Chalmers University of Technology

Dept. of Industrial- and materials science

MMF092 Report

Gothenburg

Reinvention of a coffee brewer

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Summary

The coffee brewer market is a wide and competitive market worldwide. In today's market, many companies are competing to make the best coffee brewer to a reasonable price. With coffee consumption being an everyday need for millions of people, the need for a sustainable and good performance coffee brewer is required.

The purpose of this project is to redesign and develop two new coffee brewers, by starting with a given coffee brewer with very basic functions. With the help of provided knowledge during this part of time from lectures, research and laboratories, the project began. To start the redesign of the coffee brewer, a method from Otto & Woods report Reverse Engineering and Redesign Methodology for Product Evolution[14] is used. This method has several small steps to implement this process of work into redesign.
It started with dismantling and analysis of the given coffee brewer. As the group shared a common vision on how an almost perfect coffee brewer should look and how it should preform, many things highlighted areas where the improvements are needed.

With an agreed vision on how the new developed coffee brewer should look like and preform, the project took off. Working with various methods to define the functions and the design of them, the project began to form two different coffee brewers. After discussing within the group, using methods regarding redesign and sketches, the final result led to different coffee brewers with the similar style of design, as shown in Figure 1.

The main idea was to create two coffee brewers that have a similar style but targeting two different markets. That required a simple, timeless design that suits many customers. Furthermore, the coffee brewers were intended to have a high performance and simplicity in their functions. For example, features like the coffee filter and water tank are easy to remove, to make cleaning and refilling easier for the user. The two main target groups are students and home office-workers.
The price and the environmental impact are also key points in this project. Working constantly to achieve these featured led to the usage of the same parts for both coffee brewers. The manufacturing cost would decrease and also be more sustainable. In the more premium brewer, that is mostly aimed for the home office-workers, is using a thermos. This feature aims to keep the coffee temperature more consistent and to decrease the electricity to keep continously heating the coffee.

Figure 1: Coffee brewers

Preface

This report has been written during the course Machine Design, MMF092, and it describes the process of re-designing a coffee brewer. The goal is to improve the coffee brewer in the following ways:

- Reduced cost of manufacturing
- Clear improvement of performance.
- The product must have a clear environmentally friendly profile
- The aesthetics of the design must meet the requirements and desires of the presumed consumers
- The product must have a modular product architecture

The authors of this report are from the following programs: Mechanical Engineering, Automation Engineering and Erasmus exchange program from University of Twente (Advanced Technology course), studying during the fall semester of 2023. The report describes the workflow from the product that was handed out in the beginning of the course to the reflections and discussion about the methodology.

Distribution of work

The group has had an equal work distribution throughout the course. The group contract, that had been signed at the beginning of the course, made it easy to set clear expectations, task division, and goals for the work that would be done as a group. Table 1 displays the distribution of the work, showing the individuals that are primarily responsible for each section. Every person in the project has reviewed, contributed and confirmed the work presented in the report.

Chapter	**Contributers**
Introduction	Brunon
Background	Isac
Problem statement	Andreas
Goal of the project	Andreas
Method	Andreas
Delimination	Andreas
Market investigation	Gillis, Andreas
Market scenarios	Andreas
First market scenario	Andreas
Second market scenario	Gillis
Mood boards	Andreas, Brunon, Gillis
First market segment	Andreas
Second market segment	Gillis, Brunon
Analyse of coffee brewer	Isac + Everyone
Ishikawa	Brunon, Andreas
Black box	Isac, Gillis
Hypothetical functional structure	Isac
Product analysis	Isac
Existing functional structure	Isac
Exploded view	Felix
BOM	Felix
DSM	Isac
Pugh´s Ballonos	Felix
Requirement spec	Gillis + Everyone
Redesign	Isac + Everyone
New functional structure	Isac
Generating new concepts	Isac
Selecting concepts	Isac + Everyone
Concepts	Isac + Everyone
Design & appearance	Isac, Brunon + Everyone
CAD model	Brunon, Felix, Andreas
Drawings	Felix + Everyone
Modelling and analysis	Felix
DFA	Felix
LCA	Felix
LCA - existing	Felix
LCA - developed	Felix
RD&T	Gillis, Isac, Andreas
FMEA	Gillis
Manufacturing cost	Felix
Process cost	Felix
Assembly cost	Felix
Manufacturing cost and discussion	Felix
Material selection	Isac, Gillis
Heating plate	Isac, Gillis
Filter holder	Isac, Gillis
Verification	Isac, Gillis
Conclusion	Felix
Methodology discussion	Andreas

Table 1: Distribution of work

Contents

1 Introduction

This report describes the work performed by Group 10 during the Machine Design course - redesign of a coffee brewer. This chapter provides a comprehensive introduction to the project, and its primary function is to offer a clear and detailed description of the project. By analysing the issues related to coffee brewing, it is intended to understand why and how they occur, and systematically address them. The subsequent sections state the main problem, outline the primary goal of the project, the background behind the coffee brewing and the systematic methods used to address and correct them. This will provide a guideline that sets a direction for the rest of the report.

1.1 Background

Coffee brewing stands as an essential ritual for many in today's society. According to the International Coffee Organisation, around 2,25 billion cups of coffee are consumed every day throughout the world and every single one of those cups is brewed using some sort of brewing method. One of the most common ways to brew coffee is by using a coffee brewer, which many companies all over the world try to perfect, thus making it a very competitive market. The competitiveness within the market has led to an improvement in product quality; however, it has resulted in an escalation of price. The issue lies in the fact that opting for a budget-friendly coffee brewer often entails a compromise in terms of quality. Therefore Group 10 will delve into this competitive market trying to optimise functionality and design to make a competitive coffee brewer that brews the best possible cup of coffee from the best possible experience and price.

1.2 Problem statement

The problem stated in this project is focused on the functionality and design of an already existing coffee brewer. The design and material selection of the existing product gave the impression of being very cheap. The product felt very plastic and weak in some aspects. The functionality of it was poor due to parts being hard to reach and hot, the water temperature was inconsistent while brewing as well as there were spillage both when pouring coffee and when the brewing was interrupted for pouring. The developed brewers should result in two brewers with more robust designs, more consistent brewing and minimal spillage. These brewers will focus on two different market segments with them being students and coffee enthusiasts.

1.3 Goal of the project

The goal of this project is to improve the already existing coffee brewer regarding two criteria, it should have a lower cost of manufacturing than the existing brewer and a clear improvement of performance. The final product should also have:

- A clear environmentally friendly profile
- A design that meets the requirements and desires of the presumed consumer
- Modular product architecture

1.4 Method

The method used in this report is based on Otto & Woods report Reverse Engineering and Redesign Methodology for Product Evolution[14]. An overview of the methodology in Otto & Woods report can be seen in Figure 2. Some of the tasks listed in this methodology have been used in the report.

The first step in the project was to create a Black box model, this model is done as a first investigation of the inputs and outputs of the process without analysing the internal processes. The next step was then to create a hypothetical functional structure of the product where the functional structure is the internal processes of the product described as a verb together with a noun. After the functional structure the existing brewer was tested, the test was conducted by brewing and pouring coffee while measuring the brew-time as well as brew-temperature at the start of the brew and at the end. The test revealed multiple problems and potential improvements which were later on used both to come up with requirements and possible solutions.

Furthermore two different market segments were created, with this done differences between the two developed brewers were clear which then simplified the later steps such as creating the appropriate requirement specification for each brewer. To make a visual representation of the market segment together with design inspiration for the developed product a mood board was created. With the experiences gathered from the test of the existing brewer and the produced market segment a requirement specification of the new product was created, this is a vital part of the project and enabled the development to continue. After the requirement specification two functional structures were made with the internal processes that individually or in cooperation with other processes fulfil each requirement.

Next step was then to brainstorm on different solutions for each function in the functional structure, these were then inserted into a morphological matrix. The morphological matrices were useful to find different combinations of solutions to each function, out of all the generated combinations, ten of them fulfilled the requirements set on the brewer and therefore an elimination matrix was not needed. A Pugh matrix was then used to present the best solutions, which were then chosen as the solutions going forward.

The following steps were to perform different sorts of analyses of the product and for this a product was needed, so to further continue the work a product design concept was developed. With this product design concept a Design for Assembly (DFA) analysis was performed. This analysis investigates how easy it is to assemble the product. A well designed product which is easy to assemble has a higher DFA score, lower assembly time and higher assembly yield which results in a lower manufacturing costs.

With the DFA completed, an Life-cycle Assessment (LCA) was done to analyse the environmental impact of the product during its life time. The life time is divided into three parts, the production phase, the use phase and the end of life phase. With the desire to have the least amount of environmental impact as possible this analysis gave clear indications of the consequences of material selection as well as the benefits of the ability to use recycled material and recycle the material in the end of life phase. The reduction of the environmental impact of using a thermos jug instead of continuously heating the coffee after it is done brewing, can be clearly seen.

After the decision of material in the components had been analysed in an environmental point of view, the interrelationships of the components and their contributions to the final structure of the product were analysed in a Robust Design and Tolerances (RD&T) analysis. This analyse was important to perform to visualize the possible variations in different parts of the product if it were to be produced and assembled.

