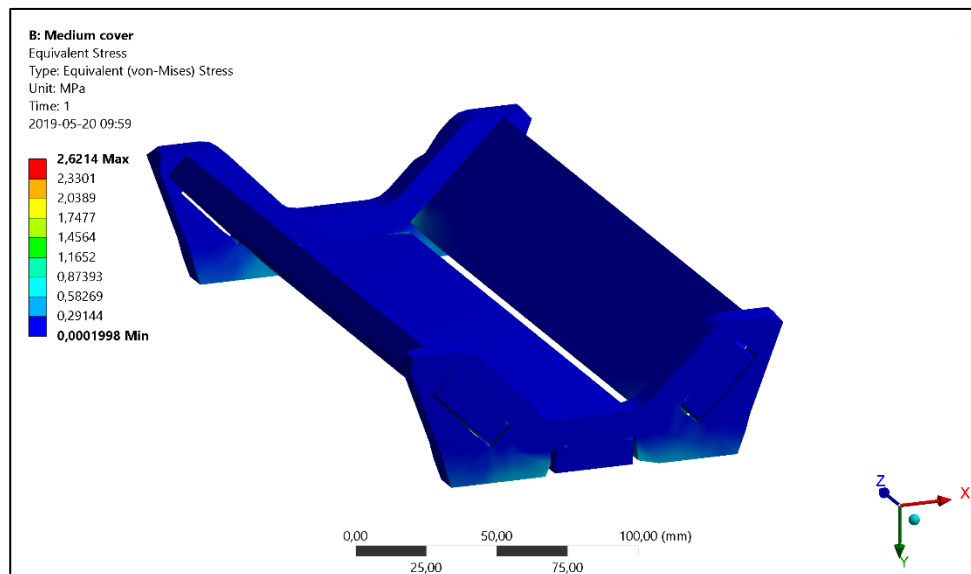


Figure 7.17: Overview of the stresses in the packaging.

### Safety factor

The lowest safety factor against failure is around 7.6. An overview of the safety factor of the top cover packaging are shown in figure 7.18. Even though the lowest safety factor is around 7.6, it is that low only on a very small spot and it is hard to see that in the figures. This could indicate on singularities and that the real lowest safety factor is higher. This means that it seems for sure that the top cover will manage the weight from the heaviest gear hob.

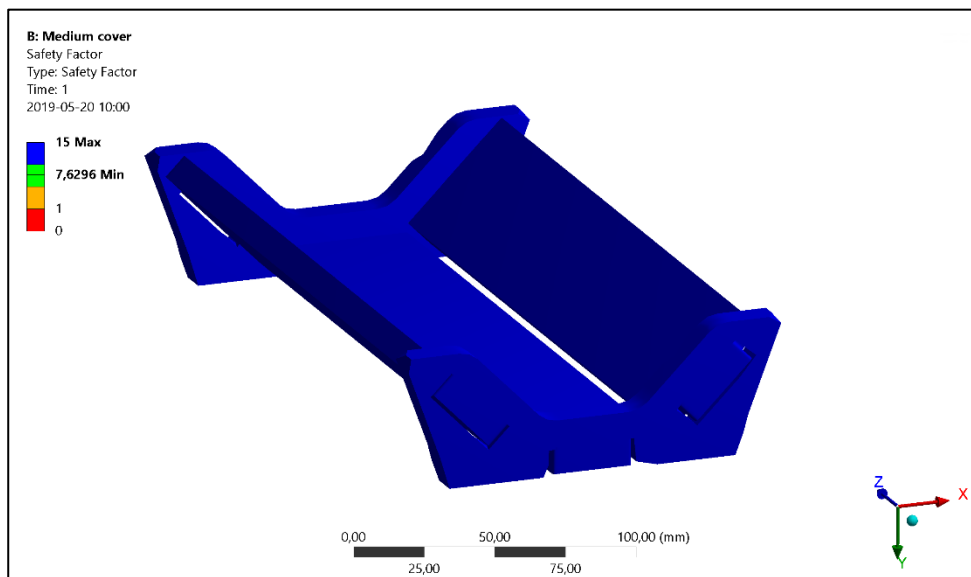


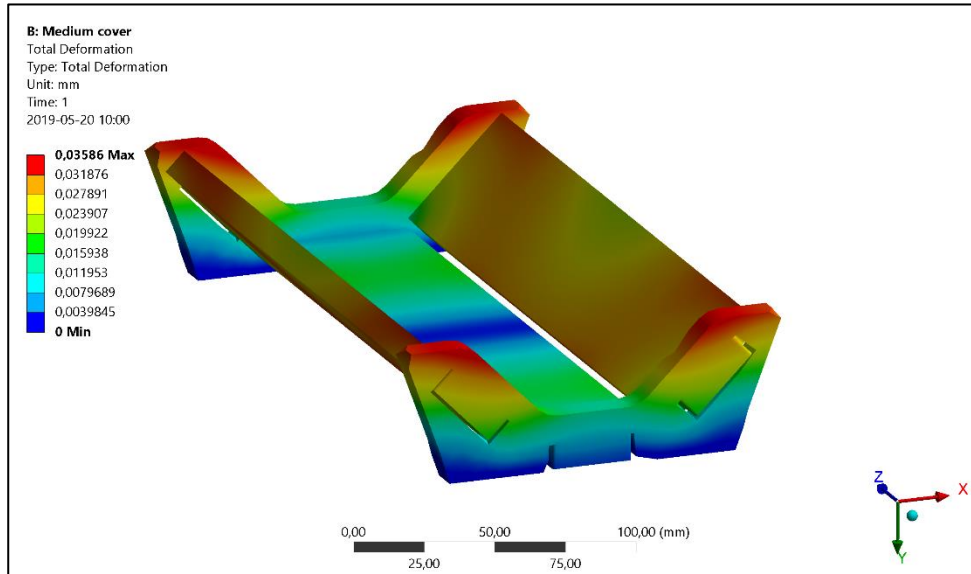
Figure 7.18: Overview of the safety factor in the top cover.



## Deformation

The largest deformations happens at the bottom of the packaging in the middle of the bottom plate, where the maximum deformation was 0.04 mm.

An overview of the deformations of the top cover are shown in figure 7.19.



**Figure 7.19: Overview of the deformations of the packaging.**

## 7.3 Prototype

Prototypes of the final concept are 3D printed, to be able to verify that the design works in reality and to get a better feeling and understanding of the new packaging concept. A solid model is printed in 30 % scale, where the different components are assembled and merged into one component before printing. This model was printed to get an overview of the design and verifying that the design works with the packaging, gear hob and top cover. Additional to the solid model all the components for one packaging are printed in 30 % scale. These components can be assembled to one packaging, simulating the assembly steps for the real packaging. Both of these 3D printed models are in the size “medium”.

### 7.3.1 Solid 3D printed model

The solid 3D printed model was printed in 30 % scale. The printed gear hob had the largest dimensions in length and diameter which suits in the “medium” size of the packaging. The 3D model verifies the design and the gear hob suits in the packaging and the top cover suits as well. See figure 7.20 for an overview of the 3D printed model with the packaging, the gear hob and the top cover.



**Figure 7.20: Overview of 3D printed solid model.**

The top cover also works as a stand for the gear hob when taken out of the packaging, see figure 7.21. The 3D printed model verifies that this works.



**Figure 7.21: Overview of gear hob placed in the top cover.**

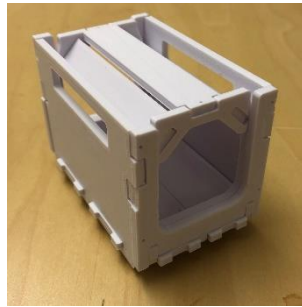
Additional views of the packaging, the top cover and the gear hob are shown in figure 7.22.



**Figure 7.22: Different views of the 3D printed packaging.**

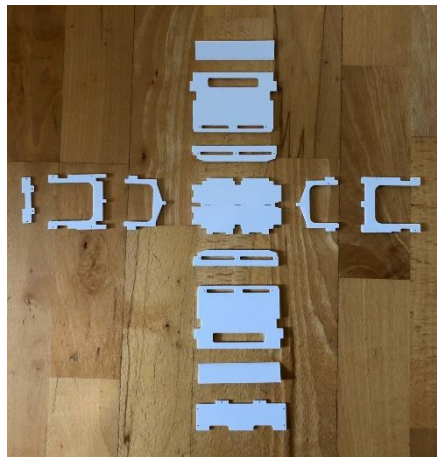
### 7.3.2 3D printed components

The 3D printed components were printed in 30 % scale. The components can be assembled to one packaging in the size “Medium”. This 3D printed model verifies that the assembly process works and a full scale model can be manufactured and then assembled in the same way. See figure 7.23 for an overview of the 3D printed components assembled to one packaging.



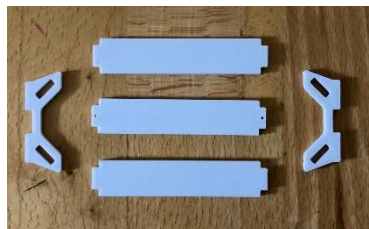
**Figure 7.23: Overview of 3D printed components assembled to one packaging.**

The packaging is assembled with the components in figure 7.24.



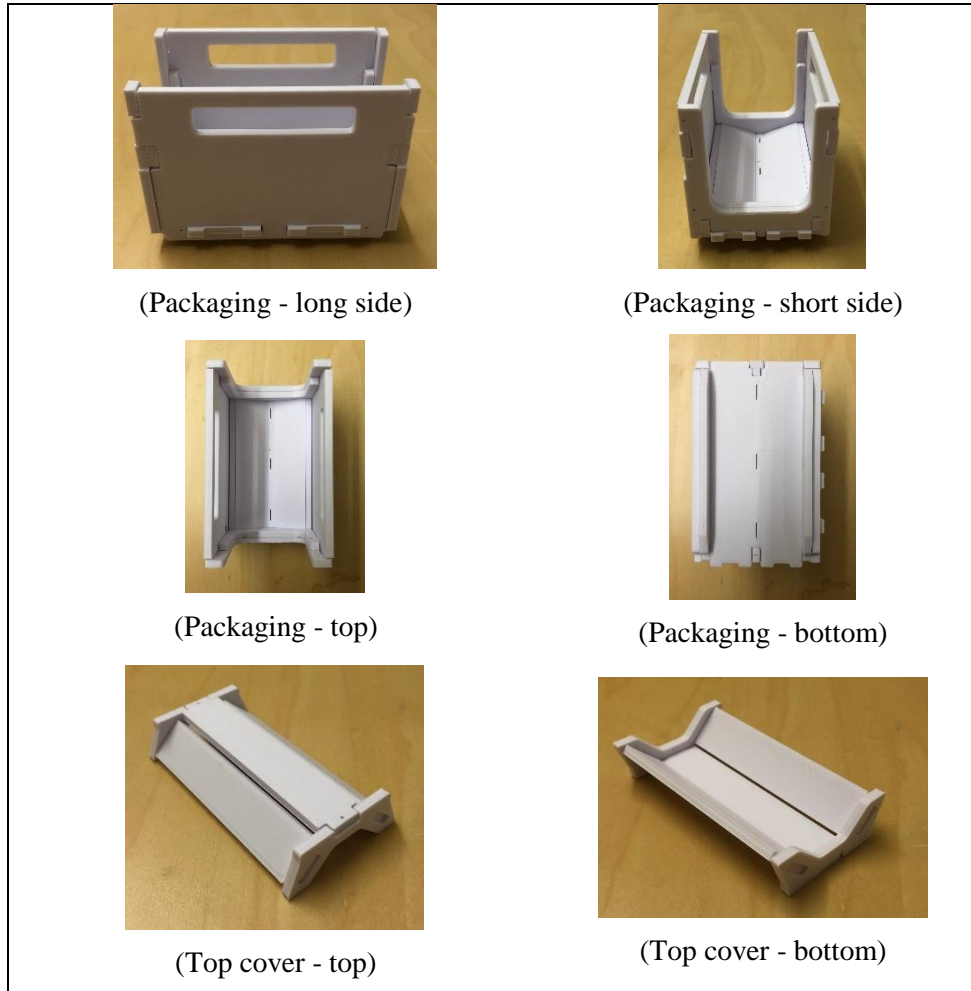
**Figure 7.24: Overview of components for the packaging.**

The top cover is assembled with the components in figure 7.25.



**Figure 7.25: Overview of components for the top cover.**

Additional views of the packaging and the top cover assembled are shown in figure 7.26.



**Figure 7.26: Different views of the 3D components assembled to one packaging.**

# 8 Discussion and conclusion

*This section contains the discussion and conclusion for thesis work. First different parts of the product development process are discussed and then the final conclusions of the project are presented.*

## 8.1 Discussion

### 8.1.1 The product development process

The product development method by Ulrich and Eppinger has been followed throughout the process. Their method was modified early in the work process to suit this project. This change simplified the workflow of this project and helped focus on the important parts of the development process. It has been very helpful to have a method to follow during the development process and by following this method a structure was possible to establish to follow throughout the work process. The process has been an iterating process with developing and designing concepts and testing and doing further developing.

### 8.1.2 Data collection

The main part of the data collection has been done through interviews with different personnel around in the factory. Since different persons experience the packaging in different ways, some customer needs could be missing or misleading. This could have been reduced further by conducting more interviews and observations. However, enough personnel were interviewed to be able to state good enough customer needs, which the target specifications are set from for the development of the new packaging. If the time frame would have been longer, more observations could have been done to see and experience the usage of the packing in the production.

### **8.1.3 Product concept**

The brainstorming part of the product development process was given a large amount of time, which were good since it took some time to come up with some ideas and some ideas came up instantly. It was hard to do the external benchmarking since the product is a specialized product and no standardized solution. Other similar manufacturing companies probably have similar packaging solutions, however often their solution is custom made for them and this makes it hard to do direct external benchmarking of comparable packaging solutions. The external benchmarking was instead mainly performed with general industrial packaging and the focus was instead on how general industrial packaging solved the stated sub-problems in this project. This external benchmarking on general industrial packaging was helpful to get ideas on concept on how to solve these sub-problems.

A large amount of concepts for each sub-problem were generated and gave the possibility to explore larger parts of the space of solutions. A large amount of time was given to this part of the development process in relationship to the length of the timeframe for the whole project. If the time frame for the project would have been longer, the time spent on brainstorming ideas could have been longer and more discussions with different persons could have been held to discuss the generated ideas and try to find even more ideas.

### **8.1.4 Target specifications**

This chapter discuss the target specifications and how the new packaging solution meet the target specifications. The target specifications were mainly based on customer needs, but also on input from supervisors and earlier conducted work.

One of the most important target specification was the size of the packaging. The existing packaging is available in two sizes and these sizes were outdated, since new longer gear hobs have been started to be used in production after that the existing packaging was designed. The newly developed packaging come in three sizes and are dimensioned for existing used gear hobs. With the implementation of feet on the packaging the packaging has become higher. The height is a critical dimension around on many places where the packaging is stored. However, the packaging is designed so that it is low enough to be used everywhere. With the addition of a top cover, supports for the top cover were necessary. The designed supports make the packaging a bit longer. The chosen idea was however the most space efficient concept of the generated concepts.

The space efficiency for the new packaging compared to the existing packaging is higher, but just slightly. This could depend on that that the new packaging come in just one more size than the existing solution. Three different sizes of the new packaging solution were chosen to be produced. This to make the packaging logistics as well as the manufacturing easier. Another reason why the space efficiency did not improve so much, could be that the height is the same for all sizes of the packaging and some gear hobs have small diameter compared to how large diameters that the packaging can handle. The same height on all sizes of the packaging were chosen, since some short gear hobs have a large diameter and to be able to reduce the number of sizes of the packaging.

The new packaging solution reaches the target specification with having an oil and water repellent material. This make it possible to wash the packaging which improves the cleanness of the packaging handling.

The handles of the new packaging are a big improvement. It is designed according to Volvo's ergonomic guidelines which greatly improves the ergonomic for operators. This is especially important for those operators who handles the packaging on a daily basis. During discussions with one of the operators it came up that he had been forced to operate his hands due to damages in his hands for having handled the existing packaging during many years.

### **8.1.5 New packaging solution**

The new packaging solution solves the main part of the problems and disadvantages of the existing packaging solution. The design with components which fit into each other like a building kit works good. This was tested with a 3D printed scaled components, which could be used to simulate the assembly process of the new packaging solution. The 3D printed solid model also verified that the overall design worked as designed.

The safety factor against failure for the packaging it was 5 as lowest and for the top cover it was 7.6 as lowest. However, it was only this low for both the packaging and the top cover on a very little spot. This could be singularities and the real values for the safety factors are presumably higher. This gives a quite high safety factor. The question is how high the safety factor should be to be able to withstand many years of continuous use without getting damaged. When the safety factor is this high it should not break from just the weight of the gear hobs. The problem and what is hard to simulate are loads, shocks and strains from continuous, daily use in the factory. The best way to determine if the packaging are enough dimensioned is to test the packaging during a longer period in the factory and then examine if it need to be dimensioned more or less.



### 8.1.6 Future work

The final design of the new packaging is fully developed and it can be manufactured with water jet cut components and assembled at the workshop at Volvo. If Volvo decides to implement the new packaging solution, the following areas could be looked more upon before ordering the new packaging:

- **Mass production**  
Depending on the numbers of packaging that should be manufactured different manufacturing method could be used. The current design is mainly developed for prototype manufacturing and for smaller batches. Before manufacturing a larger batch it could be examined if the packaging should be manufactured in the same way or if some other manufacturing method is more cost-efficient for larger batches.
- **Material selection**  
The material selection process during the product development process was made of material current used by the workshop at Volvo. The chosen material seems to be a cost-effective material suited for the task. However more material could be examined and compared and also materials which Volvo usually does not work in, to find a more optimal material.
- **Implementation of lifting devices**  
Since the development of the new packaging was done parallel with the implementation of new lifting devices in the storage, the design of feet and space underneath the packaging could not be designed for a specific dimensions of a lifting design, but a general lifting device. When the new lifting device in the storage is implemented, exact dimensions of the packaging can be designed and thereby optimize the height of the packaging.
- **Design of the top cover**  
During the development of the top cover a balance between design and manufacturability was taken into consideration. If another manufacturing method is chosen for manufacturing of the packaging, the design could be developed and changed.
- **Topology optimization**  
To be able to reduce the weight further a topology optimization could be made and see if it is possible to change the design and reduce the weight. This should be done with cautions, so that the protection of the gear hob is not reduced.

## 8.2 Conclusion

A new packaging solution for gear hobs have been developed during this project. Customer needs have been taken into account, as well as the problems and disadvantages of the existing packaging. The new packaging is designed in three different sizes and dimensioned for the current used gear hobs in the factory. A material selection study chose the most optimal material for the packaging, of the available materials. A finite element analysis have been performed to simulate the stresses and deformation of the packaging when used and results from this analysis indicates that the packaging is dimensioned correct. Scaled prototypes have been 3D printed to verify the design.

The final prototype fulfills the main part of the customer needs and solves the main part of the problems with the existing packaging solution. Manufacturing of the new packaging can be started, at least in smaller batches. If a larger batch should be manufactured of the packaging, further research and development are recommended to do and examine different manufacturing methods.