Given the new products design concept, its functions and the materials chosen for the components that are supposed to fulfil these functions a Failure Mode and Effects Analysis (FMEA) was performed. The purpose of this analysis was to find possible failures in the process, the failures probability and their severity. The failures were weighted with their probability and severity to output how important the failure were to further investigate, the analysis was therefore very important to perform to find these failures.

The last analysis performed in this project was a material selection analysis. With the results from the previous analyses and the requirements of each material that the components consists of a deeper analysis was performed to ensure that the best suited material for each component were used.

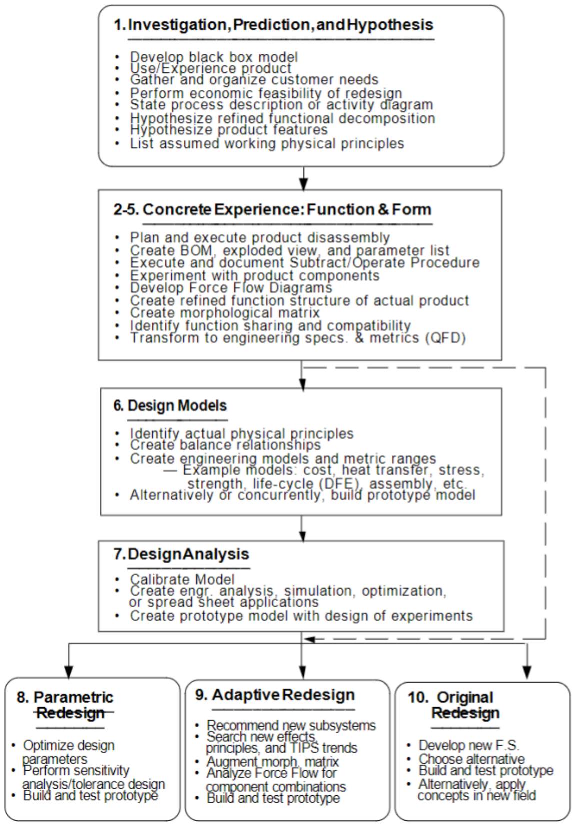


Figure 2: Plan list in reverse engineering

1.5 Delimitation

The report is written by students in a university class that lasted for eight weeks, thereby there was a limited time and some things in the machine design might not have been analysed. Those being elements like the internal architecture of electrical circuits, components and pipes. The implementation of a number of features are not detailed because of the time limit and also the limited ability to test a developed feature, because of both time and financial limits. These limitations resulted in a lack of product prototype, instead the product is presented with computer renders, and explanatory text together with a number of analyses.

2 Market investigation and product analysis

With a market investigation and product analysis, it provides a base for designing a coffee brewer. Through market investigations and scenarios, it defines the target group for the new product. By describing the target group, it explain underlying information about the design of the products. Analysing the existing coffee brewer provides insight into how a coffee brewer works, with all its components and functions, it provides information that generates ideas for improvements to the new coffee brewers.

2.1 Market scenarios

When developing new products, there is a need to have a list of requirements for the product. These requirements are based on what a potential customer wants in performance, design and cost, for example. To be able to form a requirement specification for the product it is then necessary to create a scenario of a situation with a customer that will enable a developer to think about what that customer would want from the product. Below follows two different market scenarios chosen for this project.

2.1.1 First market scenario

Meet Alex, a young college student who is juggling a demanding part-time job in a warehouse with his studies. His job entails long hours of physically demanding and repetitive tasks, such as loading and unloading heavy boxes. It is exhausting work and he often feels drained by the end of his shifts. The difference between Alex and his colleagues is that at the end of the shift the workday might be over for the coworkers and they are free to enjoy their spare time, for Alex it is just the beginning of another day of work but with his studies instead.

To stay energized and focused on both work and his studies, Alex needs a cheap way to consume caffeine. Buying coffee or energy drinks from cafes every day is too expensive for his tight budget and the convenience of having freshly brewed coffee at home would save him valuable time each morning. While Alex enjoys the taste of a good cup of coffee he would really not consider himself a coffee connoisseur and therefore he does not have much experience with different coffee brands and brewing settings. A reliable and simple coffee maker would ensure he starts his day with a much-needed caffeine boost without breaking the bank. A cheap coffee brewer is a small investment that can significantly improve Alex's quality of life, helping him power through his physically demanding job and stay on top of his college responsibilities.

2.1.2 Second market scenario

Meet Emma, a woman in her mid-thirties who works in management from home, working full-time but is very keen on getting the most out of her free time. She relaxes when she is not at work and enjoys the good things in her life. She is a self-appointed coffee enthusiast and generally demands products of high quality, not necessarily expensive. She also enjoys having friends over who generally like coffee at or close to her level of enthusiasm.

Coffee is both one of her passions and a necessity in her everyday life. On weekdays she drinks around 2-4 cups a day brewed at home and on the weekends she enjoys the occasional espresso. She enjoys manual pour-over coffee but feels that she needs a more convenient way to enjoy a high-quality cup of coffee, at home. She only brews coffee from freshly ground beans and has her own grinder at home.

2.1.3 Mood board

To enable the developer to showcase his idea and inspiration visually, a mood board has been used. This mood board can consist of pictures that gives the viewer an impression of a specific target group, a context of the product or what material and colour the product might be produced in. Overall the mood board should showcase a feeling the developer wants the product to project towards the user. In this sub section two different mood boards have been presented, one for each market scenario introduced earlier in this chapter.

2.1.4 First market segment

The first market segment is aimed for the buyers that want a reliable, simple and cheaper coffee brewer that still delivers good tasting coffee. This brewer will not be equipped with the exclusive functions or adaptable settings that its sibling might have which will result in it being a cheaper alternative. This product's potential buyers may be a young adult that just has moved away from home and has an extensive and demanding job or education and they feel the need of having a energy boost when they get home. They like coffee and would like a modern, simplistic and quality assured brewer that will be simple to operate and with next to no maintenance. Those demands together with the potential buyers limited budget and their less interest in micro adjustment settings for "just the right taste" of their coffee makes this choice of market a good alternative to our second market segment which is of the more luxurious kind. See Figure 3 to get a visual idea of the first market segment.

Figure 3: Moodboard of first market segment [2] [5] [6] [12] [13]

2.1.5 Second market segment

The second market segment is strategically designed to offer a more elevated and premium coffee brewing experience. Tailored for discerning coffee enthusiasts who appreciate the art of coffee but seek convenience, this advanced brewer incorporates specific functions and settings to meet the user's exact preferences. Targeting individuals who value their time and want to avoid the intricacies of manual brewing, this sophisticated machine promises a high-quality cup with minimal effort.

In response to the demand for precision and customization, the brewer is equipped with micro-adjustment settings, allowing users to achieve the perfect taste that distinguishes their coffee experience from the offerings in the previous market segment. Maintenance remains a low-key aspect, requiring, at most, an annual descaling to keep the brewer in optimal condition.

However, entering this market presents challenges as it is already saturated with well-established brands. Consequently, the product's higher price reflects its advanced features and the reputation of delivering a superior coffee experience. The complexity of the product aligns with the expectations of a customer seeking a blend of luxury and efficiency. The accompanying mood board, illustrated in Figure 4, visually encapsulates the essence of this premium segment, highlighting its sophistication and commitment to a refined coffee culture.

Figure 4: Mood board of second market segment [9] [8] [3] [11] [7] [1].

2.2 Analyse of generic coffee brewer

In this section a Black box and a functional structure description have been created. This method present the product inputs and outputs as well as every function making it work. By doing so, a deeper understanding of the product in question has been created, which will be beneficial at the optimisation stage of product development. The analysing of a generic coffee brewer will also include Ishikawa diagrams to show the core features of the design.

2.2.1 Ishikawa diagrams

Ishikawa diagrams presented by Figures 40 to 44 in Appendix B.2 show causes behind core features of the coffee brewer design. This method visualises the key points that had to be taken into consideration during the designing of the brewer, by listing all of the causes and parameters that lead to a corresponding outcome. As an example, temperature of the water influences the performance of the coffee brewer, and therefore the design needs to dictate the correct temperature. This analysis will be helpful to find and create improvement points during the redesign phase.

2.2.2 Black box

The black box's, see Figure 31 in Appendix A.1, purpose is to explain the fundamental inputs and outputs of a coffee brewer. It's purpose is to provide a basic understanding what a coffee brewer have for inputs and outputs. For a more in-depth explanation of the system within the black box, the functional structure explain the process of transforming inputs into outputs, providing a detailed insight into the workings of the system.

2.2.3 Functional structure - hypothetical coffee brewer

In the following functional structure diagrams, the goal is to deconstruct a hypothetical coffee brewer as well as the coffee brewer that was handed out at the beginning of the course. The functional structure should extract the individual functions that together form the machines total function. By doing this, the developer can then explore new and potentially better ways to perform the same functions. The deconstruction of the coffee brewer has been built upon what goes into and out of the black box model. All of the functions have been defined with a combination of a verb and a noun as in "Heat water". The functional structure of the hypothetical coffee brewer can be seen below in Figure 5.