# References

- [1] Volvo Group. (n.d.). This is Volvo Group. Retrieved April 11, 2019, from <https://www.volvogroup.com/en-en/about-us.html>
- [2] Volvo Group. (n.d.). Our mission and vision. Retrieved March 4, 2019, from <https://www.volvogroup.com/en-en/about-us/our-mission-and-vision.html>
- [3] Volvo Group. (n.d.). Volvo Group presentation. Retrieved May 11, 2019, from <file:///C:/Users/A315266/Downloads/Volvo-Group-Presentation.pdf>
- [4] Volvo Group. (n.d.). Organization. Retrieved March 14, 2019 from <https://www.volvogroup.com/en-en/about-us/organization.html>
- [5] Roberson, G. L. (1990). Good and Bad Packaging: Who Devides?. *International Journal of Physical Distribution & Logisitcs Management*, 20(8), 37-40. <http://dx.doi.org/10.1108/09600039010005575>.
- [6] Bowersox, D. J., Closs, D. J. & Bixby Cooper, M. (2002). *Supply Chain Logisitcs Management* (1<sup>st</sup> ed.). New York, United States: McGraw-Hill
- [7] Ulrich, K. T. & Eppinger, S. D. (2012). *Product Design and Development* (5<sup>th</sup> ed.). New York, United States: McGraw-Hill.
- [8] Volvo Group. (2017). *Ergonomiska riktlinjer – Produktion 2017* (0001-27-521).
- [9] Corbin, J. & Morse, J. (2003). The Unstructured Interactive Interview: Issues of Reciprocity and Risks when Dealing with Sensitive Topics. *Qualitative Inquiry*, 9(3), 335-354. <http://dx.doi.org/10.1177/1077800403009003001>
- [10] Wikimedia Commons. (2005, August 6). Milling Cutter Hobbing Involute. [image file]. Retrieved March 5, 2019, from <https://commons.wikimedia.org/wiki/File:MillingCutterHobbingInvolute.jpg>
- [11] MatWeb. (n.d.). Acetal (POM) Engineering Property Data. Retrieved March 13, 2019, from <http://www.matweb.com/reference/acetalpolymer.aspx>
- [12] Christian Berner AB. (n.d.). Etenplast, PE. Retrieved May 10, 2019, from <https://www.christianberner.se/globalassets/leverantorer/rochling/dokument/polyeten-pe-etenplast/etenplast-pe.pdf>
- [13] Christian Berner AB. (n.d.). Lagersortiment. Retrieved March 20, 2019, from <https://www.christianberner.se/globalassets/leverantorer/rochling/dokument/acetalplast-pom/lagersortiment-pom-c.pdf>
- [14] Christian Berner AB. (n.d.). Lagersortiment. Retrieved May 10, 2019, from <https://www.christianberner.se/globalassets/leverantorer/rochling/dokument/polyeten-pe-etenplast/lagersortiment-hd1000.pdf>
- [15] Christian Berned AB. (2016). Actealplast, POM. Retrieved March 20, 2019, from <https://www.christianberner.se/globalassets/leverantorer/rochling/dokument/acetalplast-pom/acetalplast-pom.pdf>

- [16] Woodproducts. (n.d.). Plywood. Retrieved April 3, 2019, from <https://www.woodproducts.fi/content/plywood>
- [17] MatWeb. (n.d.). Plywood. Retrieved April 3, 2019, from [http://www.matweb.com/search/datasheet\\_print.aspx?matguid=bd6620450973496ea2578c283e9fb807](http://www.matweb.com/search/datasheet_print.aspx?matguid=bd6620450973496ea2578c283e9fb807)
- [18] Ultimaker. (n.d.). Ultimaker 3. Retrieved May 16, 2019, from <https://ultimaker.com/en/products/ultimaker-3>
- [19] Gear Technology. (n.d.). Hobs. Retrieved March 19, 2019, from <https://www.geartechnology.com/dir/Hobs.htm>
- [20] SAAZOR. (n.d.). SAAZOR transport systems. Retrieved February 20, 2019, from <http://saazor.de/en/hobs/saazor-transport-systems/>
- [21] Samputensili. (n.d.). Hob. Retrieved February 20, 2019, from <https://www.samputensili.com/products/gear-hobs/>
- [22] Schoeller Allibert. (n.d.). Industrial Manufacturing. Retrieved March 19, 2019, from <https://www.schoellerallibert.com/markets/industrial-manufacturing/>
- [23] Schoeller Allibert. (n.d.). Tellus 300 x 200 x 150mm – solid base and walls. Retrieved March 19, 2019, from <https://www.schoellerallibert.com/products/4570760/>
- [24] Schoeller Allibert. (n.d.). 180° SN 600 x 400 x 300MM – solid base and walls – 2 open handholes. Retrieved March 19, 2019, from <https://www.schoellerallibert.com/products/7937800/>
- [25] Schoeller Allibert. (n.d.). Stack-nest – 800 x 600 x 350mm – solid base and walls – 4 open handholes. Retrieved March 19, 2019, from <https://www.schoellerallibert.com/products/9561000/>
- [26] Schoeller Allibert. (n.d.). Euro ALC – 600 x 400 x 385MM – solid base and walls. Retrieved March 19, 2019, from <https://www.schoellerallibert.com/products/9104004/>

# Appendix A Time plan

*In this appendix the time plans for this thesis are presented. Both the initial project time plan and the actual time plan with outcome are presented.*

This project started with planning the activities that was supposed to be done during this project in a time plan. The initial time plan divided the different activities into a course schedule over when which activity were supposed to happen. The actual outcome over how the different activities were performed are summarized into a new time plan. Both the initial and final time plan are presented in figure A.1 in Gant chart.



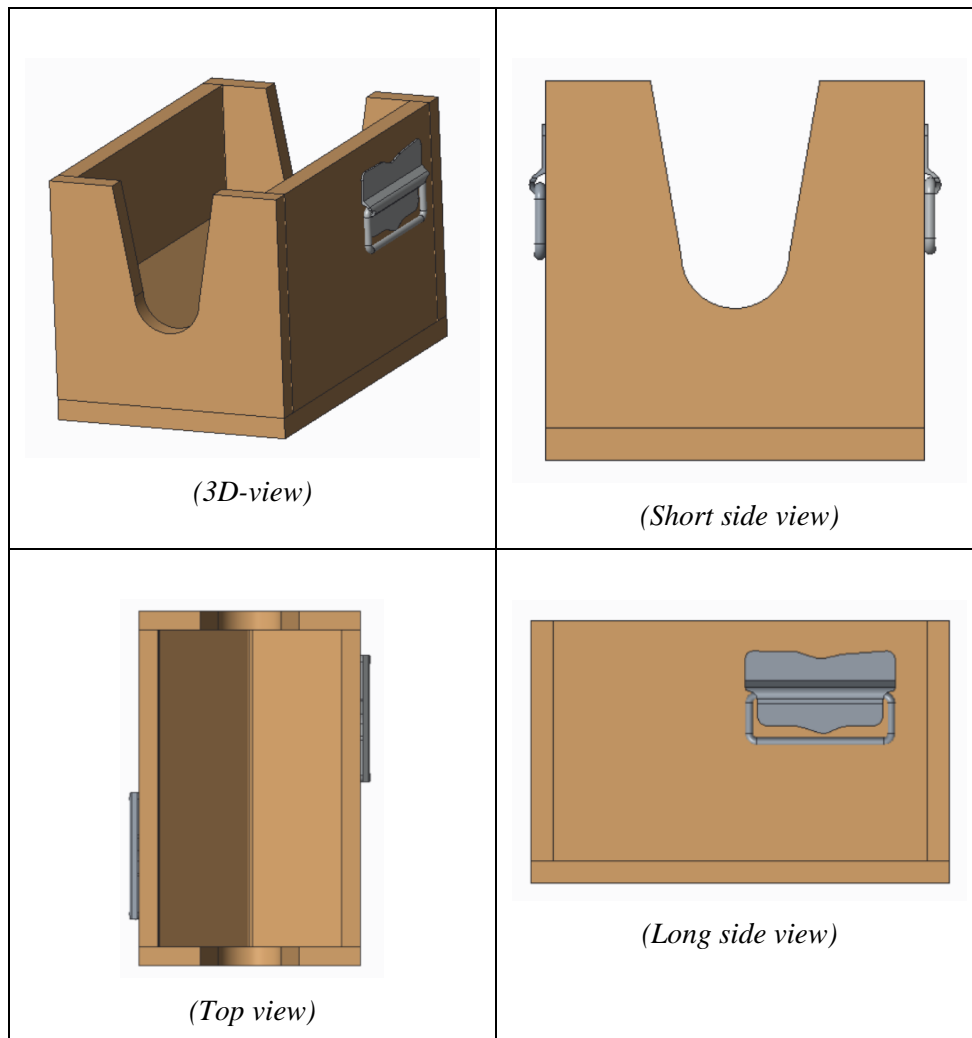
**Figure A.1: Gant chart over the time plan (Pink = initial plan, Blue = actual outcome).**

The project followed the initial time plan quite well. The concept generation took a bit longer time than expected. However, some areas are overlapping to each other and were performed parallel. The report has been written on during the whole project and has worked as a framework for the process and given a structure to the project.

## Appendix B Existing packaging

*Technical drawings and illustrations of the existing packaging are presented in this appendix.*

See figure B.1 for renderings of the existing packaging.



**Figure B.1: Existing solution.**

See figure B.2 for a technical drawing of the existing packaging.

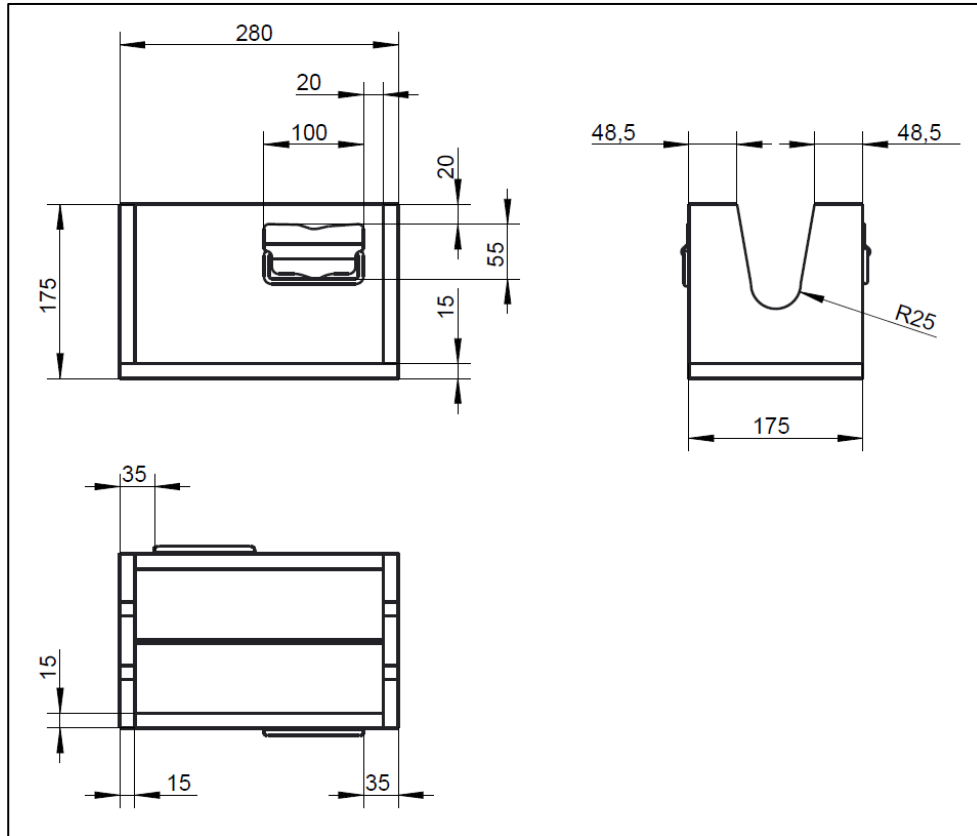


Figure B.2: Technical drawing.

## Appendix C Customer needs

*Collected data from interviews/meetings and observations are converted into customer needs.*

See table C.1 – C.6 for converted raw data into customer needs.

**Table C.1 Data interpreted and converted to customer needs.**

<i>Customer statement (Raw data)</i>	<i>Formulation needs (Customer needs)</i>
<i>Gear technicians</i>	
<i>“The gear hobs will not be larger in the future, rather at bit smaller”</i>	The packaging works for the size of existing gear hobs.
<i>“An advantage of existing packaging, is the low cost for it”</i>	The packaging has a low price.
<i>“It is hard to pick up gear hobs with shafts”</i>	The packaging works with gear hobs with shafts.
<i>“Damage occur on the gear hobs with the existing packaging”</i>	The packaging can be produced of any material.
<i>“There is no limitations in the material selection”</i>	The packaging can be produced of any material.
<i>“The packaging should be oil repellent and should be able to clean from oil”</i>	The packaging is oil repellent and washable from oil.
<i>“The gear hobs are usually lifted by hand from the packaging”</i>	The packaging makes lifting the gear hob by hand accessible.
<i>“Wood chips is torn from the packaging”</i>	The packaging is durable against damages.
<i>“Foam rubber sucks up oil and a rubber mat is a better choice for protection between the packaging and the gear hob”</i>	The packaging has good protection between the gear hob and the packaging.



<i>“All sharpening card is the same size and it is good if the sharpening card is visible from the outside”</i>	The packaging shows the sharpening card.
<i>“It would be beneficial if as much as possible of the sides of the gear hobs are visible”</i>	The packaging shows the sides of the gear hob.
<i>“A top cover for the packaging would be good for protection”</i>	The packaging has good protection from the top.
<i>“The packaging can be washed within the workshop with water”</i>	The packaging is washable with water.

**Table C.2 Data interpreted and converted to customer needs.**

<i>Customer statement (Raw data)</i>	<i>Formulation needs (Customer needs)</i>
<i>Operator T-storage</i>	
<i>“Unnecessary large packaging for the smaller gear hobs”</i>	The packaging is suitable for different sizes of the gear hobs.
<i>“It would be great to be able to lift the packaging with a lifting device”</i>	The packaging works with lifting devices.
<i>“Wood is not an optimal material for the packaging”</i>	The packaging is made of an optimized material.
<i>“The storage where the packaging is stored is old and an outdated solution and if this need to be replaced the packaging should work with a new solution”</i>	The packaging works with future storage implements.
<i>“The packaging need to be stacked sometimes”</i>	The packaging can be stacked.
<i>“There is no need to be able to see the grinding card from the outside”</i>	The packaging stores the sharpening card.
<i>“It would be great with a bar-code or similar instead of the existing identification number”</i>	The packaging works with a bar-code system or similar.

**Table C.3 Data interpreted and converted to customer needs.**

<i>Customer statement (Raw data)</i>	<i>Formulation needs (Customer needs)</i>
Ergonomist	
<i>“The weight is relatively low when the packaging is made of wood which is positive, but the risk of wood chips from the packaging is negative”</i>	The packaging has low weight and no wood chips are torn from the packaging.
<i>“It is better if the handles are placed on the same distance from the edges and not diagonally to each other”</i>	The packaging’s handles are placed on the same distance from the edges.
<i>“It is optimal to carry the long side of the packaging towards your body”</i>	The packaging’s center of gravity should be close to operator’s body when being carried.
<i>“The handles should be sturdy and preferably fixedly mounted”</i>	The packaging has sturdy and fixedly mounted handles.
<i>“If the box need to be pulled against you, the west way to pull is to have the arms close to your body”</i>	The packaging enables to be pulled with the arms close to the operator’s body.

**Table C.4 Data interpreted and converted to customer needs.**

<i>Customer statement (Raw data)</i>	<i>Formulation needs (Customer needs)</i>
Warehouse technician	
<i>“The packaging takes up a lot of space”</i>	The packaging takes up small space.
<i>“The identify badge falls out very easy”</i>	The packaging keeps the identify badge safely.
<i>“The packaging should work with a future lifting machine”</i>	The packaging works with future lifting machines.

**Table C.5 Data interpreted and converted to customer needs.**

<i>Customer statement (Raw data)</i>	<i>Formulation needs (Customer needs)</i>
External sales person from a lifting device company	
<i>“The packaging is lifted with a lifting device with a spade or forks”</i>	The packaging is lifted with a lifting device with a spade or forks.
<i>“If the packaging is lifted on the long side, it is important that packaging is lifted in the middle”</i>	The packaging is well balanced when lifted on the long side.
<i>“It should be possible to lift from both the short and long side.”</i>	The packaging is lifted from both the short and long side.

**Table C.6 Data interpreted and converted to customer needs.**

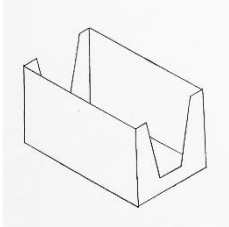
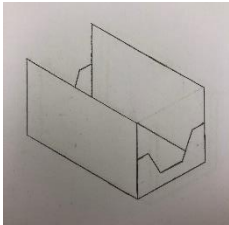
<i>Customer statement (Raw data)</i>	<i>Formulation needs (Customer needs)</i>
Observations	
<i>“The packaging are transported around at the whole worksite on trolleys and are lifted from them to the machine”</i>	The packaging works efficient for moving and handling on trolleys and are optimized for lifting.
<i>“The gear hob is lifted from the packaging and is often placed on the bench or on top of the packaging before it is inserted into the cutting machine”</i>	The packaging minimizes damages on the gear hob during the transfer from the packaging to the cutting machine.
<i>“There is limited space on many shelves and storage space around in the workshop”</i>	The packaging takes up as little space as possible, both loaded and empty.
<i>“The openings on the short sides are too small to get a good grip of the gear hob when it is lifted up from the packaging”</i>	The packaging facilitates lifting of the gear hob from the packaging.
<i>“If the packaging is lifted on the bottom of the packaging, it becomes bad balance, because the center of gravity of the gear hob is quite high”</i>	The packaging is well balanced and can be lifted stable from the bottom of the packaging.
<i>“It is quite hard to lift in the packaging in the paternoster vertical carousel”</i>	The packaging is lifted in an ergonomic way into the paternoster vertical carousel.
<i>“The packaging should be able to work with existing lifting devices”</i>	The packaging works with existing lifting devices.

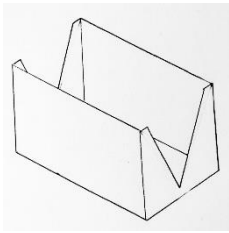
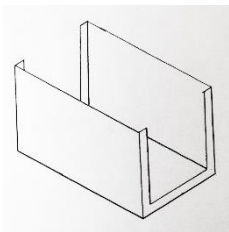
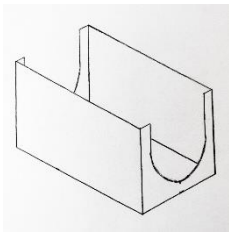
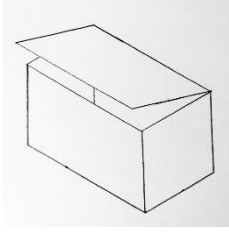
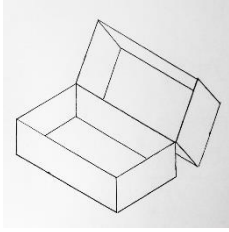
# Appendix D Brainstorming ideas

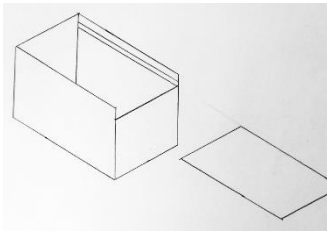
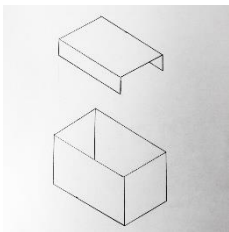
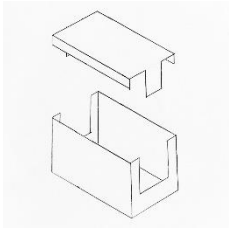
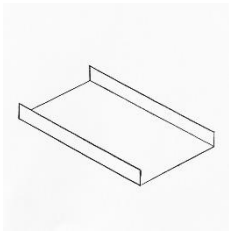
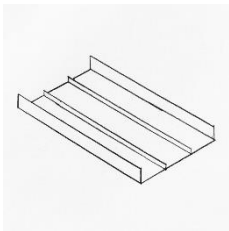
*Ideas for each sub problems were generated during the brainstorming.*

See table D.1 for brainstorming ideas for solving each sub problem.

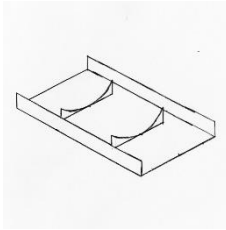
**Table D.1 Brainstorming ideas.**

<i>Idea</i>	<i>Description</i>	<i>Figure</i>	<i>Advantages/ disadvantages</i>
1. Outer design of the packaging			
1.1	Similar design to the existing solution with a rectangular opening with inclined vertical sides.		<ul style="list-style-type: none"> <li>+ Similar design as today, i.e. it works, since it is used in production</li> <li>+ Stable construction</li> <li>+/- Relative good access from the short sides</li> <li>- Can not see the whole side of the gear hob</li> <li>- Similar design as today and different operators are experiencing different problems</li> </ul>
1.2	The shorter design has lower sides, which creates good access to the gear hob.		<ul style="list-style-type: none"> <li>+ Good access from the short sides</li> <li>+ Large parts of the sides of the gear hob are visible</li> <li>- Risk for weaker construction</li> </ul>

- |   |   |   |
|---|---|---|
| <p>1.3 Triangular shape of the opening on the side, which creates good access to the gear hob, but still good side protection.</p>  |    | <ul style="list-style-type: none"> <li>+ More stable construction</li> <li>+/- Relative good access from the short sides</li> <li>- Can not see the whole side of the gear hob</li> </ul>   |
| <p>1.4 Open short side with a smaller frame around the sides, to prevent the gear hob to fall out. This creates very good access to the gear hob from the side.</p>       |    | <ul style="list-style-type: none"> <li>+ Good access from the short sides</li> <li>+ Large parts of the sides of the gear hob are visible</li> <li>- Worse side support for the gear hob</li> <li>- Risk for weaker construction</li> </ul>                                 |
| <p>1.5 Round bottom of the opening on the short side for easy access to the gear hob. The round shape makes it easy to read the markings on the side of the gear hob.</p> |   | <ul style="list-style-type: none"> <li>+ Good access from the short sides</li> <li>+ Large parts of the sides of the gear hob are visible</li> <li>+/- Round construction on the short sides could be hard to manufacture or give good drafts</li> </ul>                    |
| <p>1.6 A cover is attached to the long side and some kind of locking mechanism locks the cover on the other long side.</p>  |  | <ul style="list-style-type: none"> <li>+ Box and top cover are always attached and can not be mixed up</li> <li>- The joining of box and top cover could be worn by time and break</li> <li>- Additional components are needed for joining the box and top cover</li> </ul> |
| <p>1.7 The box is divided into two halves and they are connected on the long side and some kind of locking mechanism lock them on the other long side.</p>                |  | <ul style="list-style-type: none"> <li>+ Good access to the gear hob</li> <li>- Takes up double the amount of size compared to designs with a loose top cover</li> <li>- Large load on the hinge or similar joining parts</li> </ul>  |

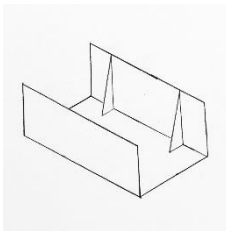
- 1.8 A loose cover is inserted from the short side into a track mounted on the inside of the long sides.
- 
- + Good full cover of the gear hob at storage
  - Possibility of dirt getting into the track for the cover and make it slide worse
- 1.9 A loose cover is inserted from the top of the box. The cover has supports on the long sides. The cover could be used as underlay when the gear hob is lifted up from the box and placed outside of it.
- 
- + Loose top cover, which is possible to turn around and place the gear hob on when it is lifted up from the packaging
  - More components gives generally higher manufacturing costs
  - Chance of mixing box and top cover if many packaging is used at the same time
- 1.10 A loose cover is inserted from the top of the box. The cover has supports on all sides. The cover could be used as underlay when the gear hob is lifted up from the box and placed outside of it.
- 
- + Good support of the gear hob on the sides
  - Can not see the whole side of the gear hob
  - The design could be sensitive
- 1.11 A plain top cover with bent up edges on the long side.
- 
- + Simple construction
  - + Plane, stable bottom
  - No inner support which hold the gear hob in place
- 1.12 A plain top cover with bent up edges on the long side and supports parallel to the long sides.
- 
- + The gear hob lies stable when placed on the cover
  - + Plane, stable bottom
  - The inner longitudinal supports could be sensitive

1.13 A plain top cover with bent up edges on the long side and rounded supports parallel to the short sides.



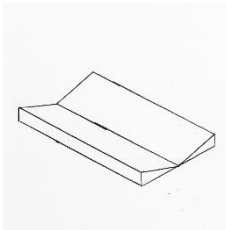
- + Plane, stable bottom
- + The inner supports fits gear hobs with different diameter
- The inner supports could be sensitive

1.14 A plain top cover with bent up longer edges on the long side and smaller support along the bent up edges.



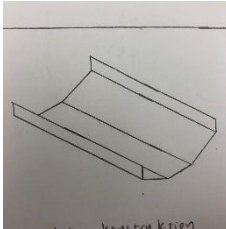
- + Good support when the gear hob is placed in the top cover
- High sides could be instable and sensitive
- Inner supports are worse fitted for gear hobs with different diameters

1.15 A plain top cover with bent up edges on the long side and inclined supports over the whole cover.



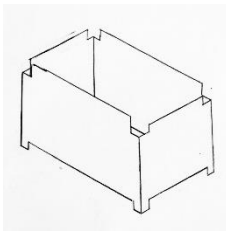
- + Stable, plane bottom
- + Fits gear hobs with different diameter
- +/- Stable construction, eventually sensitive on the middle over the thin part
- More complex construction
- High material consumption

1.16 A top cover with a smaller plain part and the cover is inclined and has bent up edged on the long side.



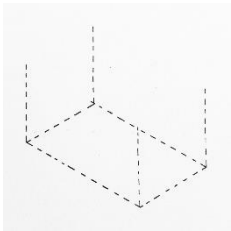
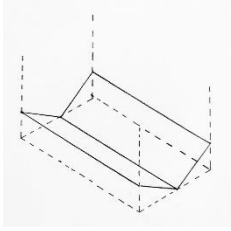
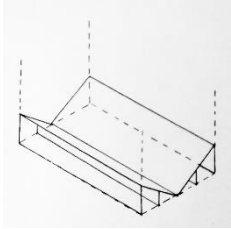
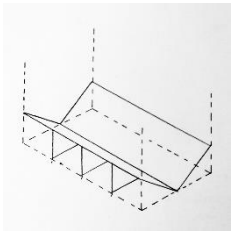
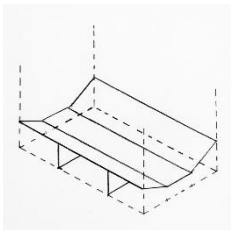
- + Relative simple construction
- + Fits gear hobs with different diameter
- Small plain bottom, which makes the cover more unstable

1.17 The box can be stacked on top of another box.

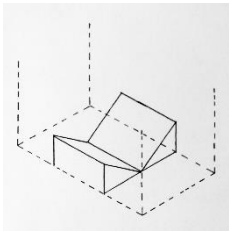
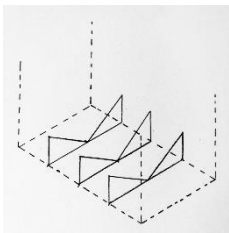
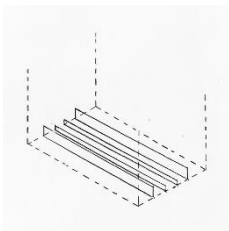
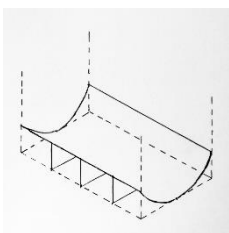
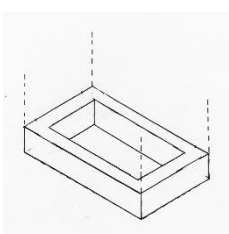


- +Possibility to stack packaging
- + Handles are created on the long and short sided at the bottom
- Higher complexity on the construction

## 2. Inner design/support of the packaging

- |     |  |   |  |
|-----|--|---|--|
| 2.1 | No supports on the bottom of the box. The gear hob is held in position by supports from the top cover.   |    | <ul style="list-style-type: none"> <li>+ Simple construction</li> <li>+/- A cover or the design of the box must hold the gear hob in place</li> </ul>  |
| 2.2 | The same support as existing solution, since the existing supports in its shape works good.  |    | <ul style="list-style-type: none"> <li>+ Similar support as existing solution, which works relative good.</li> <li>+ Fits gear hobs with different diameter</li> <li>- No supports below the main support</li> <li>- Difficult construction in some materials, like plastic materials</li> </ul> |
| 2.3 | Similar support construction as existing solution, but with supports underneath the main support. The underneath support are parallel with the long sides. The gear hob is resting on the larger support plates.   |   | <ul style="list-style-type: none"> <li>+ Supports underneath the main support</li> <li>- Harder to implement a lifting device</li> </ul>   |
| 2.4 | Similar support construction as existing solution, but with supports underneath the main support. The underneath support are parallel with the short sides. The gear hob is resting on the larger support plates.  |  | <ul style="list-style-type: none"> <li>+ Supports underneath the main support</li> <li>+ Opportunity for placement of handles on the long sides</li> <li>- Harder to implement a lifting device</li> </ul>   |
| 2.5 | Similar support construction as existing solution, but with supports underneath the main support. The main support is divided into three sections, with a flat section in the middle. The underneath supports are parallel with the short sides. The gear hob is resting on the larger support plates. |  | <ul style="list-style-type: none"> <li>+ Fits gear hobs with different diameter</li> <li>+ Relative simple construction for manufacturing</li> <li>+ Free access underneath the main supports for handles or lifting devices</li> <li>- High load on the supports underneath</li> </ul>          |



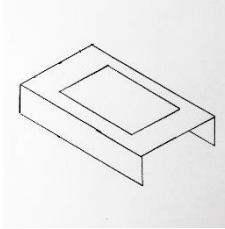
- |   |   |   |
|---|---|---|
| <p>2.6 Smaller support in the middle of the bottom of the box with whole support plates, which the gear hob is resting on.</p>  |    | <ul style="list-style-type: none"> <li>+ Stable construction</li> <li>+ Opportunity for placement of handles on the short sides</li> <li>- Worse support for longer gear hobs</li> </ul>                                |
| <p>2.7 Thinner supports which are parallel to the short sides. The gear hob rests on these supports.</p>  |    | <ul style="list-style-type: none"> <li>+ Simple construction</li> <li>+ Fits gear hobs with different diameter</li> <li>- High load on each support</li> </ul>  |
| <p>2.8 Thinner supports which are parallel to the long sides. The gear hob rests on these supports.</p>   |   | <ul style="list-style-type: none"> <li>+ Opportunity for placement of handles on the long sides</li> <li>+ Simple construction in some material, like plastic materials</li> <li>- High load on each support</li> </ul> |
| <p>2.9 Similar support construction as existing solution, but with supports underneath the main support. The support are parallel with the short sides. The main support plates is rounded and the gear hob is resting on this plate.</p> |  | <ul style="list-style-type: none"> <li>+ Gear hobs with larger diameter could be placed low in the packaging</li> <li>- Gear hobs can roll from side to side</li> <li>- Eventual more complex to manufacture</li> </ul> |
| <p>2.10 A solid form of a softer material supports the gear hob.</p>  |  | <ul style="list-style-type: none"> <li>+ Equal distribution of loads</li> <li>+/- Must be produced in an oil repellent material</li> </ul>  |

---

### 3. Placement of the sharpening card.

---

- 3.1 The sharpening card is placed on top of a loose cover. This works with the different concepts of covers.

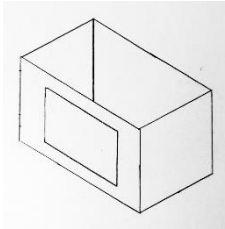


+ The sharpening card is readable when the top cover is on the box and stands on a trolley or a table

- The sharpening card is unreadable when the packaging is stored in a paternoster vertical carousell or when the cover lies upside down

- The sharpening card can be worn when the cover lies upside down

- 3.2 The sharpening card is placed on the side of the outside of the box.



+ The sharpening card can be read without being removed from the packaging

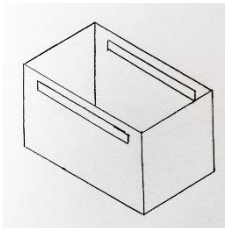
- The sharpening card is only visible from one side

---

### 4. Design of handles

---

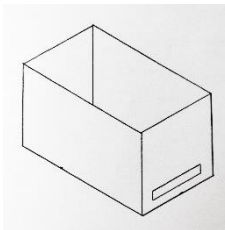
- 4.1 Longer handles on the long sides on top of the box.



+ Possibility to lift the packaging over the whole long side

- Weakening of the construction with long handles

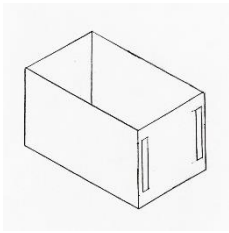
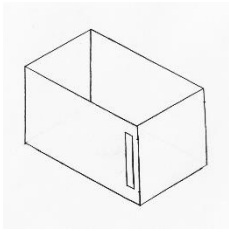
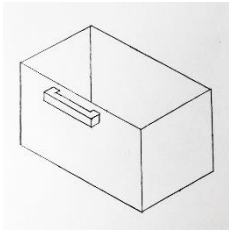
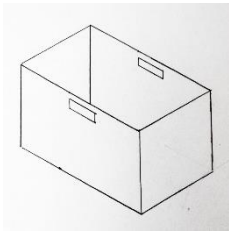
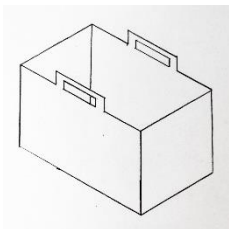
- 4.2 Longer handles on the short sides on bottom of the box.



+ The packaging can be carried with the long side towards the body

- Complicates the design of the inner support

- The packaging is lifted underneath its center of gravity

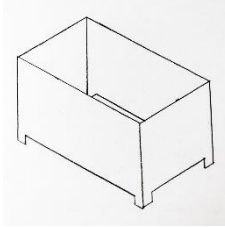
- |     |   |   |  |
|-----|---|---|--|
| 4.3 | Longer vertical handles on the short sides on the sides of the box. |    | <ul style="list-style-type: none"> <li>+ The packaging can be pulled towards the operator</li> <li>- Reduces the area on the short side where the opening can be placed</li> <li>- A protection is required on the inside for protection</li> </ul>        |
| 4.4 | Longer vertical handles on the long sides on the sides of the box.  |    | <ul style="list-style-type: none"> <li>+ The packaging can be pulled towards the operator</li> <li>- A protection is required on the inside for protection</li> </ul>  |
| 4.5 | External handles on the long sides on top of the box.               |   | <ul style="list-style-type: none"> <li>+ No risk for injuries on the gear hob</li> <li>+ Does not affect plausible inner designs</li> <li>- A distance of two handles is required between the packaging, when placed next to each other</li> </ul>         |
| 4.6 | Shorter handles on the long sides on top of the box.                |  | <ul style="list-style-type: none"> <li>+ Simple design</li> <li>+ Same distance to the handles</li> <li>- The packaging can not be carried with the long side towards the body</li> <li>- A protection is required on the inside for protection</li> </ul> |
| 4.7 | External handles on top of the long sides of the box.               |  | <ul style="list-style-type: none"> <li>+ No risk for injuries on the gear hob</li> <li>- The bottom of the packaging need to be adapted to be able to be stacked</li> <li>- Sensitive construction of the handles</li> </ul>                               |

---

## 5. Integration of possibilities for lifting devices

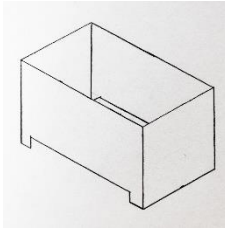
---

- 5.1 Openings on the bottom from both the long and short sides for lifting devices.



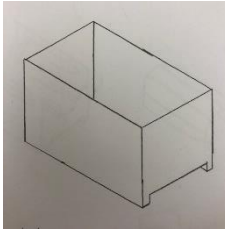
- + Possibility to use a lifting device which grips the bottom from the long side
- Extra height of the packaging is required

- 5.2 Openings on the bottom from the long sides for lifting devices.



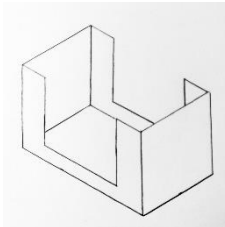
- + Possibility to use a lifting device which grips the bottom from the long and short side
- Extra height of the packaging is required

- 5.3 Longitudinal beams along the long sides creating a space underneath for a lifting device.



- + Possibility to use a lifting device from the short sides, directly after it has been taken out from the paternoster vertical carousel.
- + Suits future discussed lifting device.
- Extra height of the packaging is required

- 5.4 Opening on the long side, which makes it possible for a lifting machine to grip around the gear hob with easy access.



- + Possibility to lift the gear hob over the long side
- Weaker construction
- Reduced possibility to place handles on the long side

---

# Appendix E Selection matrixes for ideas from brainstorming

The selection matrixed for ideas from the brainstorming is presented in this appendix.

## Sub problem 1 (Outer design of the packaging)

The sub problem 1 (Outer design of the packaging) is divided into different smaller problems within the sub problem. Five different concepts (1.1 – 1.5, Appendix D) are focusing on the outer design of the short sides of the packaging. See table E.1 for the matrix for decision for these concepts.

**Table E.1 Matrix for decision – Short sides (sub problem 1).**

	<i>Concept</i>				
<i>Selection criteria</i>	1.1 (Ref.)	1.2	1.3	1.4	1.5
Short side access	0	+	-	+	+
Short side visibility	0	+	-	+	+
Side support	0	-	0	-	-
Manufacturability	0	0	-	0	-
Stability of construction	0	-	0	-	0
Number of +	0	2	0	2	2
Number of 0	5	1	2	1	1
Number of -	0	2	3	2	2
Sum	0	0	-3	0	0
Rankings	1	1	5	1	1

Five different concepts (1.6 – 1.10, Appendix D) are focusing on how a top cover could be implemented on the outer design. See table E.2 for the matrix for decision for these concepts.

**Table E.2 Matrix for decision – Top cover integration (sub problem 1).**

<i>Concept</i>					
<i>Selection criteria</i>	1.6	1.7	1.8	1.9 (Ref.)	1.10
Simplicity of top cover	+	-	+	0	-
Accessibility to gear hob	0	+	0	0	0
Complexity of components	-	-	0	0	0
Manufacturability	0	-	0	0	-
Durability	-	-	0	0	-
Stability of construction	0	-	-	0	0
Number of +	1	1	1	0	0
Number of 0	2	0	4	6	3
Number of -	2	5	1	0	3
Sum	-1	-5	0	0	-3
Rankings	3	5	1	1	4

Six different concepts (1.11 – 1.16, Appendix D) are focusing on the design of the top cover. See table E.3 for the matrix for decision for these concepts.

**Table E.3 Matrix for decision – Top cover design (sub problem 1).**

<i>Concept</i>						
<i>Selection criteria</i>	1.11 (Ref.)	1.12	1.13	1.14	1.15	1.16
Simplicity	0	-	-	-	-	-
Support for gear hob	0	+	+	+	+	+
Manufacturability	0	0	0	-	-	-
Complexity of components	0	-	-	-	-	0
Durability	0	-	-	-	0	0
Stability of construction	0	-	-	-	0	0
Number of +	0	1	1	1	1	1
Number of 0	6	1	1	0	0	0
Number of -	0	4	4	5	3	2
Sum	0	-3	-3	-4	-2	-1
Rankings	1	4	4	6	3	2

Matrix for decision – Sub problem 2 (Inner design/support of the packaging)

Ten different concepts (2.1 – 2.10, Appendix D) are focusing on the inner design/support of the short sides of the packaging. See table E.4 for the matrix for decision for these concepts.