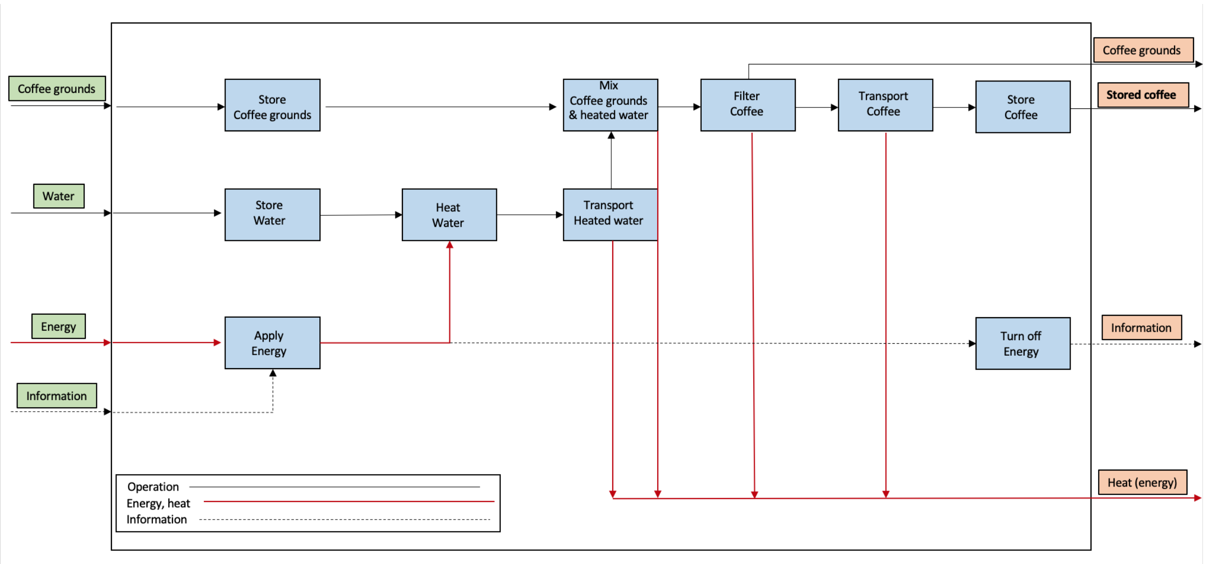


Figure 5: Functional structure of hypothetical coffee brewer

2.3 Product analysis

With a product analysis of the existing product, it offers general information of how a coffee brewer works and insight into its components. Beginning with a functional structure of the existing coffee brewer and then dismantling it, this process provides a prospective on all the components of the brewer and offering a general overview on how the coffee brewer is built.

2.3.1 Functional structure - existing coffee brewer

A functional structure is also made on the coffee brewer that's intended to optimise. The functional structure can be seen in Figure 6. The reason to make secondary functional structure on an already existing coffee brewer is to have a reference to the function that potentially could be optimised.

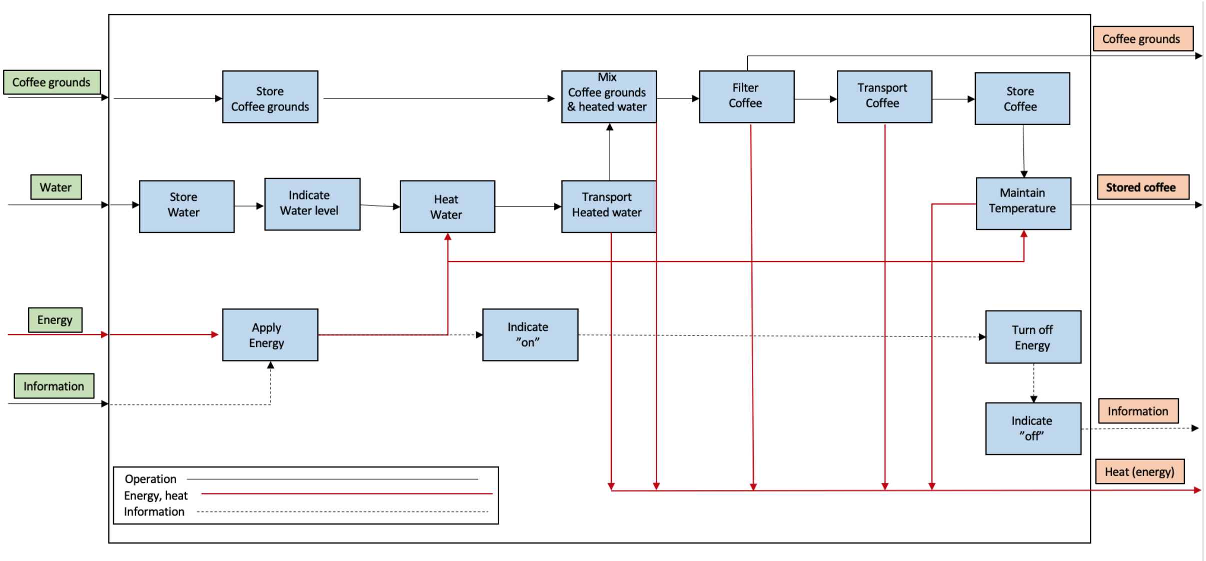


Figure 6: Functional structure of existing coffee brewer

2.3.2 Exploded view

The exploded view, Appendix B.1, is a picture with all the components of the original coffee brewer. The project is based on how a coffee brewer is made and what type of components it has in general. Through dissembling the coffee brewer, it provides with a general knowledge of how a coffee brewer is made and how it works. Examining each components individually generates ideas of potential improvements and highlights what areas that is necessary to improve.

2.3.3 BOM-existing product

With a Bill of Materials (BOM) table all the components are listed with individual article number. This provides a good understanding and an easy structure of the components that the coffee brewer is made of. In the Table 2, each component is provided with detailed information as, the amount of quantity, description, article number, weight, material and manufacturing methods. It is a valuable point to gain a general understanding what types of components their is in the product and what types of raw materials that is used.

Table 2: BOM of the coffee brewer

Part	Qty	Description	Article number	Weight per part (g)	Total Weight (g)	Material	Manufacturing methods
Coffee measure	1	A tool to measure the amount of coffee	A-1	3.33	3.33	PP	Injection moulding
Lid for jug	1	Lid for the jug to prevent spills	A-2	7.46	7.46	PP	Injection moulding
Glass jug	1	Collects coffee after brewing	A-3	160.99	160.99	Glass	Casting
Handle jug	1	Handle for easy pouring	A-4	14.37	14.37	PP	Injection moulding
Metal around the jug	1	Stabilizes the handle	A-5	6.49	6.49	Steel	Melting, casting, and forming
Clamp	1	Stabilizes the jug	A-6	1.15	1.15	PP	Injection moulding
Screw clamp	1	Locks the clamp	A-7	0.73	0.73	Steel	Melting, casting, and forming
Packing sump holder	1	Prevents coffee leaks	A-8	0.19	0.19	Silicone rubber	Injection moulding
Spring sump holder	1	Prevents leaks when jug is removed	A-9	0.47	0.47	Steel	Melting, casting, and forming
Flow stopper sump holder	1	Prevents coffee spillage	A-10	1.23	1.23	PP	Injection moulding
Sump filter	1	Contains coffee powder	A-11	11.32	11.32	PP	Injection moulding
Sump holder	1	Contains coffee powder	A-12	31.32	31.32	PP	Injection moulding
Base plate	1	Chassis part for protection	A-13	54.49	54.49	PP	Injection moulding
Screw metal holder	2	Locks metal holder	A-14	0.69	1.38	Steel	Melting, casting, and forming
Metal holder	1	Stabilizes the heating element to the brewer	A-15	10.13	10.13	Steel	Melting, casting, and forming
Screw for chassis middle	2	Locks main parts	A-16	0.47	0.94	Steel	Melting, casting, and forming
Lock washer	1	Secures a screw	A-17	0.12	0.12	Steel	Melting, casting, and forming
Nut to screw	1	Grips the screw	A-18	0.3	0.3	Steel	Melting, casting, and forming
Power button	1	Controls power and brewing	A-19	1.48	1.48	PP	Injection moulding
Radiator	1	Heats the water	A-20	75.21	75.21	Al and Steel	Melting, casting, and forming
Circuit board screw	1	Secures circuit board	A-21	0.37	0.37	Steel	Melting, casting, and forming
Top chassis	1	Upper chassis part	A-22	218.85	218.85	PP	Injection moulding
Hose clamp	2	Prevents water leaks	A-23	0.46	0.92	Steel	Melting, casting, and forming
Hose short	1	Guides water to the shower head	A-24	4.49	4.49	Silicone rubber	Injection moulding
Hose long	1	Guides water to the shower head	A-25	4.96	4.96	Silicone rubber	Injection moulding
Metal plate	1	Heats the jug	A-26	50.92	50.92	Steel	Melting, casting, and forming
Rubber sealing to metal plate	1	Seals metal plate	A-27	5.80	5.80	Silicone rubber	Injection moulding
Lower chassis	1	Lower chassis part	A-28	173.12	173.12	PP	Injection moulding

2.3.4 Component-based DSM

This section lists all of the components concluded in the coffee brewer and compare them individually. The comparison is weather the components are related to the compared component or not. By sorting this into a DSM-table as seen in Table 3 and Table 4, it clarifies weather the component have few or many related parts. This method is done to make it easier for the developer to see weather changing a component affects other components as well. Thus considering changing one component with many related parts can lead to a need to change the related components to make the product work.