**Table E.4 Matrix for decision – Inner design/support (sub problem 2).**

	<i>Concept</i>									
<i>Selection criteria</i>	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	2.10
	(Ref.)									
Simplicity	+	0	-	-	-	0	0	0	-	-
Support for gear hob	-	0	0	0	0	-	-	-	-	-
Manufacturability	+	0	0	0	0	0	+	+	-	-
Complexity of components	+	0	-	-	-	0	0	0	-	0
Durability	+	0	0	0	0	0	-	-	0	-
Stability of construction	+	0	+	+	+	+	-	-	+	+
Number of +	5	0	1	1	1	1	1	1	1	1
Number of 0	0	6	3	3	3	4	2	2	1	1
Number of -	1	0	2	2	2	1	3	3	4	4
Sum	4	0	-1	-1	-1	0	-2	-2	-3	-3
Rankings	(1)	1	3	3	3	1	6	6	8	8



Matrix for decision – Sub problem 3 (Placement of sharpening card)

Two different concepts (3.1 – 3.2, Appendix D) are focusing on the placement of the sharpening card on the packaging. See table E.5 for the matrix for decision for these concepts.

**Table E.5 Matrix for decision – Placement of sharpening card (sub problem 3).**

<i>Selection criteria</i>	<i>Concept</i>	
	3.1 (Ref.)	3.2
Visibility	0	-
Durability	0	+
Manufacturability	0	-
Number of +	0	1
Number of 0	3	0
Number of -	0	2
Sum	0	-1
Rankings	1	2

Matrix for decision – Sub problem 4 (Design of handles)

Seven different concepts (4.1 – 4.7, Appendix D) are focusing on the design of the handles on the packaging. The different designs works for different concepts and are not directly substitute to each other. Therefor no matric for decision will be done for this sub problem. Different concepts for the packaging require different handles and the best suited handle for each concept should be chosen.

Matrix for decision – Sub problem 5 (Integration of possibilities for lifting devices)

Four different concepts (5.1 – 5.4, Appendix D) are focusing on the integration for lifting devices on the packaging. See table E.6 for the matrix for decision for these concepts.

**Table E.6 Matrix for decision – Integration of possibilities for lifting devices (sub problem 5).**

<i>Selection criteria</i>	<i>Concept</i>			
	5.1 (Ref.)	5.2	5.3	5.4
Works with existing lifting devices	0	0	0	+
Works with future lifting devices	0	0	+	0
Manufacturability	0	+	+	+
Stability of construction	0	0	0	-
Number of +	0	1	2	2
Number of 0	4	3	2	1
Number of -	0	0	0	1
Sum	0	1	2	1
Rankings	4	2	1	2

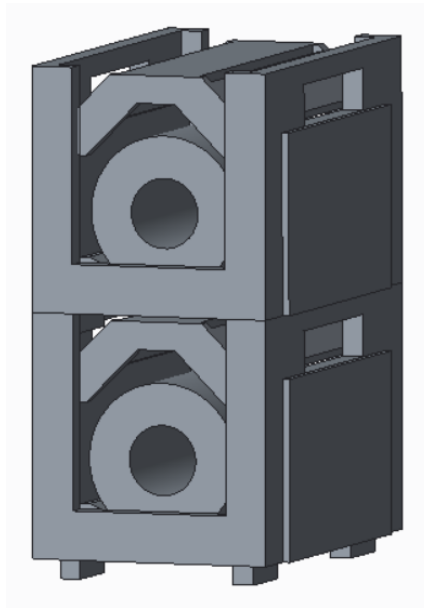
# Appendix F Detailed views of Concept A, Concept B & Concept C

*Detailed views of Concept A, Concept B and Concept C are presented in this appendix.*

## **Concept A**

### Stackable

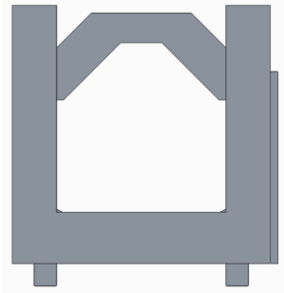
In figure F.1 two packaging are stacked on top of each other.



**Figure F.1: Stacked packaging.**

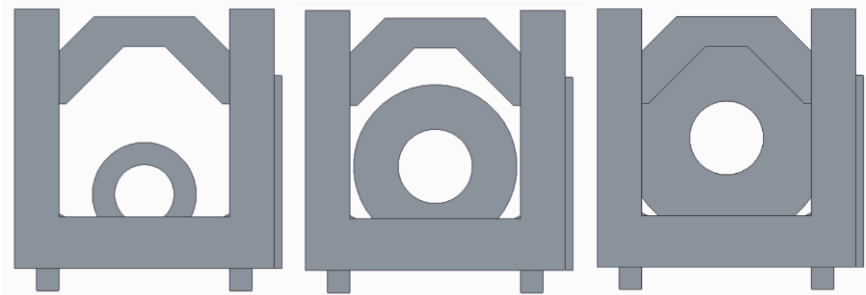
Side view (Short side)

In figure F.2 a side view of the short side of the packaging without a gear hob is shown.



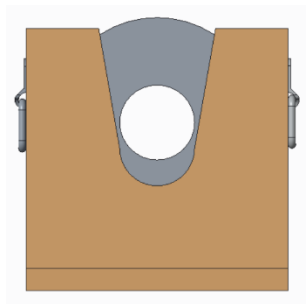
**Figure F.2: Side view of short side (Without gear hob).**

In figure F.3 a side view of the short side of the packaging with three different gear hobs placed in the packaging. The three chosen diameters are the smallest, median and largest which are used in production.



**Figure F.3: Side view of short side (With gear hobs, from left: Ø70 mm, Ø110 mm & Ø145 mm).**

In figure F.4 a side view of the short side of the existing packaging with a gear hob (Ø145 mm) is shown for reference.



**Figure F.4: Side view of short side (With gear hobs 145 mm).**

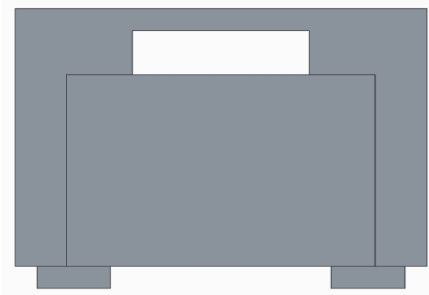
Side view (Long side)

In figure F.5 a side view of the long side of the packaging without a gear hob and without the sharpening card is shown.



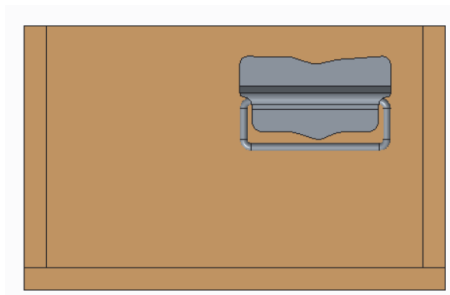
**Figure F.5: Side view of long side (Without grinding card).**

In figure F.6 a side view of the long side of the packaging without a gear hob and with the sharpening card is shown.



**Figure F.6: Side view of long side (Without grinding card).**

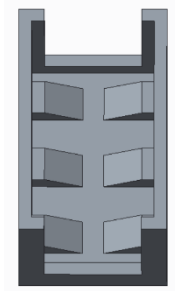
In figure F.7 a side view of the long side of the existing packaging without a gear hob is shown for reference.



**Figure F.7: Side view of short side (Without gear hob).**

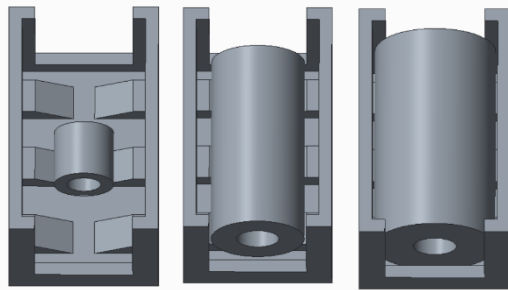
Top view

In figure F.8 a top view of the packaging without a gear hob is shown.



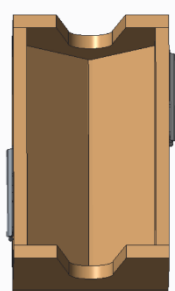
**Figure F.8: Top view (Without gear hob).**

In figure F.9 a top view of the packaging with three different gear hobs placed in the packaging. The three chosen diameters are the smallest, median and largest which are used in production.



**Figure F.9: Top view (With gear hobs, from left:  $\text{Ø}70$  mm L:65 mm,  $\text{Ø}110$  mm L:225 mm &  $\text{Ø}145$  mm L:245 mm).**

In figure F.10 a top view of the existing packaging without a gear hob is shown for reference.

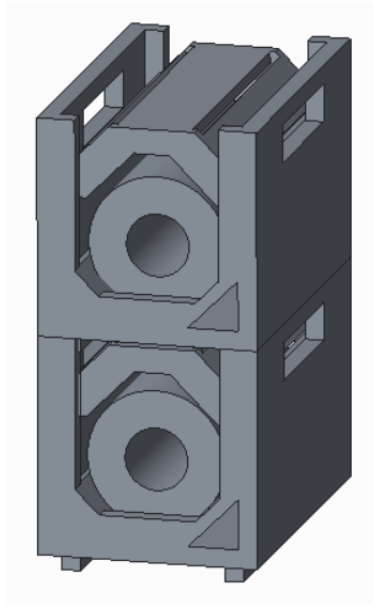


**Figure F.10: Top view of short side (Without gear hob).**

**Concept B**

Stackable

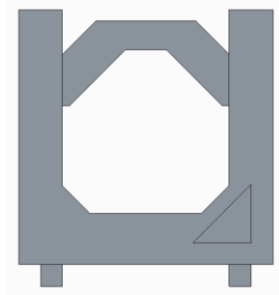
In figure F.11 two packaging are stacked on top of each other.



**Figure F.11: Stacked packaging.**

Side view (Short side)

In figure F.12 a side view of the short side of the packaging without a gear hob is shown.



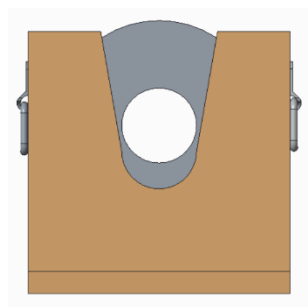
**Figure F.12: Side view of short side (Without gear hob).**

In figure F.13 a side view of the short side of the packaging with three different gear hobs placed in the packaging. The three chosen diameters are the smallest, median and largest which are used in production.



**Figure F.13: Side view of short side (With gear hobs, from left: Ø70 mm, Ø110 mm & Ø145 mm).**

In figure F.14 a side view of the short side of the existing packaging with a gear hob (Ø145 mm) is shown for reference.

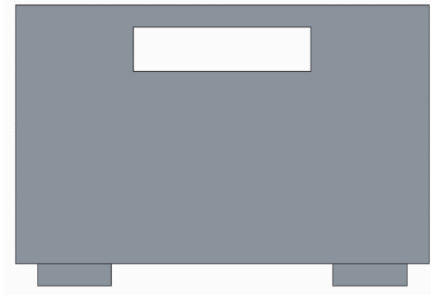


**Figure F.14: Side view of short side (With gear hobs 145 mm).**



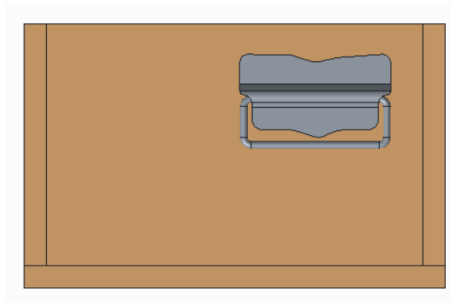
Side view (Long side)

In figure F.15 a side view of the long side of the packaging without a gear hob and without the sharpening card is shown.



**Figure F.15: Side view of long side.**

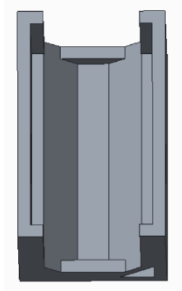
In figure F.16 a side view of the long side of the existing packaging without a gear hob is shown for reference.



**Figure F.16: Side view of long side.**

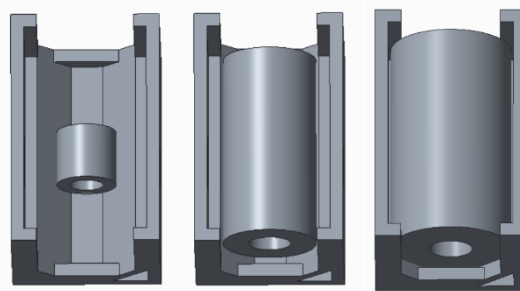
Top view

In figure F.17 a top view of the packaging without a gear hob is shown.



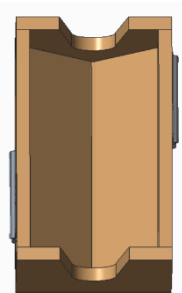
**Figure F.17: Top view (Without gear hob).**

In figure F.18 a top view of the packaging with three different gear hobs placed in the packaging. The three chosen diameters are the smallest, median and largest which are used in production.



**Figure F.18: Top view (With gear hobs, from left:  $\text{\O}70$  mm L:65 mm,  $\text{\O}110$  mm L:225 mm &  $\text{\O}145$  L:245 mm).**

In figure F.19 a top view of the existing packaging without a gear hob is shown for reference.

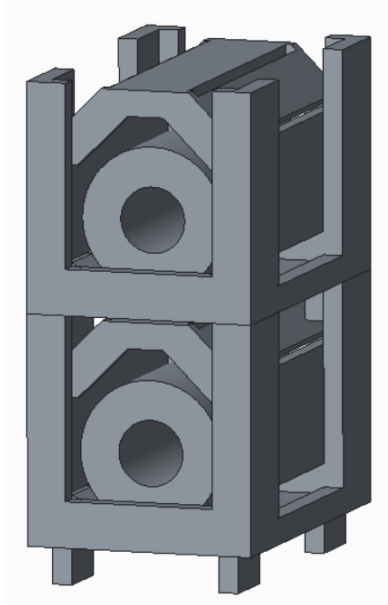


**Figure F.19: Top view of short side (Without gear hob).**

**Concept C**

Stackable

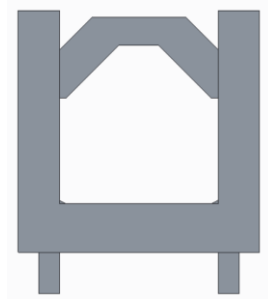
In figure F.20 two packaging are stacked on top of each other.



**Figure F.20: Stacked packaging.**

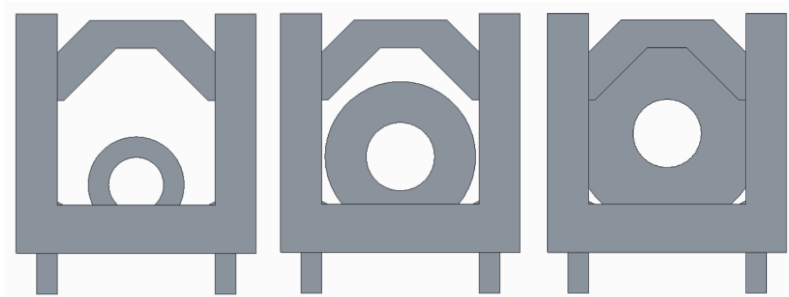
Side view (Short side)

In figure F.21 a side view of the short side of the packaging without a gear hob is shown.



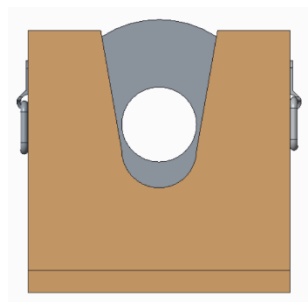
**Figure F.21: Side view of short side (Without gear hob).**

In figure F.22 a side view of the short side of the packaging with three different gear hobs placed in the packaging. The three chosen diameters are the smallest, median and largest which are used in production.



**Figure F.22: Side view of short side (With gear hobs, from left: Ø70 mm, Ø110 mm & Ø145 mm).**

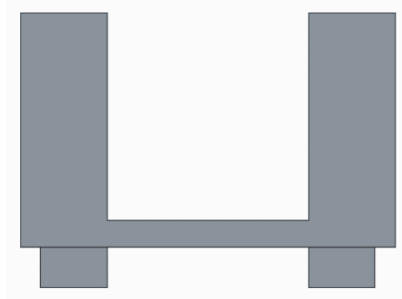
In figure F.23 a side view of the short side of the existing packaging with a gear hob (Ø145 mm) is shown for reference.



**Figure F.23: Side view of short side (With gear hobs 145 mm).**

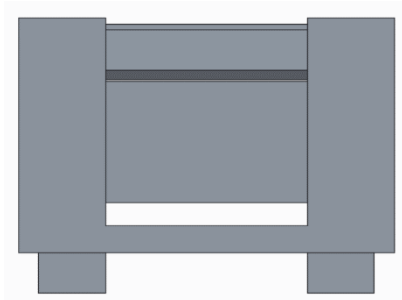
Side view (Long side)

In figure F.24 a side view of the long side of the packaging without the top cover and gear hob.



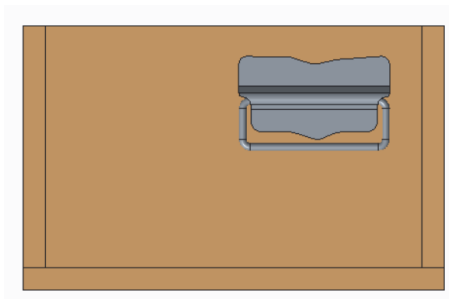
**Figure F.24: Side view of long side (Without grinding card).**

In figure F.25 a side view of the long side of the packaging with the top cover and without a gear hob.



**Figure F.25: Side view of long side (Without grinding card).**

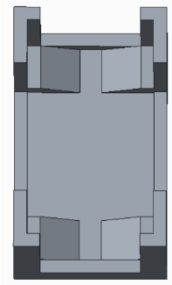
In figure F.26 a side view of the long side of the existing packaging without a gear hob is shown for reference.



**Figure F.26: Side view of short side (Without gear hob).**

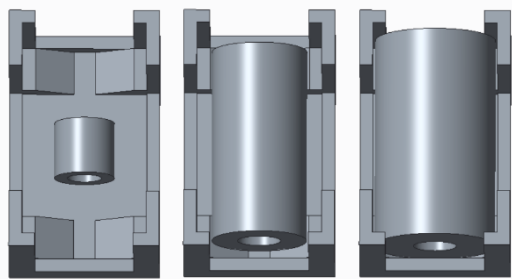
Top view

In figure F.27 a top view of the packaging without a gear hob is shown.



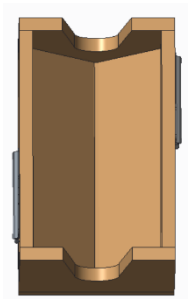
**Figure F.27: Top view (Without gear hob).**

In figure F.28 a top view of the packaging with three different gear hobs placed in the packaging. The three chosen diameters are the smallest, median and largest which are used in production.



**Figure F.28: Top view (With gear hobs, from left:  $\text{Ø}70$  mm L:65 mm,  $\text{Ø}110$  mm L:225 mm &  $\text{Ø}145$  mm L:245 mm).**

In figure F.29 a top view of the existing packaging without a gear hob is shown for reference.



**Figure F.29: Top view of short side (Without gear hob).**

# Appendix G Technical drawings

*Technical drawings for each components are presented in this appendix.*

Technical drawings for each component and for the size “Medium” of the packaging are presented in this appendix. Only one size is presented since the different sizes have the same design and it is only the length who varies. See figure G.1 – G.14 for the drawings.