Table 3: DSM on existing coffee brewer

		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
Lid for jug	A	A	X	X	X				X													
Glass jug	B	X	B	X	X														X			
Handle jug	C	X	X	C	X	X																
Metal around the jug	D	X	X	X	D	X																
Clamp	E			X	X	E																
Packing filter holder	F						F				X											
Spring filter holder	G							G	X		X											
Flow stopper filter holder	H	X						X	H		X											
Filter	I									I	X											
Filter holder	J						X	X	X	X	J					X						
Base plate (chassi)	K											K									X	
Metal holder	L												L		X						X	
Power button	M													M							X	X
Radiator	N												X		N		X	X				
Top chassi	O										X					O	X	X			X	
Hose short	P														X	X	P				X	
Hose long	Q														X	X		Q			X	
Metal plate	R		X																R	X	X	
Rubber sealing metal plate	S																		X	S	X	
Lower chassi	T											X	X	X		X	X	X	X	X	T	X
Circuit board	U													X							X	U

By sorting every component to their most related parts as seen in Table 4, modules can be made. In this case three different modules where made; "Jug", "Lower part" and "Upper part". This was done to get a clearer view of which components that where related so that it will be easier to know which components that are affected from any changes made by the developer. It also helps the developer to come to a conclusion of which components or modules that are worth changing.

Table 4: Sorted DSM on existing coffee brewer

		A	C	D	E	B	R	S	N	L	P	Q	T	M	K	U	O	J	I	H	G	F
Lid for jug	A	A	X	X		X														X		
Handle jug	C	X	C	X	X	X																
Metal around the jug	D	X	X	D	X	X																
Clamp	E		X	X	E																	
Glass jug	B	X	X	X		B	X															
Metal plate	R					X	R	X					X									
Rubber sealing metal plate	S						X	S					X									
Radiator	N						X		N	X	X	X										
Metal holder	L								X	L			X									
Hose short	P								X		P		X				X					
Hose long	Q								X			Q	X				X					
Lower chassi	T						X	X		X	X	X	T	X	X	X	X					
Power button	M												X	M		X						
Base plate (chassi)	K												X		K							
Curcuit board	U												X	X		U						
Top chassi	O										X	X	X				O	X				
Filter holder	J																X	J	X	X	X	X
Filter	I																	X	I			
Flow stopper filter holder	H	X																X		H	X	
Spring filter holder	G																	X		X	G	
Packing filter holder	F																	X				F

2.3.5 Pugh's Balloon's matrix

Using a Pugh's Balloon matrix helps to define the structure of the coffee brewer. With these specific specifications for the coffee brewer, it forms the basis for its development. With some design aspects it contributes to the goal of the coffee brewer, as illustrated in Figures 34 and 35 in Appendix A.3. Starting with a broad exploration of the features that a coffee brewer should have, and the refine the discussion to form a more precise set of features.

With a Pugh's Balloon matrix it forms the groundwork for the specific requirements of the coffee brewer. In the Requirement specifications section, it provides a more detailed specifications of the coffee brewer.

2.3.6 Requirement specification

This section aims to create a requirement specification for the coffee brewer. This is done by listing all the different requirements that the coffee brewer should manage to accomplish, as well as desired values. The listing is done by describing the criteria and if needed, the target value to know how to verify the given criteria. The requirements are mainly taken from the functions in the functional structure, but also from different environment requirements such as the geometry. The requirements are marked as "R" and the desired values are marked as "D" as seen in Figure 37, Appendix A.4. All the requirements and desired values also need to have some sort of method to verify if the product will manage. Thus the verifying method and the reference have been listed for every requirement and desired value. It is crucial when developing a product to always have a functional reference of what the product should be capable to perform.

3 Redesign

After analysing all the aspects of the existing coffee brewer, shown in the chapters above, a redesign of the product has been made. This redesign is based on the functional structures made in chapter 2.2.3 and the requirement specification in chapter 2.3.6, but established by the problems that has occurred during the analyses of the existing coffee brewer. The redesign is done to optimise the product´s functionality and design to make it more appealing to the consumer.

3.1 New functional structure

After analysing the functional structures of an already existing coffee brewer and a hypothetical one, the next step will be to create a functional structure of the product that will be made. By having the previous functional structures as a reference point this can be done by adding, deleting and changing the

functions. The new functions resemble what Group 10 would want to change about the functionality to be able to optimise the existing coffee brewer as wanted. The new functions are also made by analysing the market groups that are intended to aim for to know what will be important to add.
Two different functional structures were made for each market group. For the coffee enthusiasts the need for a luxury feel and regulation of inputs were important, thus adding functions that can find solutions for this were made. A big flaw in the existing coffee brewer was the automatic flow stop which did not work as intended and lead to spillage. Thus a function for stopping the flow was made to solve this problem.

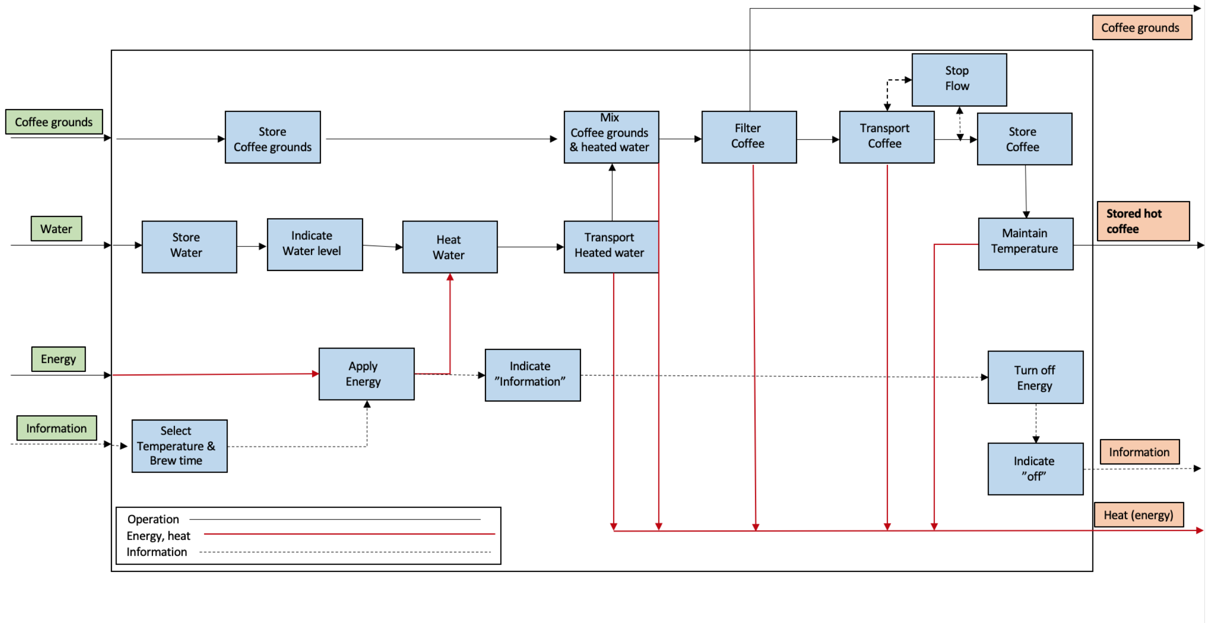


Figure 7: New functional structure

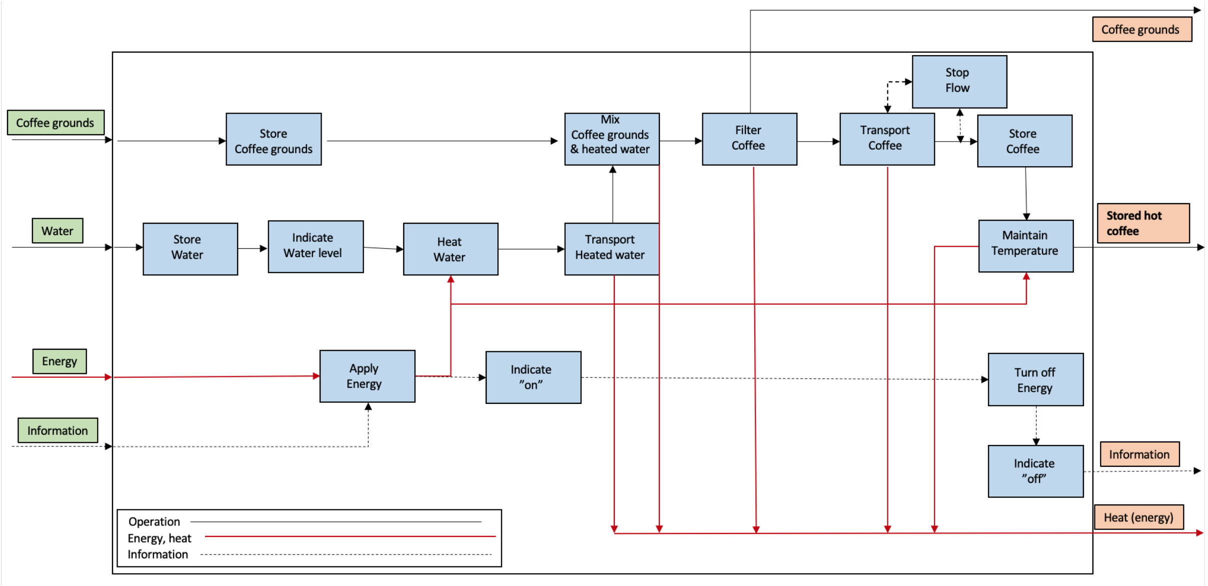


Figure 8: New functional structure cheap

3.2 Generating new concepts

To get the the best possible product that checks all the requirements and desires, different concepts had to be made before choosing the most suitable solution. This was done by using a method called the morphological matrix. From the newly made functional structures this was assembled by sorting all the different functions in a table. For each functions different solutions were computed by brainstorming in the group. All the functions and solutions were put in a morphological matrix as seen in Figure 9. All the solutions were produced to work together to simplify the generating procedure. By combining the different solutions fully functional solutions can be computed. This lead to a high number of different solutions and thus Group 10 hand picked 10 solutions that either were thought to compete to be the best or add some new and different functionalities.

Functions	Solutions				
Store Coffee grounds	cone shaped filter holder	straight filter holder	cone and straight		
Store water	Removable water tank	non removable water tank	integrated	external	
Indicate water level	Lines on watertank	digital guage	analog guage		
Apply energy	Electrical	mechanical	battery	Chemical	
Heat water	Heated tube	Radiator			
Transport heated water	Heat difference, tubes	Pump	Mechanical		
Mix coffee grounds & heated water	Shower head - as big as possible	single hole outlet	shower head - small		
Filter coffee	Paper filter	Reusable filter	Both reusable and paper filter (modular)		
Transport coffee	Gravity, a hole at the bottom of filter holder				
Stop coffee flow	manual flow stop - lever	automatic flow stop			
Store hot Coffee	Thermos jug	thermos cup	Glass cup	Glass jug	
Maintain coffee temperature	Not (thermos)	Heat plate (only glass)	Integrated heater in jug		
Turn off energy	Timer	Manual	both		
Select temperature & brewtime	Digitaly	Analog	not		
Indicate information	Led light/button	Screen	Sound	Analog	None
	A	B	C	D	E

Figure 9: Morphological Matrix

3.3 Selecting concepts

From all of the 10 different solutions computed in the chapter above, one need to be chosen as the most suitable solutions for each market group. A Pugh matrix is one way to make that choice. This method compares all the solutions to a reference solution and ranks them after how their functionalities manage to solve the different requirements computed in chapter 2.4.5. A "-" means that the solution solves the requirement worse than the reference, an "0" means that it is equally as good and a "+" means it is better. This method can be done multiple times with different reference solutions to get the best possible ranking. In this case, the best solutions were clear after two iterations. The two solutions, that each represented one of the market groups, were the the best ranked ones, as seen in Figure 10 and 11 - Solution 3 and 4. The benefit of this method is that the comparison is completely subjective. This can rule out better solutions that the group thinks are worse. This method is also fast and easy to read, and clearly indicates what solutions are better or worse.

Chalmers	Pugh matrix 1							
Group 10				Made: 28/11 23				
Kriteria	**Alternative**							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Consistence coffee quality	R	-	-	+	-	-	-	+
Lifespan	E	-	-	0	-	-	-	-
Weight	F	-	0	0	-	+	0	0
Size	E	-	0	0	-	+	0	0
Enviroment	R	+	+	0	-	-	+	-
Cost	E	-	+	-	-	-	+	-
Complexity	N	-	+	+	-	-	+	-
Keeps coffee warm	C	0	-	0	-	-	-	0
Maintainance	E	-	0	0	-	+	0	0
Performance		-	+	+	-	+	-	+
Σ+		1	4	3	0	4	3	2
Σ 0		1	3	6	0	0	3	4
Σ -		8	3	1	10	6	4	4
Net worth		-7	1	2	-10	-2	-1	-2
Ranking		5	2	1	6	4	3	4

Figure 10: Pugh Matrix 1

Chalmers	Pugh matrix 2							
Group 10				Made: 28/11 23				
Kriteria	**Alternative**							
	8	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Consistence coffee quality	R	-	-	-	0	-	-	-
Lifespan	E	+	-	+	+	-	0	+
Weight	F	0	-	0	0	-	+	0
Size	E	0	-	0	0	-	+	0
Enviroment	R	+	+	+	+	-	-	+
Cost	E	+	-	+	+	-	0	+
Complexity	N	+	-	+	+	-	-	+
Keeps coffee warm	C	0	0	-	0	-	+	-
Maintainance	E	0	-	0	0	-	+	0
Performance		-	-	0	0	-	-	-
Σ+		4	1	4	4	0	4	4
Σ 0		4	1	4	6	0	2	3
Σ -		2	8	2	0	10	4	3
Net worth		2	-7	2	4	-10	0	1
Ranking		2	5	2	1	6	4	3

Figure 11: Pugh Matrix 2

3.4 Concepts

The two final concepts chosen after the Pugh matrices can be seen in Figure 12 and in this section all the big functionality changes will be shown and described to make sense of why these changes were needed and why it improves the product. One big design feature that was kept from the reference coffee brewer is that the product should be compact and isolated to keep constant temperature. This will lead to less energy losses and better tasting coffee in the end.

Figure 12: Render of the redesigned coffee brewers

The first big change to the product was the design of the filter holder that can be seen in Figure 13. One important feature when brewing coffee is to make the water flow through the grounded coffee beans as constant as possible to get the best taste. To solve this problem a cylindrical straight filter holder that goes into a conical one was made. The straight part will have a reusable straight filter and the conical will make it possible to use store bought paper filters if wanted. This makes it modular but also able to flow into the jug and environment friendly.

In the filter holder of the reference coffee brewer, the automatic flow stopper had some flaws that lead to spillage. Thus replacing this with a manual stopper was done. This is both cheaper and more reliable due to no spillage when at place. The flow stopper will be placed at the side of the filter holder to be reachable and easy to use. This can also be seen in Figure 13.

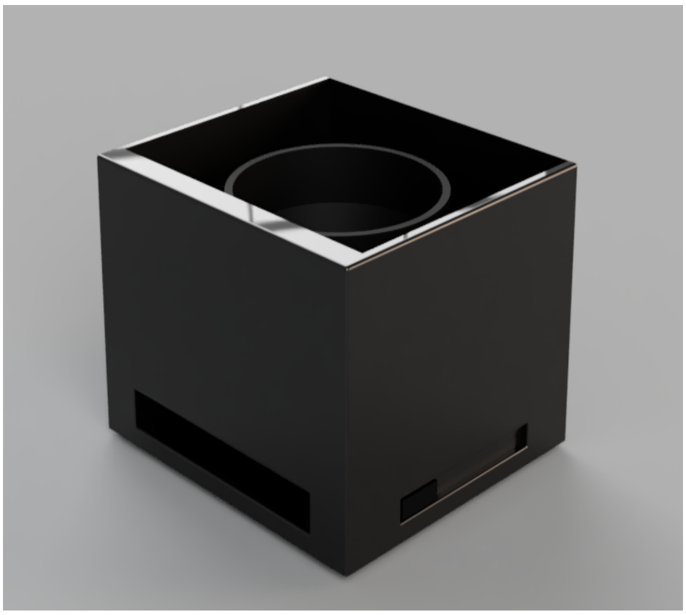


Figure 13: Render of the redesigned filter

In the same functionality area as above a change in size of the shower head was made. The shower head is made just as big in diameter as the filter holder to get flow through every part of the grounded coffee beans. As described earlier this will lead to a constant flow and better taste. The shower head can be seen in Figure 14.

Figure 14: Render of the redesigned shower head

Another important feature to get a good cup of coffee is constant temperature as stated above. In the concept aiming towards coffee enthusiasts, it will be possible to regulate the temperature as well as a regulating system that keeps a constant temperature. A timer was also added to be able to set a specific time when to start the brewing process. A feature thought to be helpful in busy times. The chassis of the coffee brewer will contain analogue displays for both temperature and timer to make it easy for the consumer to see and regulate. These regulators and displays - gauges, can be seen in Figure 15.

Figure 15: Render of the designed displays

To still keep the coffee at a constant temperature to not change the taste, a thermos will be included in the one for the coffee enthusiasts. This will remove the heating plate and instead of heating the coffee and risking changing the temperature, the thermos will instead keep the liquid at the same temperature with low heat losses. The thermos can be seen in Figure 16 The other coffee brewer aims to keep the price down as much as possible and add cheap features to make it appear more luxury. Thus this concept will keep the heating plate and glass jug.