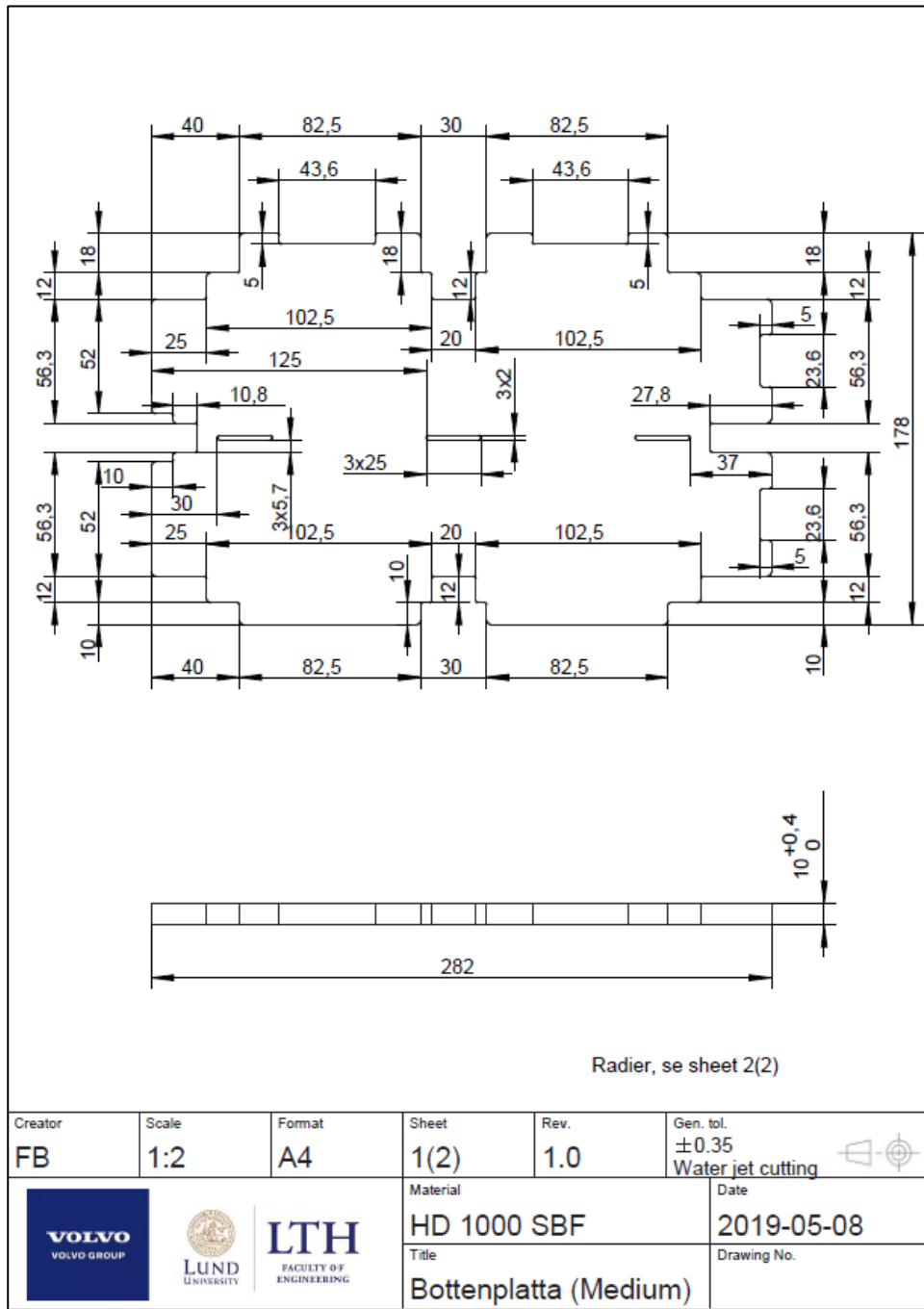


Figure G.1: Bottenplatta (1 of 2)



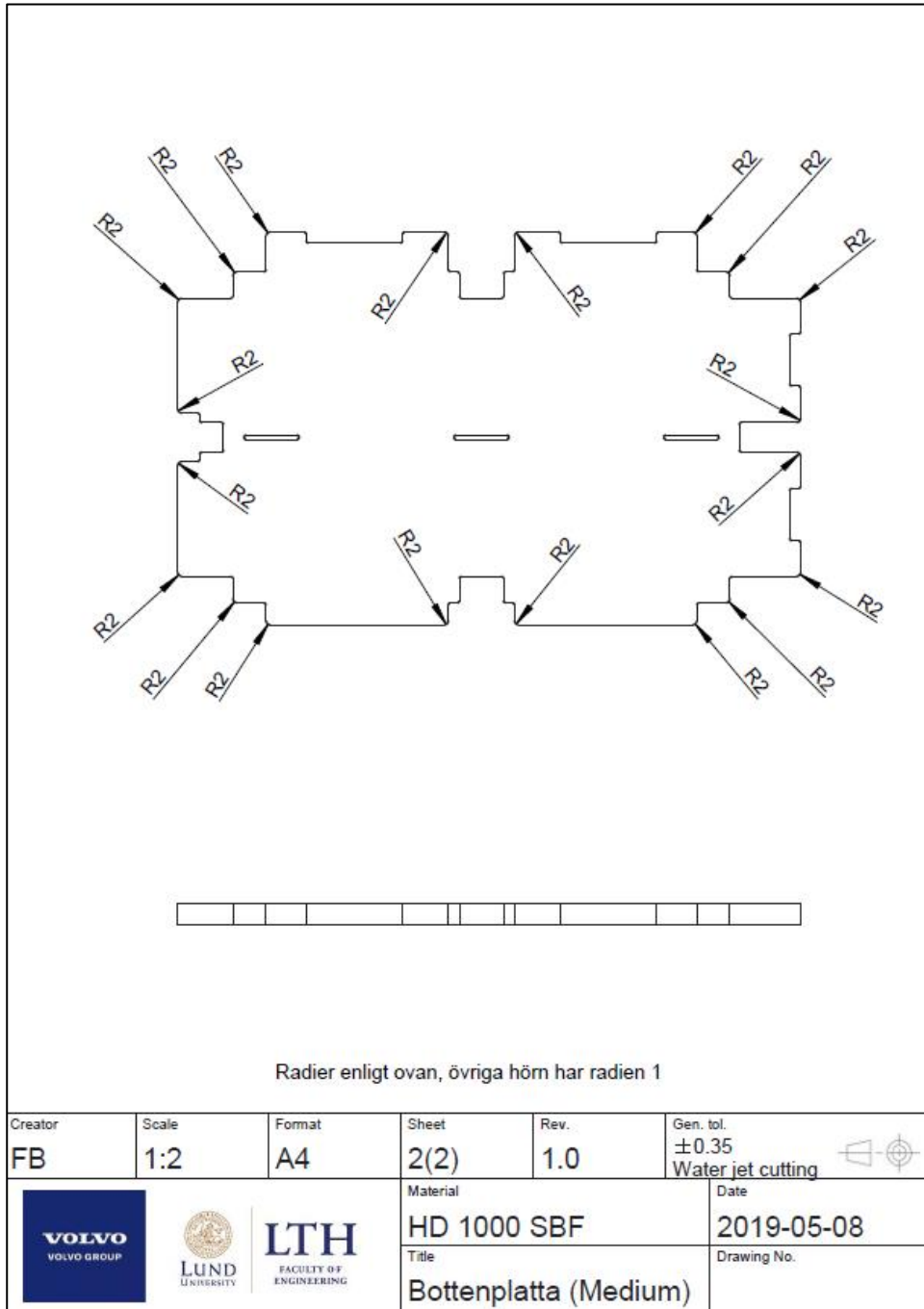


Figure G.2: Bottenplatta (2 of 2)

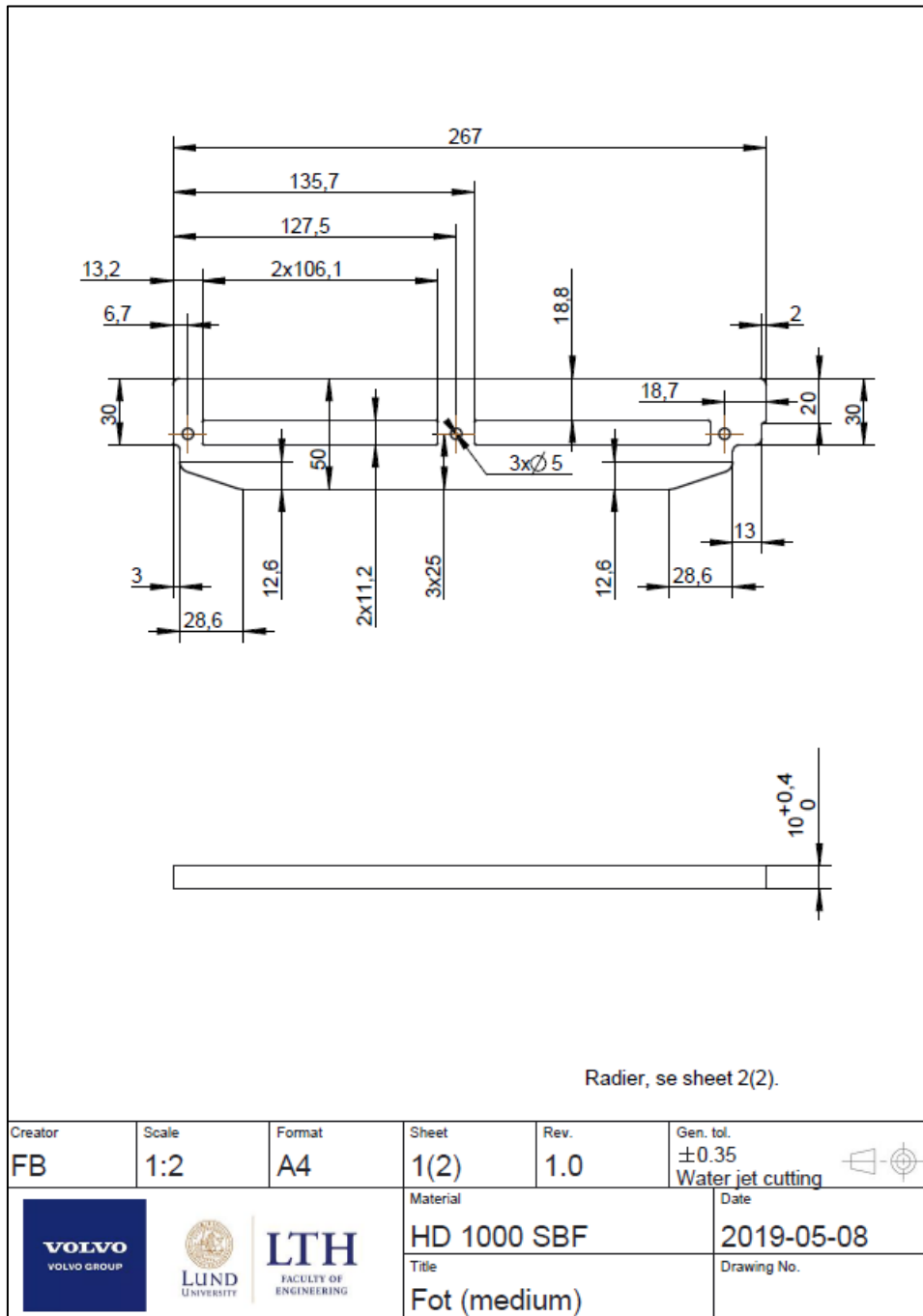


Figure G.3: Fot (1 of 2).

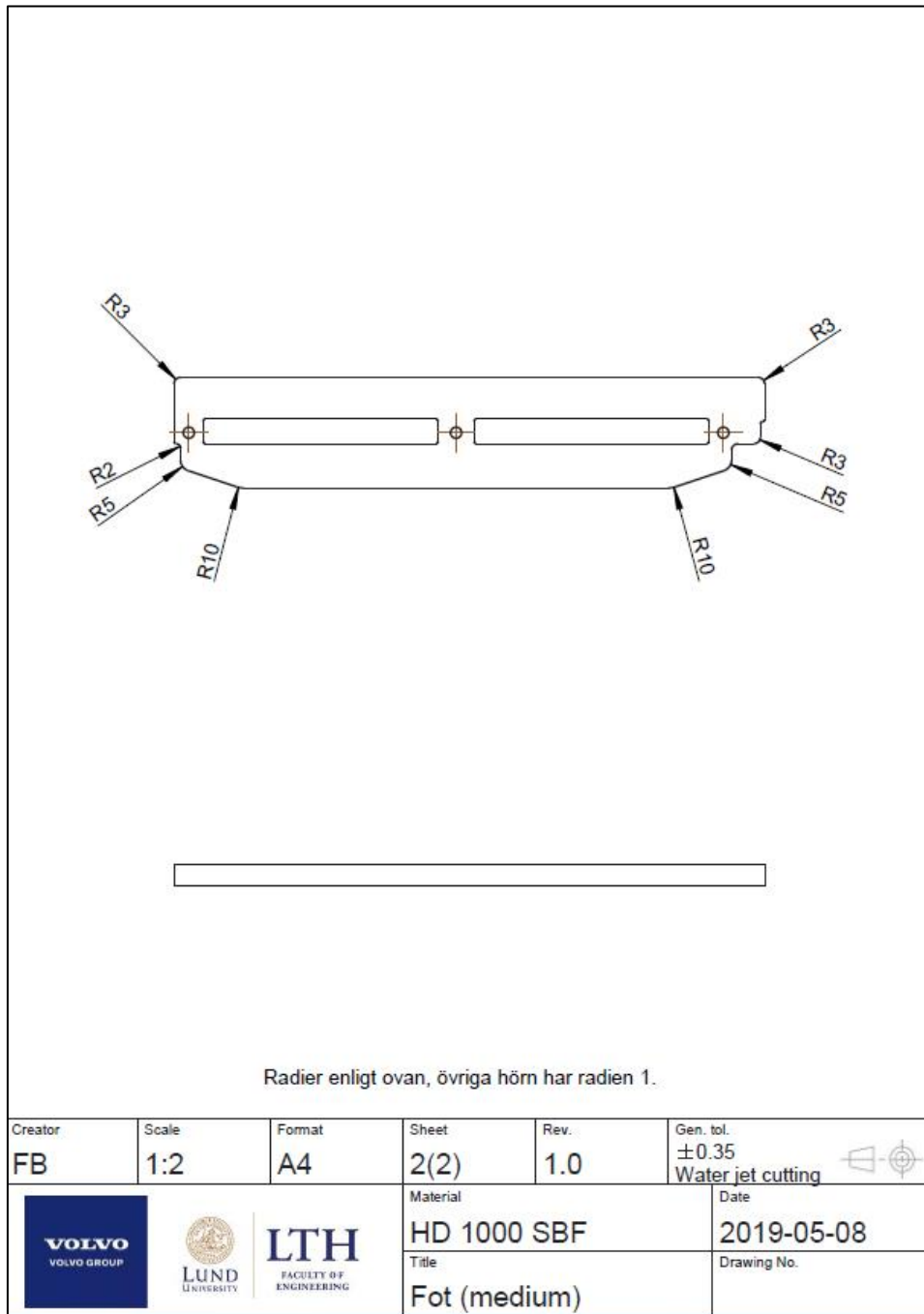


Figure G.4: Fot (2 of 2).

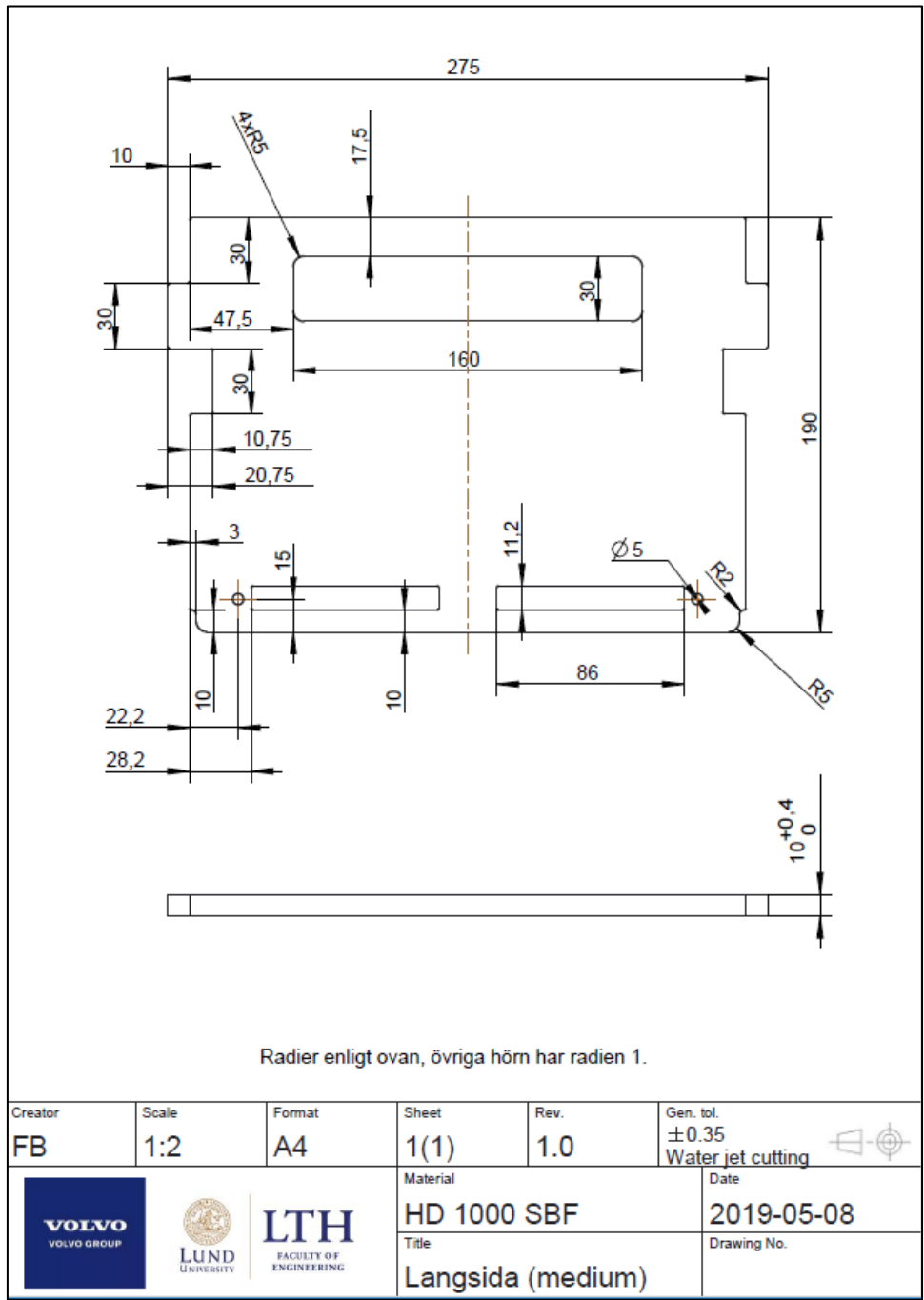


Figure G.5: Langsida.