Figure 16: Render of the designed thermos

One thing that was in mind when constructing both of the products was to make it modular for easy replaceable parts. Therefor all the parts seen in Figure 12 are suitable for both products. Another functionality that improves the modularity was the detachable water tank as seen in Figure 17. This makes it easy to detach and refill with water so that the costumer do not need to bring the water to the coffee brewer. The same thought went into the filter holder. With an integrated rail system in the chassis and the filter filter holder it will be easy to detach and refill the grounds or remove them. The left over functionalities are remaining the same as the referenced coffee brewer as they were thought to solve the requirement well.

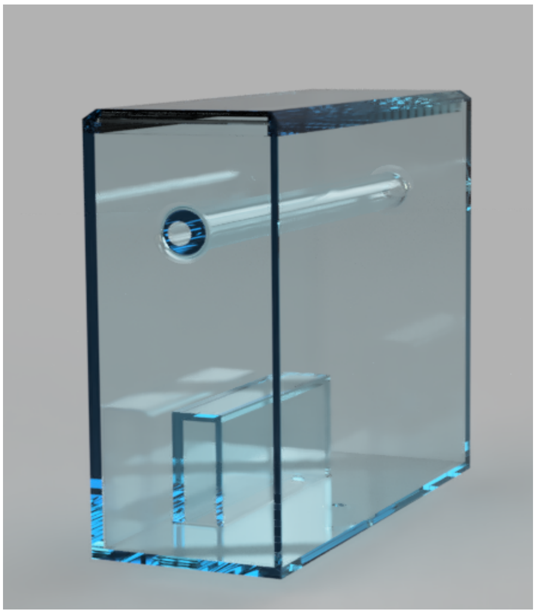


Figure 17: Render of the designed water tank

3.5 Design and appearance

The functionality redesign of the coffee brewer was not the only redesign that has been done. In order to make a coffee brewer compatible to all the new functionalities a redesign to the appearance and design aspect was also needed. Redesigning the design of the products will not only support the functions but also make it appear as appealing as possible to the costumer.

The two final products that were constructed are aimed to appear as luxury and qualitative as possible with small and cheap changes in the design. While doing these changes, one important thing was to not change the overall concept to much from the original existing coffee brewer. This is because the concept of having a compact coffee brewer that can fit in most places thought to be important. Also the idea of having an outer shell surrounding all the parts contributes to less heat losses.

The modularity in the design is also an important feature. Thus making all the components fit perfectly across both products. This will facilitate in both the production but also when the customer needs to replace parts or customise the product to its liking. The production cost will be less because of less production methods and machines being used and the customers will save money by not replacing the whole brewer if parts break. This can lead to more sales as a trust between the company and the customer can be formed.

One small change that makes a big different in appearance is the change in the coating material selection. The chassis in both the new products will have a steel coating to get that luxury feeling. It will still have an inner layer of PP-polymer as the existing brewer, as PP-polymer has low heat conductivity which leads to less heat losses and is sturdy. This provides a qualitative product and improves the user experience which is important to both the customer and the seller.

The existing brewer were thought to be easy to use and Group 10 wanted to transfer that to the new constructed brewers. This is important because it includes more potential customers. All the interactions with the two products should be easy to use and the information needed should be clear. Therefore the on and off button will be labeled and red, with an LED that lights up when the brewer is on. The timer and temperature can be regulated with knobs located beside each analogue display. The filter holder is made of a different outer material (PP-polymer) compared to the other parts coating to differentiate the part making it easier for the user to understand that it's interactable and removeable. The front handle on the filter holder also support this design feature. A handle in the water tank is also made. This will not only make it easier for the user to remove the tank but also understand that the part is detachable.

To avoid visable spacing created between different parts after assembly, group 10 made sure to design the coffee brewer without connecting points with more than two parts. This reduces the risk of parts not aligning correctly when assembled. The detachable parts can also easily form these visable spacings from slitage and not inserted completely correctly. Therefore producing these parts with a different coating material and colour makes it harder to identify the gaps for the user. Avoiding gaps in a product makes it seem more robust and qualitative to the user which is important for the user experience.

The first design sketches that where done to define the overall imagine of the brewers can be seen in the appendix E: Drawings.

3.5.1 Drawings of the design

Considering the design, several drawings have been made, see Figure 18 to 21. These figures serve to provide an understanding of the parts in the coffee brewer and how they are assembled. For a full size view of them, they can be seen in Appendix E.

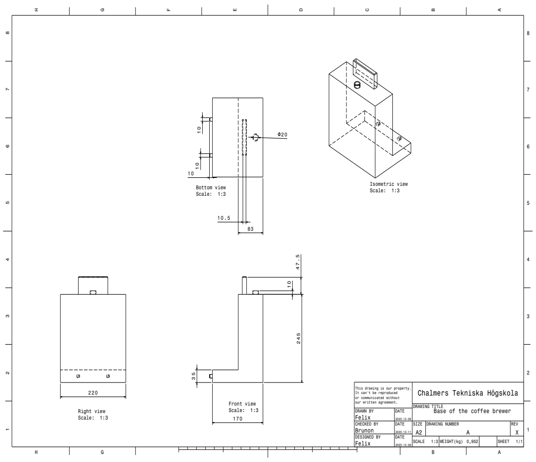


Figure 18: Drawing of the base

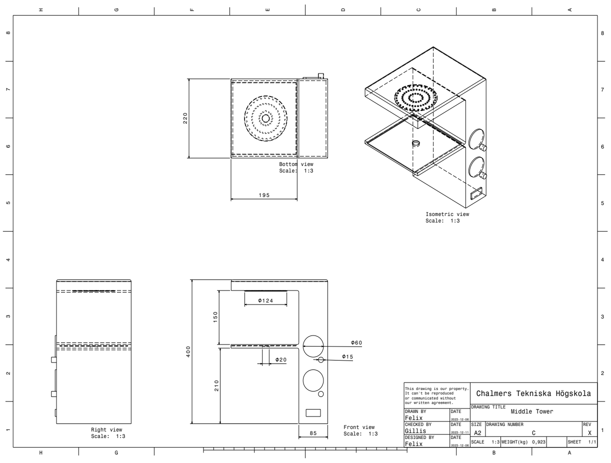


Figure 19: Drawing of the middle tower

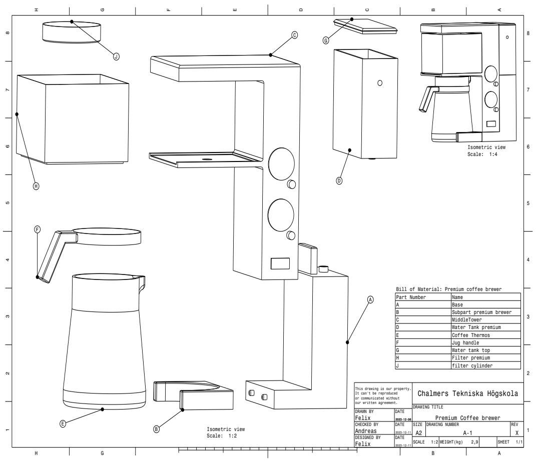


Figure 20: Exploded view

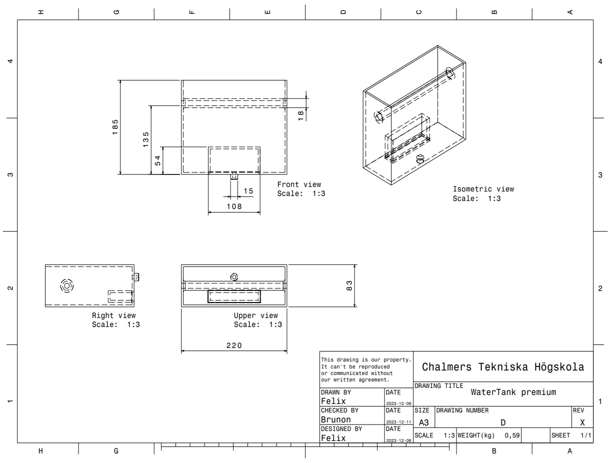


Figure 21: Drawing of the water tank

4 Modelling and analysis

This chapter will describe the structure and the environmental impact that the existing brewer and the developed brewers has. By analysing all the components that the existing coffee brewer has through a Design for assembly (DFA), examine the structure in the assembly and looking at the environmental aspect through Life cycle assessment (LCA). The same will be made for the new improved brewers.

4.1 Design for assembly (DFA)

Design for Assembly (DFA) is a process by which the product is designed with easier assembly in mind. The main goal is to cut down the manufacturing cost and make the assembly process more efficient. Using a DFA in general is to analyse every part of the product and see if there is any unnecessary ones that can be left out during the assembly.
The AVIX tool allows the DFA to identify opportunities for upgrading the assembly process and reducing costs. The DFA can be applied for the existing brewer and the new improved brewers. This has been done to identify ways to upgrade the assembly process and reduce the costs.

The DFA of the existing brewer, Figure 22, has been made with all the components that where in the exploded view, Figure 12. All the different parts has been analysed and view on with the questions asked in AVIX. The final score for the existing brewer can be seen in the top right corner of Figure 39a. The final score that the existing brewer got was 62%, which is not that good. The lowest tolerated score is 70% to not have to make changes like a redesign or eliminate parts of the product. As can be seen in the existing brewer there are many parts that can be eliminated or integrated with others based on the score it has. With all the components there are many parts that should be changed and thought of when doing the new brewer.

Component	Nee...rt	Gri...nd	Reac...ity	Insertion	Tolerances	Holdi...arts	Fast...hod	Sep...ns	DFA Score: Score	Score (%)	Agg Score	Agg ...(%)	Time	Agg Time	Agg ...(%)
Existing coffee brewer									0		1 244	62 %		254,6	303 %
[A-1] Coffee measure 1 pcs	1	9	9	1	9	1	9	9	48	67 %			7,5		
[A-2] Lid for jug 1 pcs	1	9	9	1	9	9	3	9	50	69 %			6,5		
[A-3] Glass jug 1 pcs	9	9	9	1	9	9	3	9	58	81 %			6,5		
[A-4] Handle jug 1 pcs	1	9	9	1	9	1	9	9	48	67 %			7,5		
[A-5] Metal around the jug 1 pcs	9	9	9	3	9	1	3	9	52	72 %			10,2		
[A-6] Clamp 1 pcs	1	9	9	3	9	9	9	1	50	69 %			3,2		
[A-7] Screw clamp 1 pcs	9	9	9	9	3	9	3	1	52	72 %			6,2		
[A-8] Packing sump holder 1 pcs	1	9	3	1	3	3	9	9	38	53 %			8,2		
[A-9] Spring sump holder 1 pcs	1	9	3	3	3	3	9	3	34	47 %			7,9		
[A-10] Flow sto...p holder 1 pcs	1	9	3	3	3	9	3	3	34	47 %			10,9		
[A-11] Sump filter 1 pcs	9	9	3	9	9	3	9	9	60	83 %			7,5		
[A-12] Sump holder 1 pcs	9	9	9	9	9	3	9	9	66	92 %			3		
[A-13] Base plate 1 pcs	9	9	9	1	9	3	3	9	52	72 %			6,5		
[A-14] Screw metal holder 1 pcs	9	9	3	9	3	9	3	1	46	64 %			10,7		
[A-15] Metal holder 1 pcs	1	9	3	3	3	1	3	1	24	33 %			14,9		
[A-16] Screw chassis middle 1 pcs	9	9	3	9	3	9	3	1	46	64 %			10,7		

(a) DFA existing coffee brewer - Part 1

[A-17] Lock washer 1 pcs	1	9	3	1	3	1	3	3	24	33 %			15,2		
[A-18] Nut to screw 1 pcs	1	9	1	3	3	9	3	3	32	44 %			13,4		
[A-19] Power button 1 pcs	9	9	9	9	3	3	3	3	48	67 %			6,2		
[A-20] Radiatior 1 pcs	9	9	3	3	9	9	3	9	54	75 %			10,7		
[A-21] Screw Circuit board 1 pcs	9	9	3	9	3	9	3	1	46	64 %			10,7		
[A-22] Top chassis 1 pcs	9	9	9	9	3	1	3	9	52	72 %			10,2		
[A-23] Hose clamp 1 pcs	9	9	3	1	3	3	3	3	34	47 %			11,2		
[A-24] Hose short 1 pcs	1	9	3	1	1	9	3	3	30	42 %			11,4		
[A-25] Hose long 1 pcs	1	9	3	1	1	9	3	1	28	39 %			11,4		
[A-26] Metal plate 1 pcs	9	9	3	9	3	1	9	9	52	72 %			11,7		
[A-27] Rubber se...tal plate 1 pcs	1	9	3	1	3	3	9	9	38	53 %			8,2		
[A-28] Lower chassis 1 pcs	9	9	9	3	3	3	3	9	48	67 %			6,4		

(b) DFA existing coffee brewer - Part 2

Figure 22: DFA existing coffee brewer

The DFA analysis for the new coffee brewers indicates a significant improvement over the existing model, with less parts and more efficient assembly process. Reviewing the two new brewers, both of them preform better then existing one, both in the Aggregated Score and the Aggregated Time.
The new brewers have similar structure, with only a few parts that set them apart. The differences in the structure is around the coffee jug and heating plate. This results in a different outcome in the AVIX analysis. With the premium preforming slightly better then the budget one. The premium version has the score of 506 and the budget one has 554. This makes the premium versions Aggregated Score almost 9.5% better and 6,2 seconds faster then the budget brewer.

Component	Nee...rt	Gri...nd	Reac...ity	Insertion	Tolerances	Holdi...arts	Fast...hod	Sep...ns	DFA Score: Score	Score (%)	Agg Score	Agg ...(%)	Time	Agg Time	Agg ...(%)
New coffee brewer									0		506	78 %		41,2	153 %
[A-1] Base 1 pcs	9	9	9	3	9	3	3	9	54	75 %			6,2		
[A-2] Base premium part 1 pcs	1	9	9	9	9	9	3	9	58	81 %			6		
[A-3] Coffee jug 1 pcs	9	9	9	9	9	3	9	9	66	92 %			3		
[A-4] Jug handle 1 pcs	1	9	9	3	1	9	3	3	38	53 %			6,6		
[A-5] Filter chassi 1 pcs	9	9	9	9	3	3	9	9	60	83 %			3,2		
[A-6] Fliter cylinder 1 pcs	9	9	9	3	3	9	9	9	60	83 %			3,4		
[A-7] Middle tower 1 pcs	9	9	9	9	3	9	3	3	54	75 %			6,2		
[A-8] Water tank 1 pcs	9	9	9	9	3	9	9	9	66	92 %			3,2		
[A-9] Wanter tank top 1 pcs	1	9	9	9	1	3	9	9	50	69 %			3,4		

Figure 23: DFA Premium Brewer

Component	Need...art	Grip...and	Reach...lity	Insertion	Tolerances	Holdi...arts	Fast...hod	Sepa...ons	DFA Score							
									Score	Score (%)	Agg Score	Agg ...(%)	Time	Agg Time	Agg ...(%)
New coffee brewer									0		554	77 %		47,4	158 %
[A-1] Base 1 pcs	9	9	9	3	9	3	3	9	54	75 %			6,2		
[A-2] Base budget part 1 pcs	1	9	9	9	9	9	3	9	58	81 %			6		
[A-3] Coffee jug 1 pcs	9	9	9	9	9	3	9	9	66	92 %			3		
[A-4] Jug handle 1 pcs	1	9	9	3	1	9	3	3	38	53 %			6,6		
[A-5] Filter chassi 1 pcs	9	9	9	9	3	3	9	9	60	83 %			3,2		
[A-6] Fliter cylinder 1 pcs	9	9	9	3	3	9	9	9	60	83 %			3,4		
[A-7] Middle tower 1 pcs	9	9	9	9	3	9	3	3	54	75 %			6,2		
[A-8] Water tank 1 pcs	9	9	9	9	3	9	9	9	66	92 %			3,2		
[A-9] Wanter tank top 1 pcs	1	9	9	9	1	3	9	9	50	69 %			3,4		
[A-10] Heating plate 1 pcs	9	9	9	9	3	3	3	3	48	67 %			6,2		

Figure 24: DFA Budget Brewer

4.2 Life-cycle assessment (LCA)

Life Cycle Assessment (LCA) is a analysis that takes the environmental impact for the product during it's life cycle.
During a LCA it takes in counter all of the different materials that is used in the product. This reveals what the different materials has for impact during it's life cycle, pre-use, use and post-use. Analysing the different materials impact to the environment shows how sustainable the product is during it's life cycle.

4.2.1 LCA- Existing Brewer

By conducting a LCA on the existing brewer, valuable information about what environmental impact the coffee brewer has. The largest part of the existing brewers environmental impact is the coffee grounds and the electricity that is used by the brewer. With the calculations based on the average brewing of 5 cups for 10 000 times, the total impact is approximately 647 ELU, Appendix C.1.
The LCA for the existing brewer indicates that all the components in the existing brewer is expected to be reused, as can be seen in the calculated values and the total impact of the ELU for the existing brewer. The most common materials in the existing brewer was polypropylene (PP) and alloy steel. The only two materials that is destined to go to landfill from the existing brewer is the alloy steel and the aluminium cast. Around 67% of the alloy steel and aluminium cast goes to landfill. The remained material of the alloy steel and aluminium will be reused.

Analysis of the existing brewer reveals that the most common material in it is PP, around 67%. This is not surprising given that PP is a low-cost material and easy to manufacture. PP has an ELU index at 0.950 which is relatively high. But due to that PP is recyclable and it's assumed that all the PP is reused, its ELU impact significantly decreases.

Examining the manufacturing process for the different materials in the existing brewer, it appears that the polymers, PP had been injected moulding, which is expected, due to it's a cheap and common way of manufacturing polymers. The metal components has the most common manufacturing methods, molding, stamping, bending and welding.
After looking at the different manufacturing methods and the different post-use distribution it can be told that most of the impact in the ELU is the coffee grounds and electrical use. This accounting approximately 99.8% of the overall ELU impact for the existing brewer. This underscores that the material of the existing brewer does not have much impact on the environment, primarily because most of it is reused.