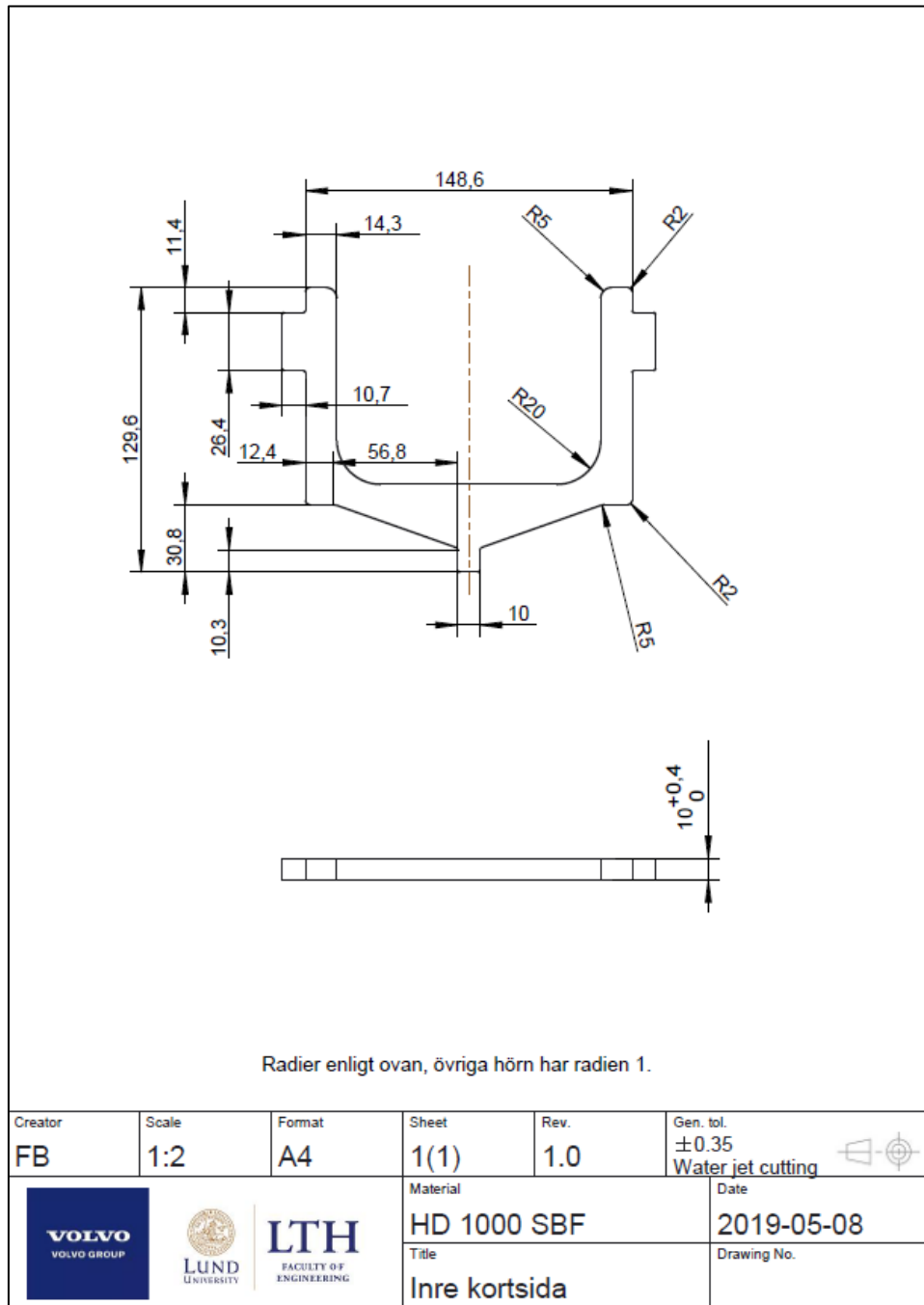


Figure G.6: Inre kortsida.

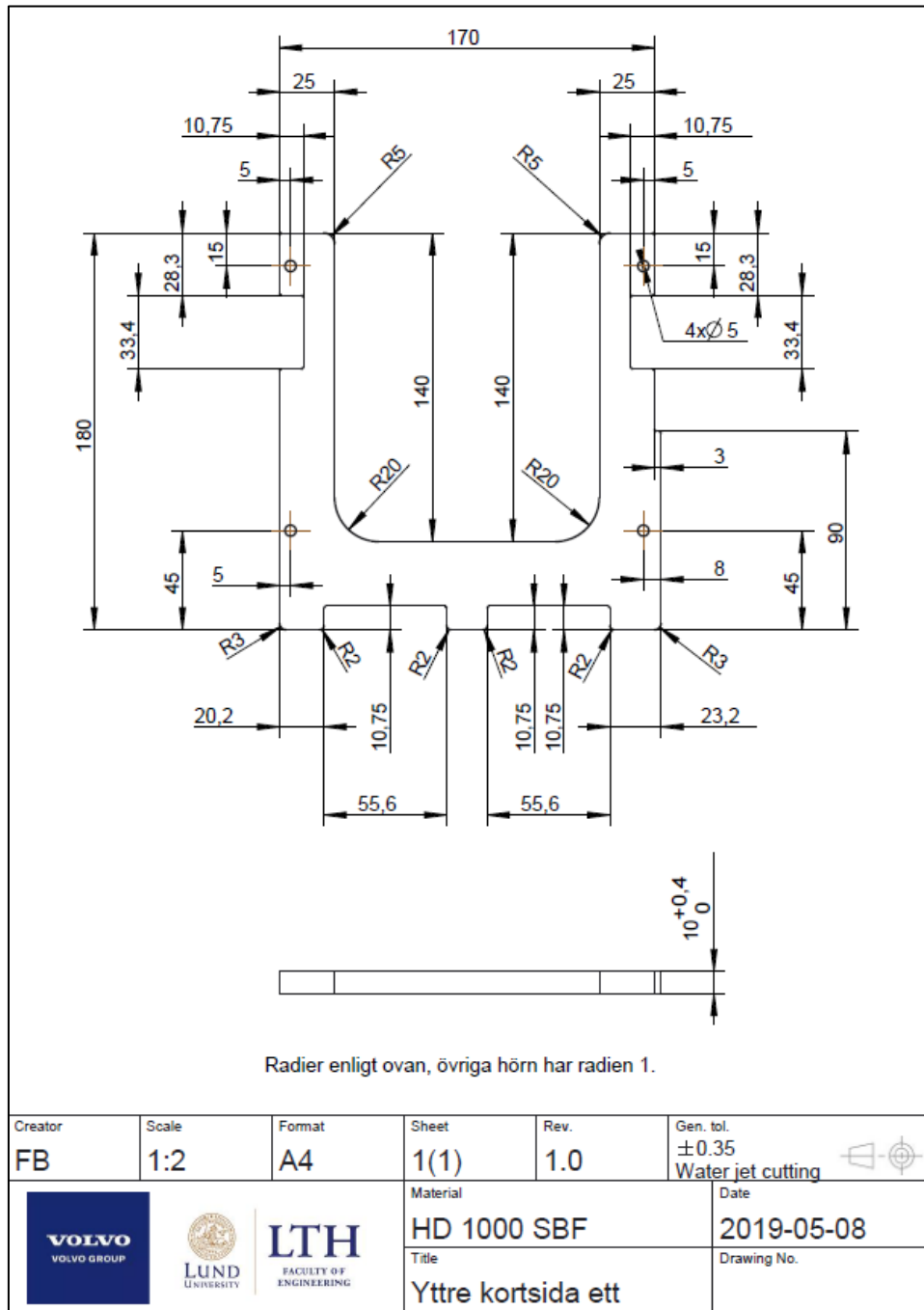


Figure G.7: Yttre kortsida ett.

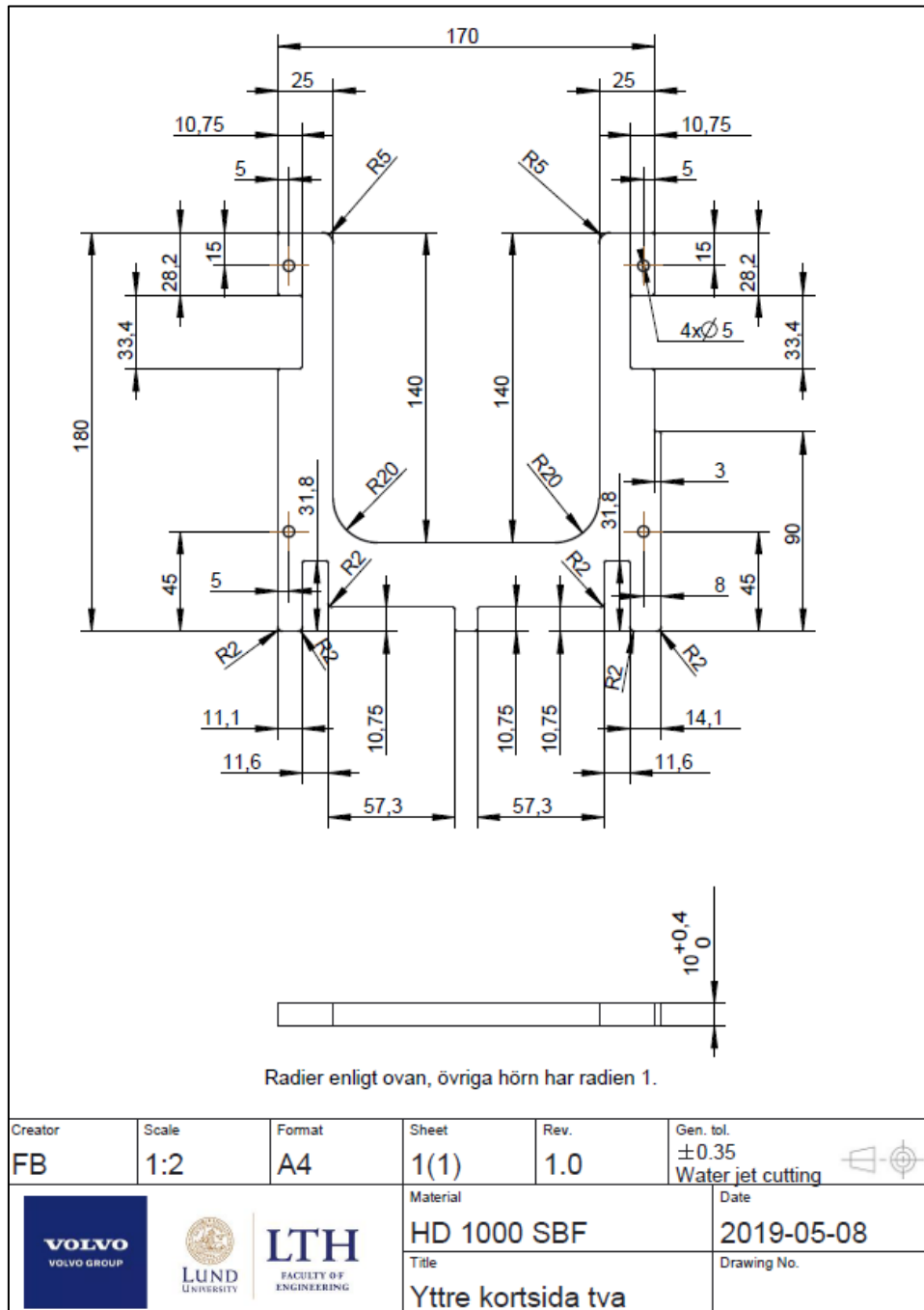


Figure G.8: Yttre kortsida tva.

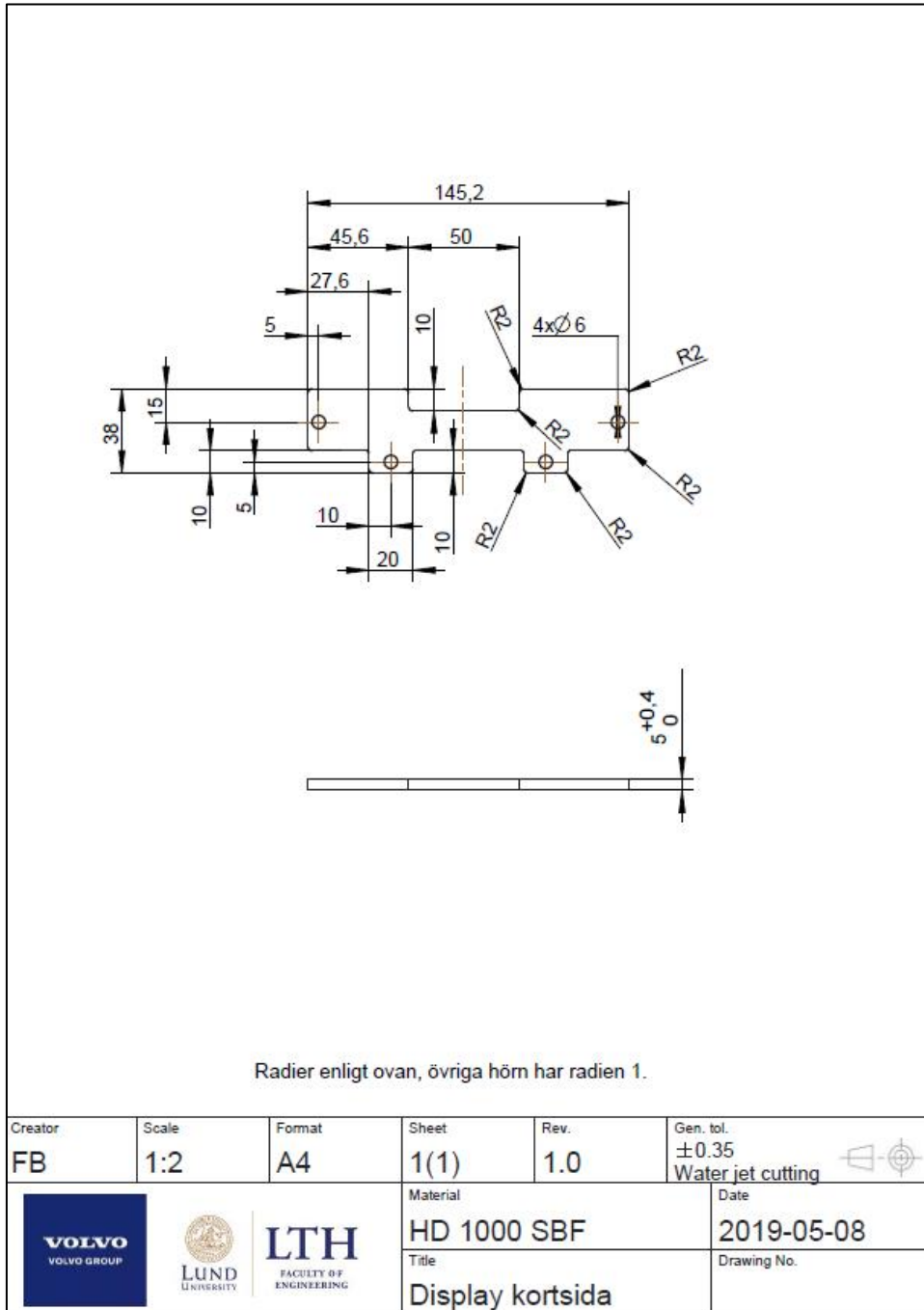


Figure G.9: Display kortsida.



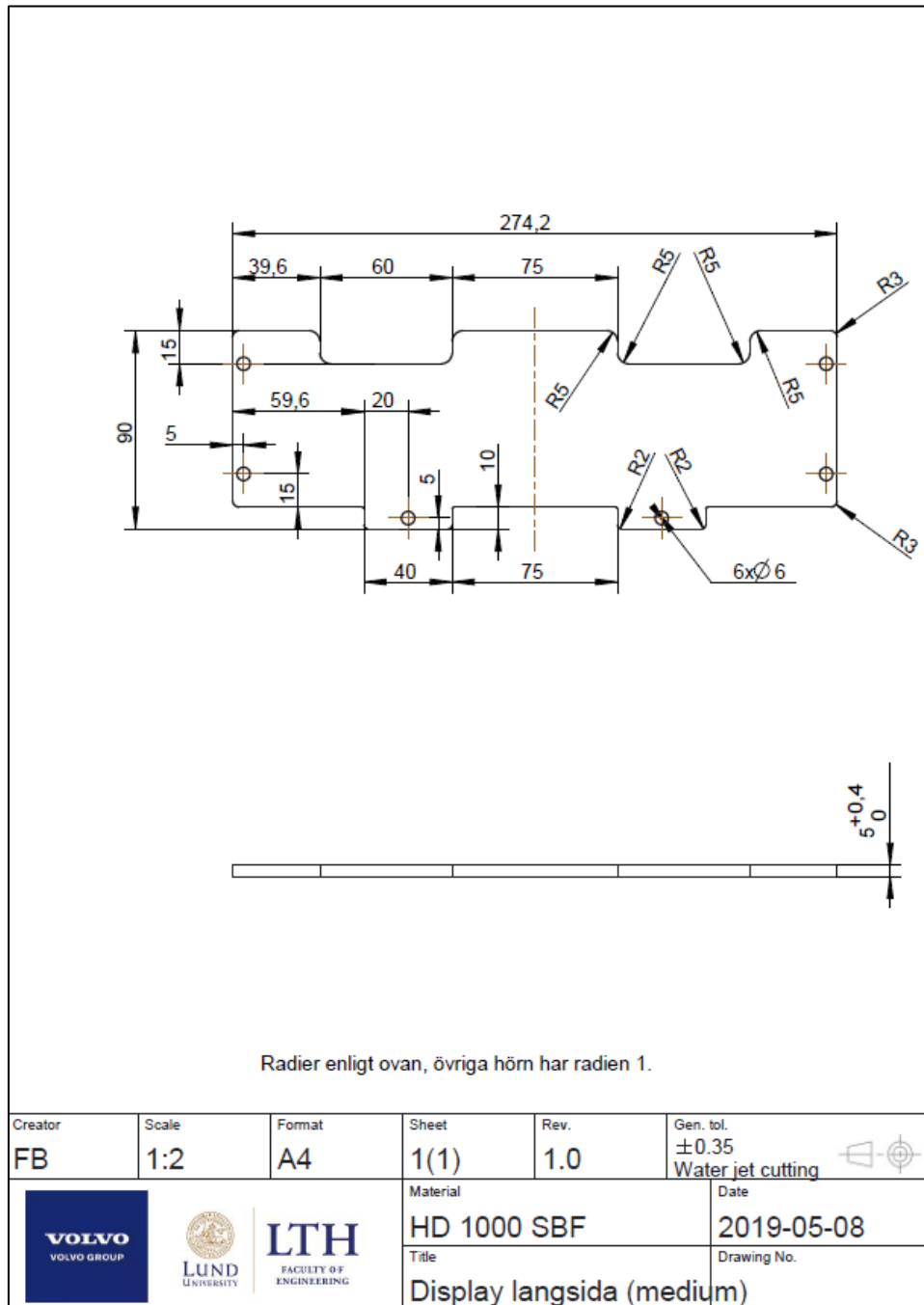


Figure G.10: Display langsida.

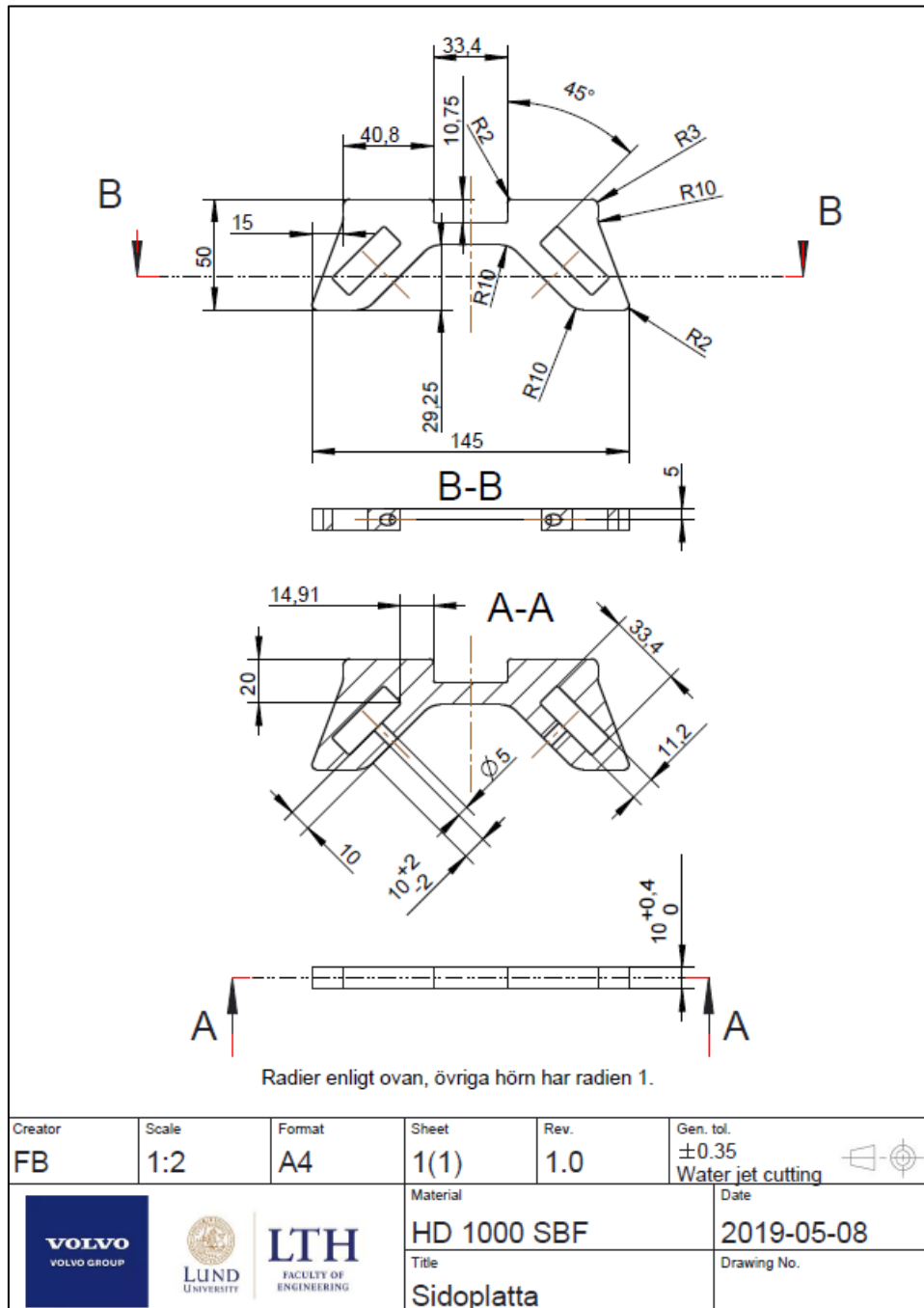


Figure G.11: Sidoplatta.

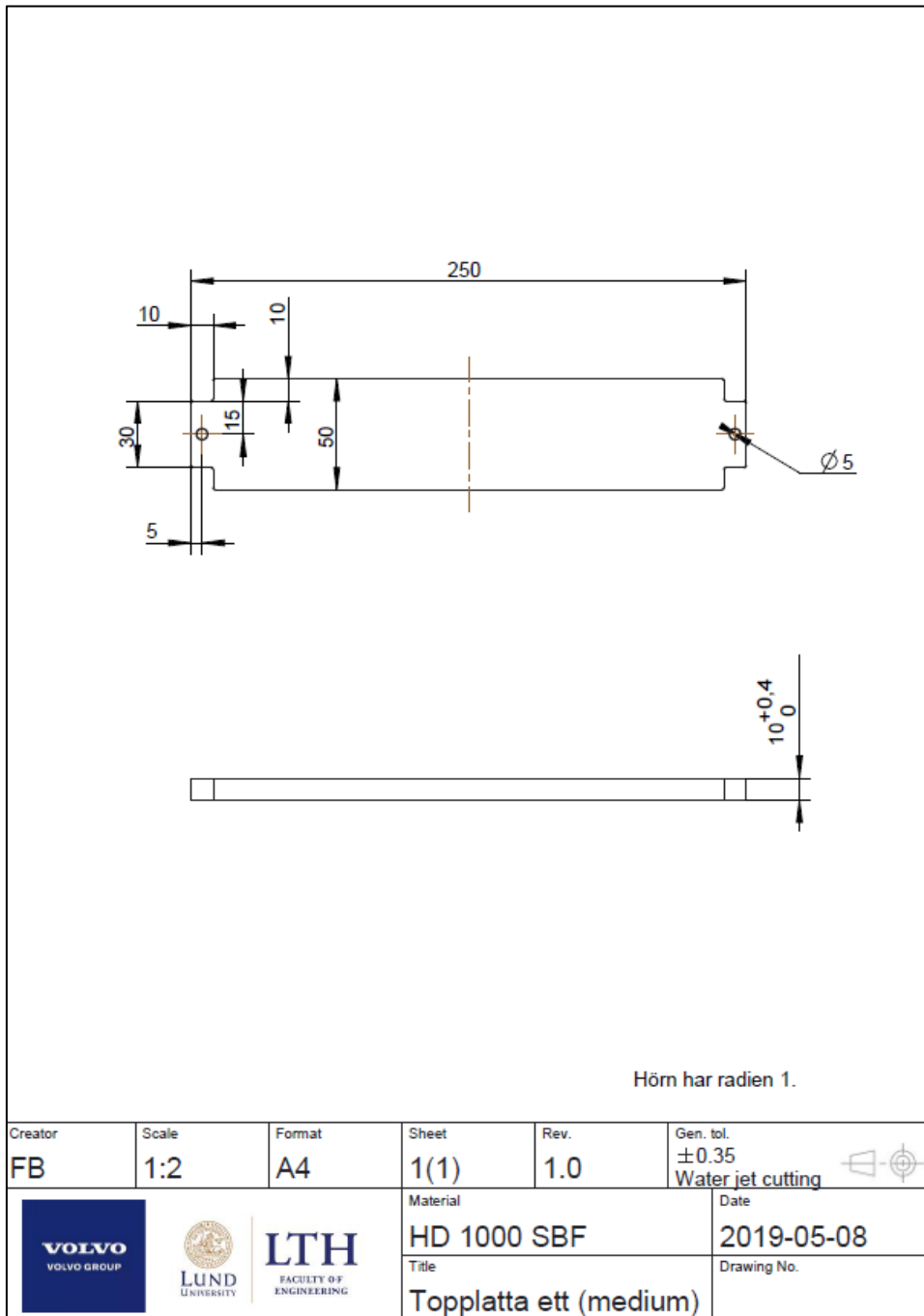


Figure G.12: Topplatta ett.

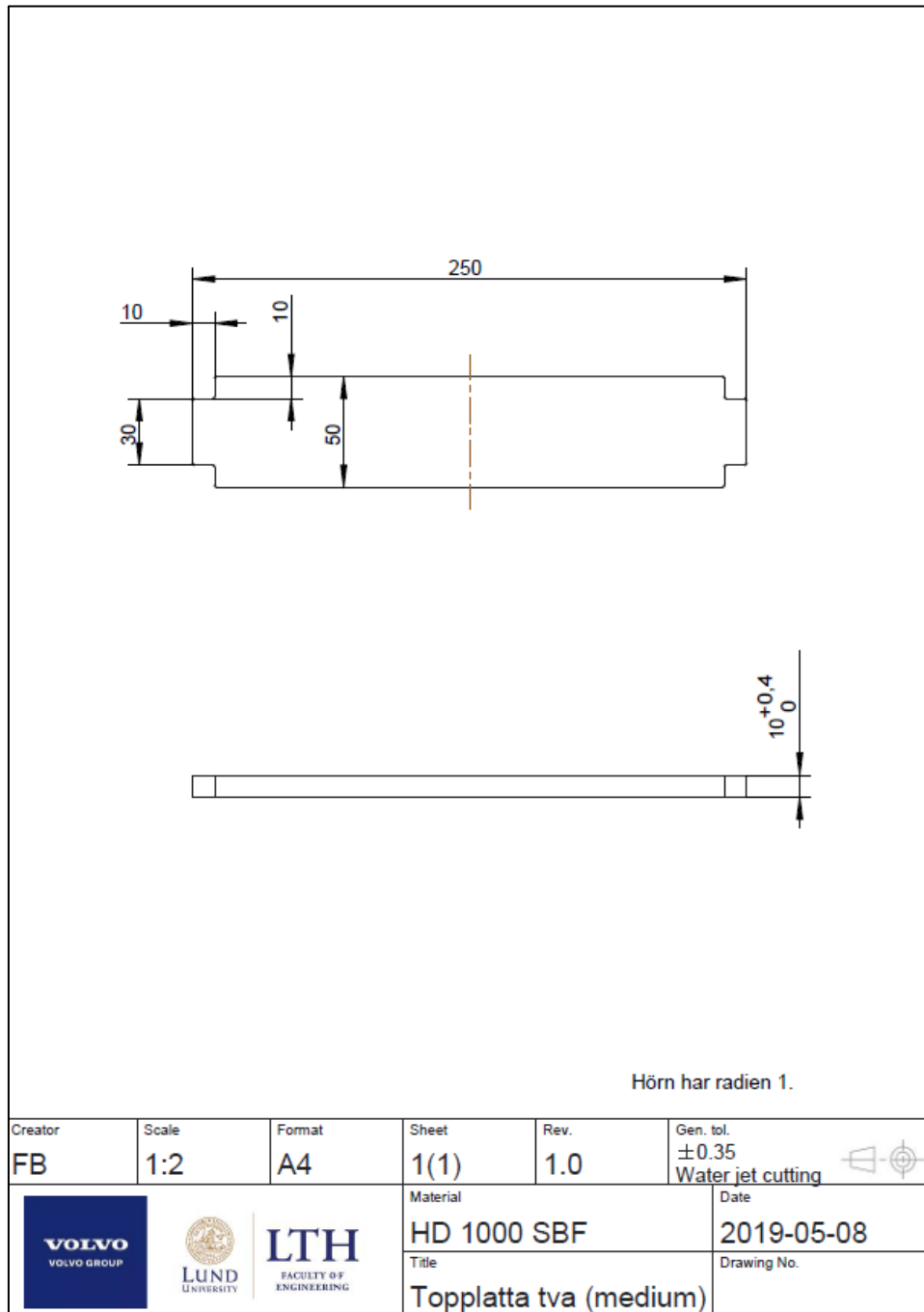


Figure G.13: Topplatta tva.

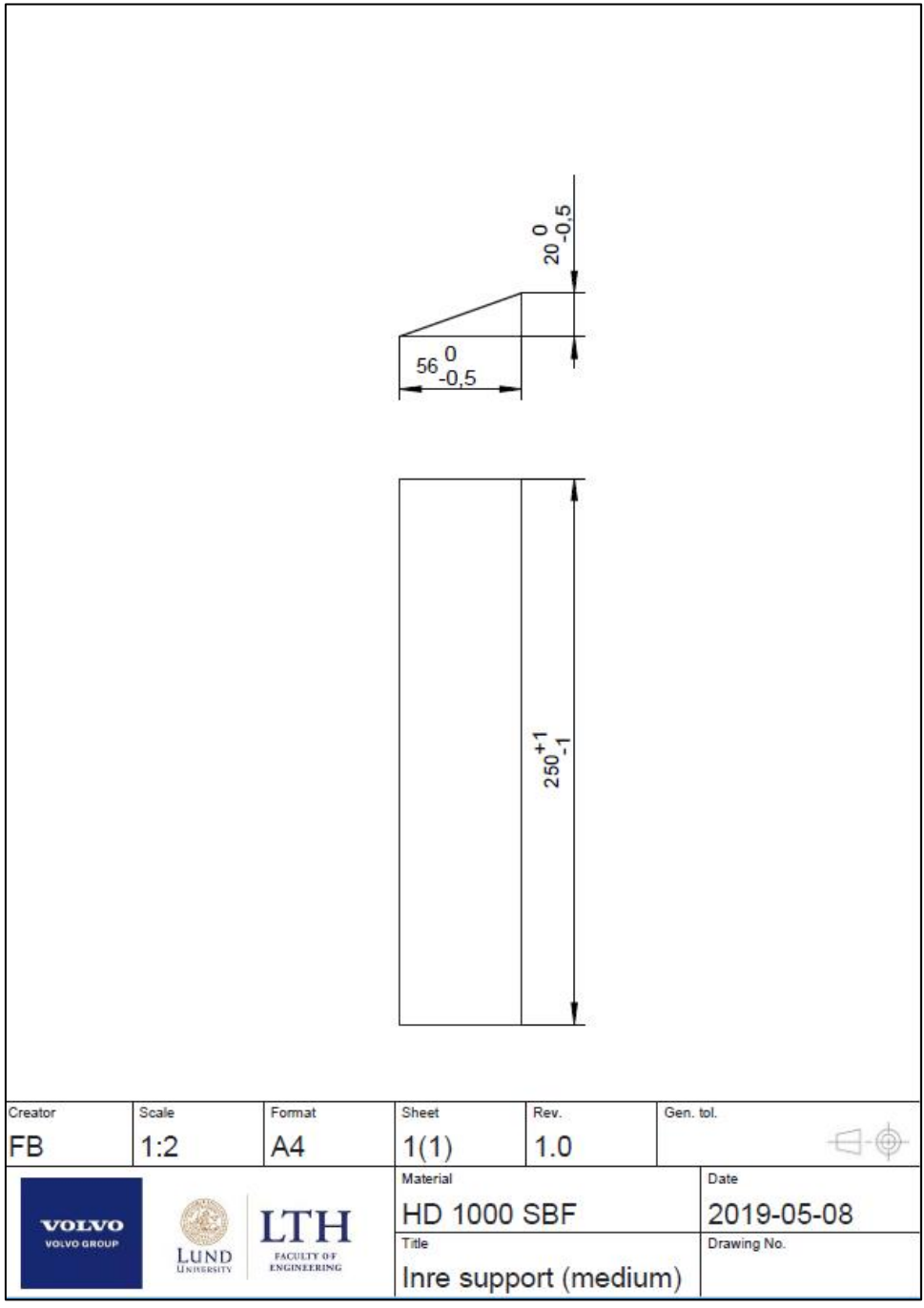


Figure G.14: Inre support.

## Appendix H Assembly instructions

*The assembly instructions for both the main packaging and the top cover are presented in this appendix.*

Components in table G.1. are used to manufacture one packaging.

**Table G.1 Components of one packaging.**

<i>Component</i>	<i>Quantity [no]</i>
<i>Bottenplatta</i>	1
<i>Fot</i>	2
<i>Langsida</i>	2
<i>Inre kortsida</i>	2
<i>Yttre kortsida ett</i>	1
<i>Yttre kortsida tva</i>	1
<i>Display kortsida</i>	1
<i>Display langsida</i>	1
<i>Sidoplatta</i>	2
<i>Topplatta ett</i>	1
<i>Topplatta tva</i>	2

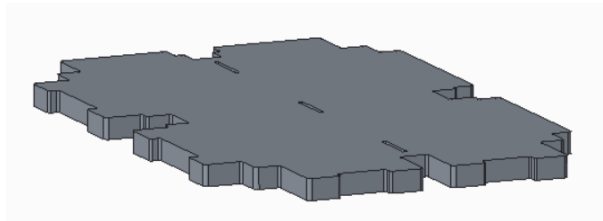
Where there are pre-cut holes, the components must be assembled with a suitable screw for the material. The holes are dimensioned for an M5 screw and the countersunk head screw should be used as much as possible. This assembly instruction applies to all sizes and it is only the length and some design of certain components that are different between the different sizes, but it is the same mounting step for all sizes. The different components are assembled in the following steps:

## H.1 Packaging

The main packaging is assembled with the following steps and order.

### Step 1

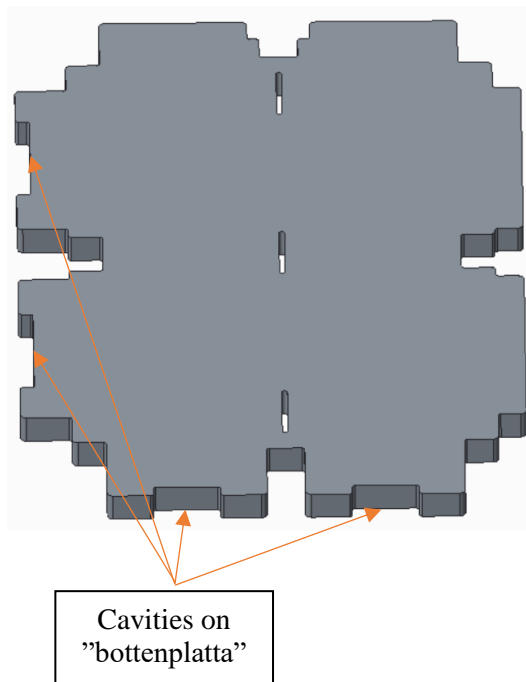
The first step is to start with the component "bottenplatta", see figure H.1.



**Figure H.1: Step 1.**

### **IMPORTANT!**

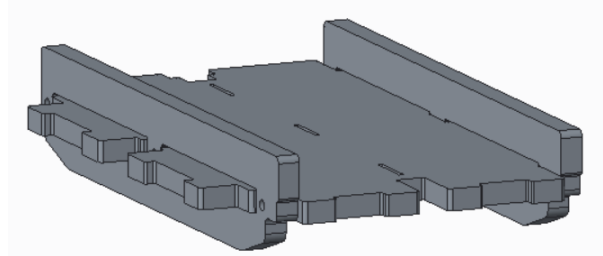
Lay the "bottenplatta" with the side up, so that the cavities on the long side are on the left side seen from the short side with cavities, see figure H.2.



**Figure H.2: Step 1.**

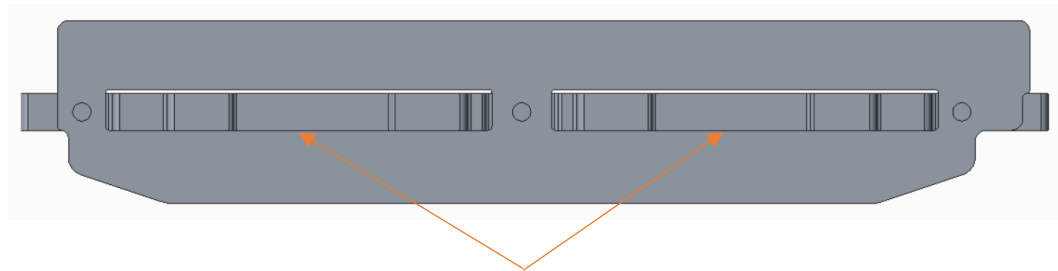
Step 2

The next step is to mount two "fot" components, see figure H.3.



**Figure H.3: Step 2.**

Each "fot" is fastened with three screws. "Bottenplatta" should lie against the lower edge of the holes on the "fot" during assembly and be centred, see figure H.4.

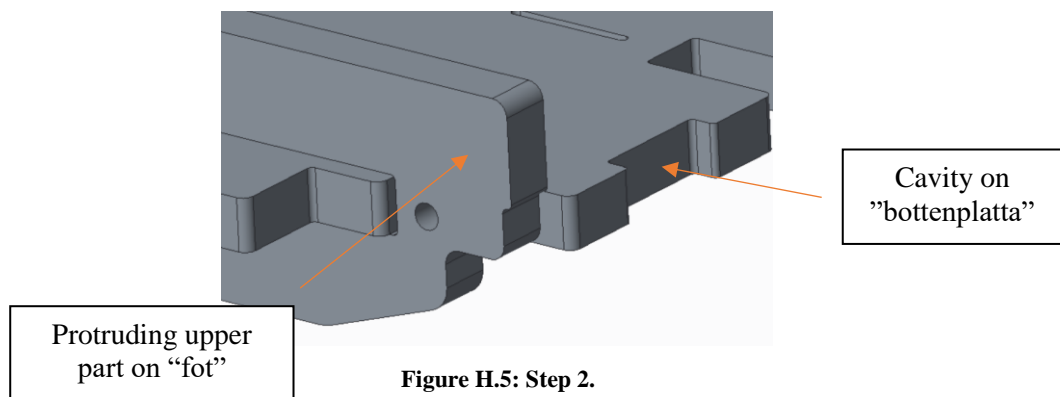


Contact between the lower part of the "bottenplatta" and the lower part of the holes on the "fot"

**Figure H.4: Step 2.**

**IMPORTANT!**

The side on the "fot" that has a protruding upper part on the side should be on the same side of "bottenplatta" which have cavities on the shorter side, see figure H.5.

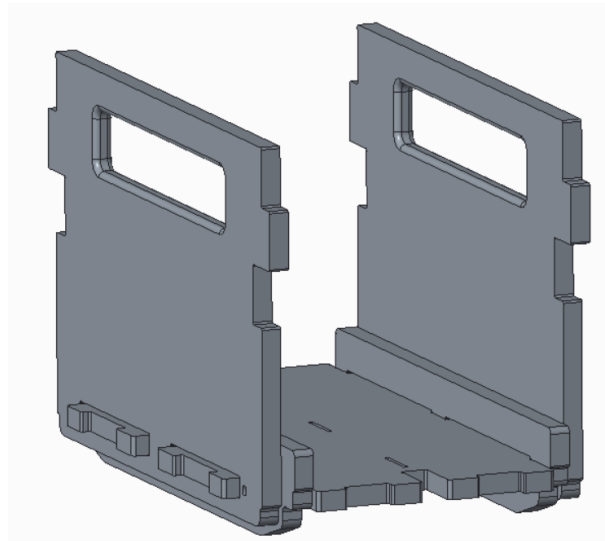


**Figure H.5: Step 2.**



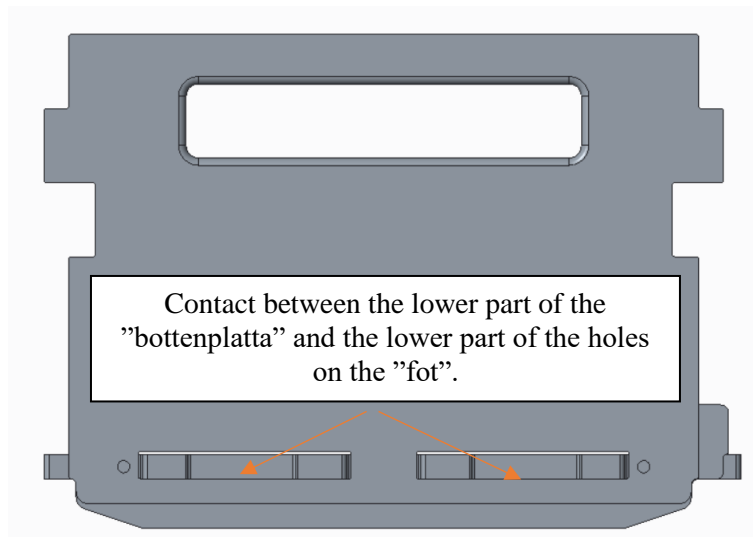
### Step 3

The next step is to mount two components "langsida". "Langsida" is symmetrical and consideration must not be given to which direction they are mounted on, see figure H.6.



**Figure H.6: Step 3.**

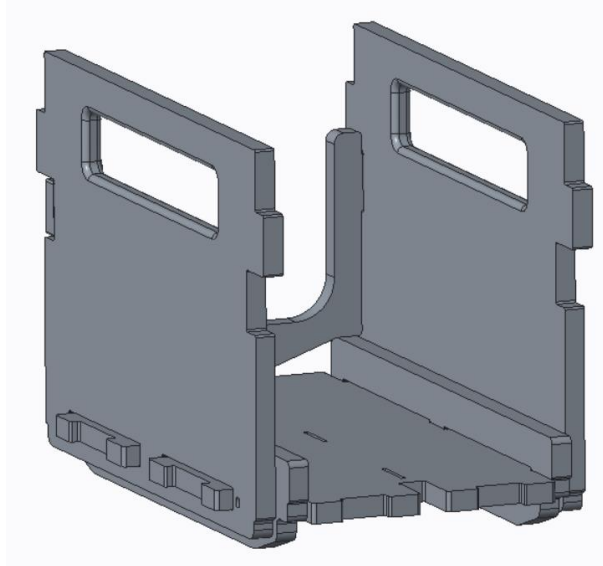
Each "langsida" is fastened with two screws. "Bottenplatta" should lie against the lower edge of the holes on the "foot" during assembly, and be centered, see figure H.4.



**Figure H.7: Step 3.**

Step 4

The next step is to mount one component "inner short side", see figure H.8.

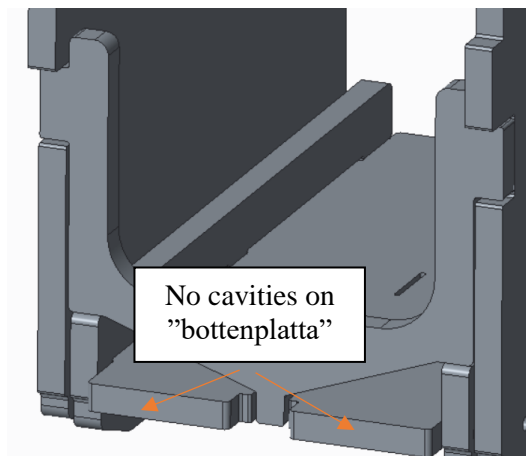


**Figure H.8: Step 4.**

"Inre kortsida" is mounted in place and is not fastened with screws.

**IMPORTANT!**

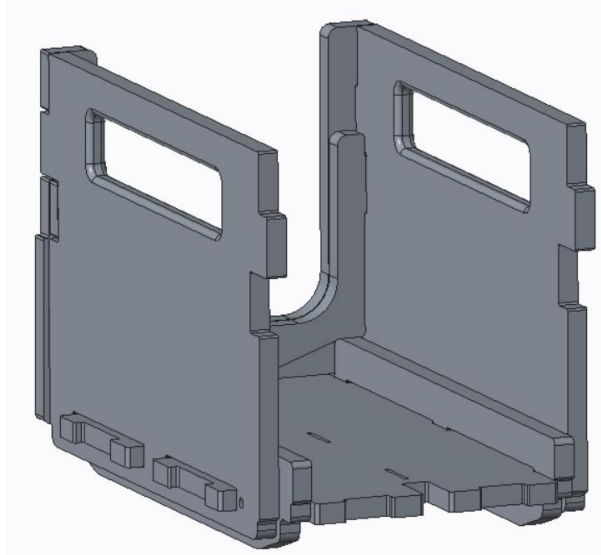
Mount the "inre kortsida" on the side of the packaging that does not have cavities on the short side of the "bottenplatta", see figure H.9.



**Figure H.9: Step 4.**

### Step 5

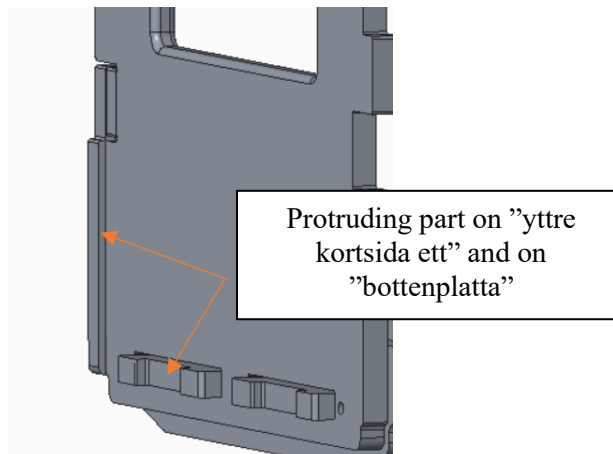
The next step is to mount on one piece "yttre kortsida ett" and attach it with four screws, see figure H.10.



**Figure H.10: Step 5.**

### **IMPORTANT!**

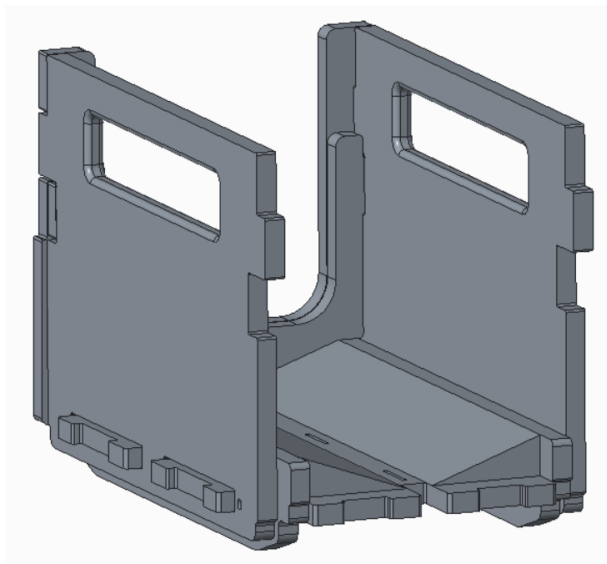
Mount "yttre kortsida ett" on the same side of the package as "inre kortsida" was mounted in step 4 and mount "yttre kortsida ett" with the right side in, so that the protruding part is on the same side as the protruding part on "bottenplatta", see figure H.11.



**Figure H.11: Step 5.**

### Step 6

The next step is to mount two components "inre support", see figure H.12.

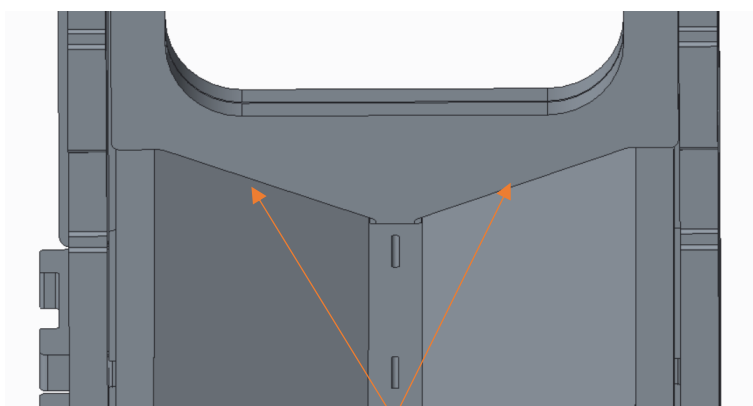


**Figure H.12: Step 6.**

"Inre support" is mounted in place on is not fastened with screws.

### **IMPORTANT!**

The "inre support" should be pushed in under "inre kortsida" to be held in place and to be pushed in as far as possible, see figure below.

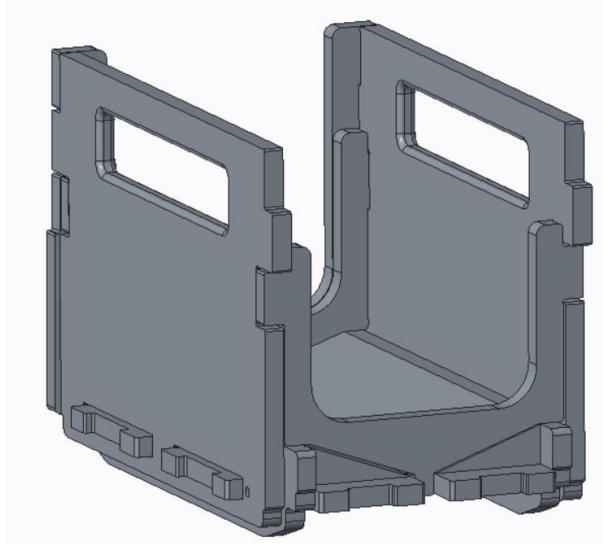


Push in "inre support" under "inre kortsida" as far as possible

**Figure H.13: Step 6.**

Step 7

The next step is to mount one component "inre kortsida", see figure H.14.

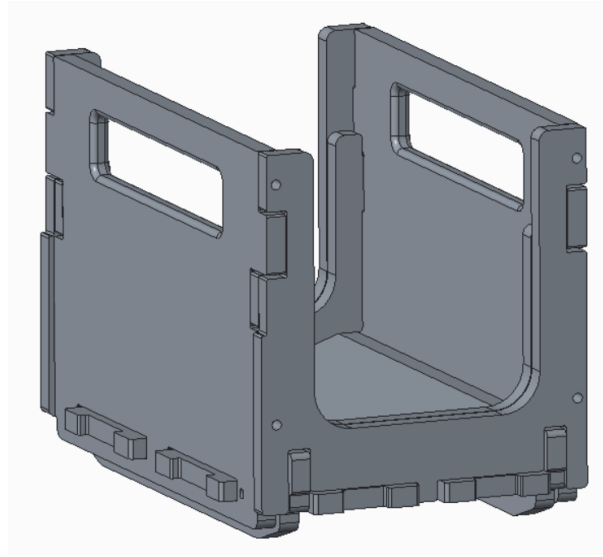


**Figure H.14: Step 7.**

"Inre kortsida" is mounted in place on the opposite side as "inre kortsida" was mounted on in step 4 and is not fastened with screws.

### Step 8

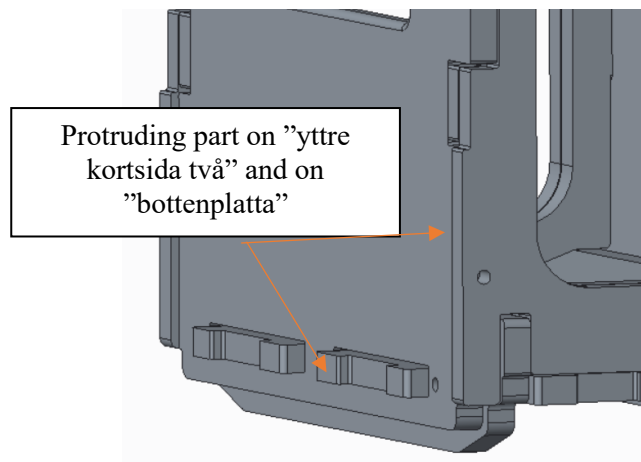
The next step is to mount on one component "yttre kortsida två" on the opposite side as "yttre kortsida ett" was fixed on in step 5 and it is fixed with four screws, see figure H.15.



**Figure H.15: Step 8.**

### **IMPORTANT!**

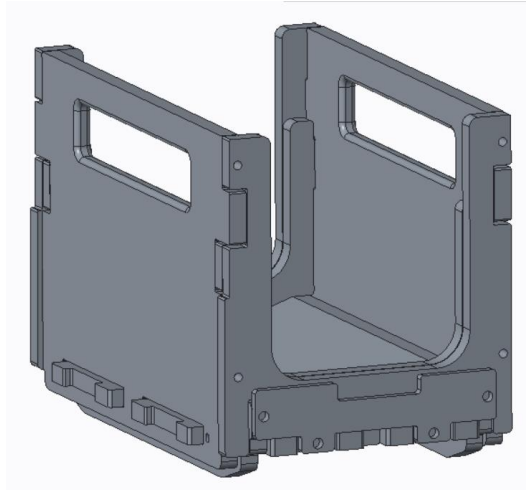
Mount "yttre kortsida ett" on the same side of the package as "inre kortsida" was mounted on in step 7 and mount "yttre kortsida ett" so that the protruding part is on the same side as the protruding part on "bottenplatta", see figure H.16.



**Figure H.16: Step 8.**

### Step 9

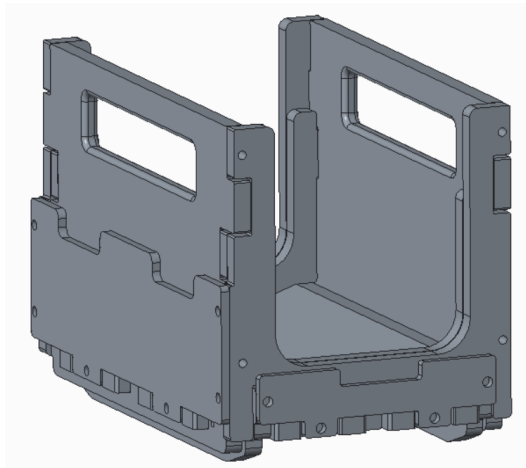
The next step is to mount one component "display kortsida". "Display kortsida" is symmetrical and no consideration must be given to which direction it is mounted on. "Display kortsida" is fastened with four screws and is centered.



**Figure H.17: Step 9.**

### Step 10

The next step is to mount one component "display långsida". "Display långsida" is symmetrical and no consideration must be given to which direction it is mounted on. "Display långsida" is attached with six screws and is centered.

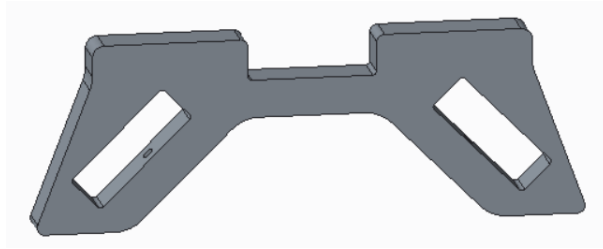


**Figure H.18: Step 10.**

## H.2 Top cover

### Step 1

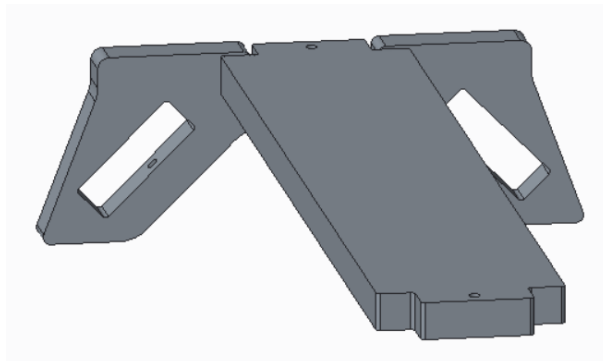
The first step is to start with the component "sidoplatta". "Sidoplatta" is symmetrical and does not have to be taken into account to which direction it is mounted.



**Figure H.19: Step 1.**

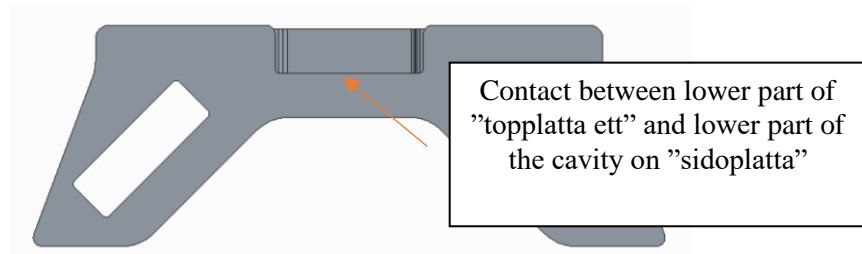
### Step 2

The next step is to mount on one component "topplatta ett".



**Figure H.20: Step 2.**

"Topplatta ett" is fastened with a screw. "Topplatta ett" should lie against the lower edge of cavity in the middle of the upper part of the "sidoplatta" when mounting and be centered, see figure below.

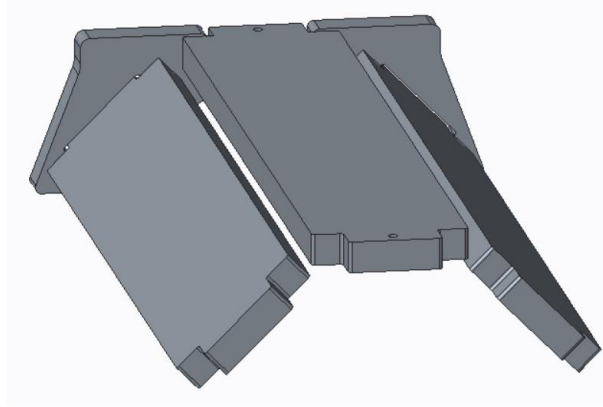


**Figure H.21: Step 2.**



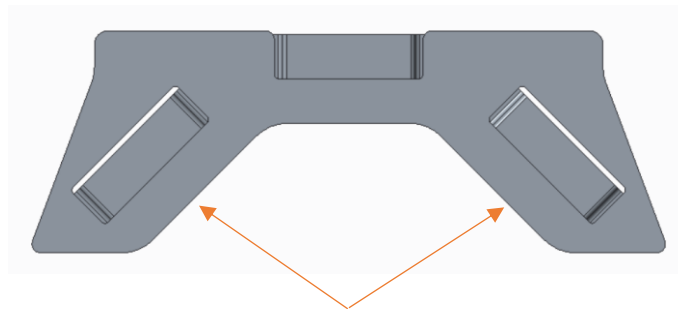
Step 3

The next step is to mount two components "topplatta två", see figure H.22.



**Figure H.22: Step 3.**

Each "topplatta två" is fastened with a screw and centered, see figure H.23.

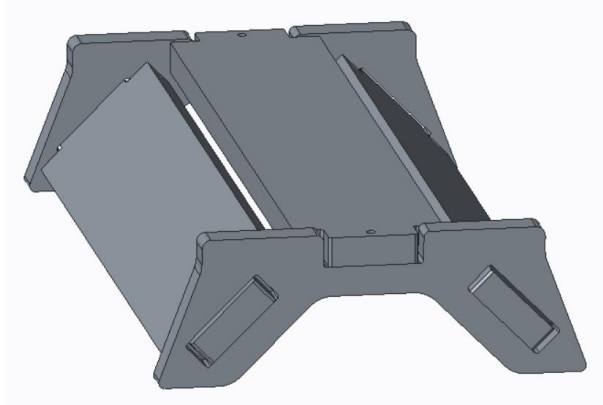


Each "topplatta två" is fastened with a screw from the inside.

**Figure H.23: Step 3.**

#### Step 4

The next step is to mount one component "sidoplatta". "Sidoplatta" is attached with a screw in "topplatta ett" and one screw in respective "topplatta tva".



**Figure H.24: Step 4.**