The LCA for the existing brewer is a good starting point to understand the environmental impact for a coffee brewer. In the next section there will be a closer look at the LCA for the new brewers.

4.2.2 LCA- Developed brewers

Upon examining the new brewers, it was concluded that both of them have the same amount of coffee ground use and water use. The big difference is that the premium version has a significant lower energy consumption. This attributed to it has a thermos jug instead of a heating plate. While the majority of the material will be the same for both models, the difference will be in the amount of the material due to it different designs. The initial key in the models is to have mostly the same parts, only a few changes, to minimise the manufacturing cost.

Comparing the LCAs for the two models, as shown in Appendix C.2 and Appendix C.3. It is clear that the budget version has a lower environmental impact then the premium version. The primary reason to this is because the premium version has stainless steel for the thermos. With the material ELU is much higher then the budget version, the premium one using less energy, approximately 26% less. When calculating the ELU for both of the new brewers, it shows that the budget version has a lower impact then the existing brewer. On the other hand the premium one has a higher score due to the materials that been used in its construction.

4.3 Robust Design and Tolerances (RD&T)

In a Robust Design and Tolerances (RD&T) framework, ensuring the product's robustness, stability and variance are critical factors. The simulations investigates how the assembly are effected by variance after different attachment points are placed on the parts. The location of the attachment points have a significant impact on how the variance will alter. The main reason of doing a RD&T is to improve the product quality so that it is not sensitive to material variation, manufacturing variation and operational variation. With the simulations the attachment points are set, this is set so that the six degrees of freedom are locked, this is called the 3-2-1 locating scheme. With this scheme the robustness can be controlled for the product.

During the RD&T analysis of the new brewers, particular observance were directed to the middle tower. The simulation results in a rather high variance, as can be seen in Figure 25, for full size see Figure 48 in Appendix D. To avoid a rather higher variance in the product, some redesign would be needed. A possible strategy to reduce the variance is to have attachment point on the water tank too, this would contribute to more stability and decrease the variance.

In Figure 26, for full size see 49 in Appendix D figures, some design changes have been made to make the model more robust. The tolerances were brought down to reduce the variation which was to high in version 2. This was done by changing the water tank holder as the part from which the first points are defined.

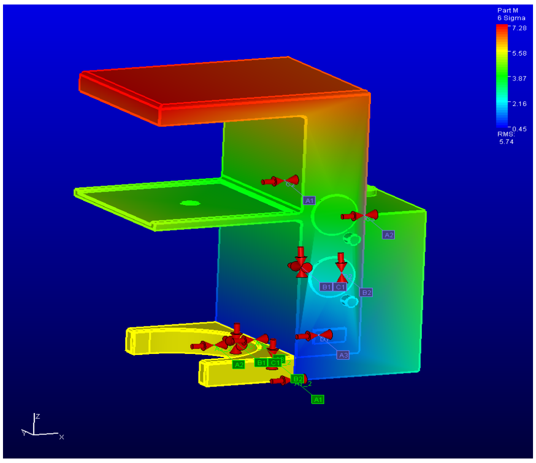


Figure 25: Robust Design and Tolerances v.1

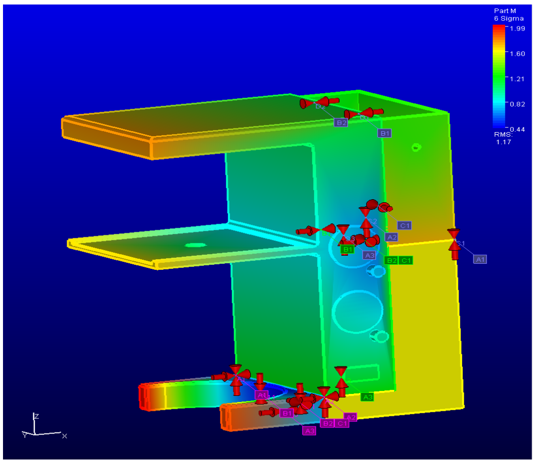


Figure 26: Robust Design and Tolerances v.2

4.4 Failure mode and effects analysis (FMEA)

Failure mode effect analysis (FMEA), is a way to assess a product or process. The main objective is to prevent errors instead of fixing actual ones. Assess what risks and errors can occur while the product or process is in use and evaluate the severity of possible failure and if changes need to be made to the design.

All possible malfunctions will be graded by three categories on a scale of 1-10. The categories are probability of malfunction, severity of malfunction, and probability of discovery. Where the coveted value is 1 for all categories. These three numerical values are then multiplied by each other to get a **Risk index** or **Risk priority number, RPN**. The risk index gives a numerical value of how dangerous a malfunction can be. From the FMEA:s, seen in Figures 27 and 28, the risk index can be seen in the second to last column in both tables. It was decided that possible malfunctions with an RPN higher than 10 will be examined in more detail.

The heating element is the component that receives the worst rating out of all components on the student oriented brewer. Similarly the thermos recives the worts rating in the home office oriented brewer. This shows the importance of precaution when designing and assembling these parts.

FMEA - Failure mode and effect analysis - new student product									
Projekt: MMF092	Produkt: Coffee machine		Issued by: Group 10			Date:			FMEA nr:
System/ component	**Possible malfunction**	**Possible cause**	**Possible effect**	**Controll method**	**Probabilty of malfunctiion**	**Severity of malfunction**	**Probability of discovery**	**Risk index**	**Recommended measure**
Electrical	Short circuit	Bad cables, bad connections	Stops brewing, overheating	Follow electrical guidelines and have a quality check	2	7	1	14	Make sure electrical system is well regulated and isolated. Design so that water cannot reach electronics due to malfunction.
Coffepot	Unable to pour, crack	Handle loose, crack	retained coffee, leaking	dropping, fatigue	2	6	1	12	Well secured handle
Pipes	Leak	loosen from connection, crack	Short circuit, damage the sourroundings	Pressure test	1	4	1	4	
Heating element	To hot, to cold	Damaged electronics, wrongly wired from beginning	Melting sourrounding plastic, starting fire	Follow electrical guidelines, safety features such as timer	2	9	2	36	Make sure heating system is well regulated and isolated. Design so that water cannot reach electronics due to malfunction.
Plastic filter	Crack	dropping the machine, quick temperature changes	Leaking, damages electronics,	Test dropping	1	4	4	16	Make it durable enough to be dropped empty from chest height
Filter	Clog	No coffe is brewed, hot heating plate(in the student brewer)	Incompatible coffee filter	Design to be used by multiple filters or one specific typer of filters	2	2	1	4	Clear instructions on what filter that works
Pouring spout	Spilling, retained coffee	Bad design	Coffee is wasted, irrateted user	Pour test	2	4	1	8	A well designed pouring spout will avoid any problems.

Figure 27: Student coffee brewer

FMEA - Failure mode and effect analysis - new expensive product									
Projekt: MMF092	Produkt: Coffee machine		Issued by: Group 10			Date:			
System/ component	Possible malfunction	Possible cause	Possible effect	Controll method	Probabilty of malfunctiion	Severity of malfunction	Probability of discovery	Risk index	Recommended measure
Electrical	Short circuit	Bad cables, bad connections	Stops brewing, overheating	Follow electrical guidelines and have a quality check	2	7	1	14	Make sure electrical system is well regulated and isolated. Design so that water cannot reach electronics due to malfunction.
Coffepot	Unable to pour, crack	Handle loose, crack	retained coffee, leaking	dropping, fatigue	2	6	1	12	Well secured handle
Pipes	Leak	loosen from connection, crack	Short circuit, damage the sourroundings	Pressure test	1	4	1	4	
Thermos	Does not keep coffee hot	Bad seal of thermic isolator	Serves cold coffee	Quality control test, leak test	3	6	2	36	Quality control, small tolerances
Plastic filter	Crack	dropping the machine, quick temperature changes	Leaking, damages electronics,	Test dropping	1	4	4	16	Make it durable enough to be dropped empty from chest height
Filter	Clog	No coffe is brewed, hot heating plate(in the student brewer)	Incompatible coffee filter	Design to be used by multiple filters or one specific typer of filters	2	2	1	4	Clear instructions on what filter that works
Pouring spout	Spilling, retained coffee	Bad design	Coffee is wasted, irrateted user	Pour test	2	4	1	8	A well designed pouring spout will avoid any problems.

Figure 28: Premium coffee brewer

4.5 Manufacturing costs

Performing a manufacturing cost analysis helps to reveal how much the two coffee brewers would cost to manufacture and also indicate if it is realistic to start producing these products. With the two different models, the manufacturing analysis is based on the CAD-models and the different parts that is in them. With a manufacturing cost including, process cost and assembly cost, this is added to the total cost for the products.

4.5.1 Process cost

To estimate the process cost for the brewers, both GRANTA EDUPACK and "Swift and Booker, 2003" were used. This to give a price on the material through GRANTA EDUPACK and to do calculations with (Swift and Booker, 2003)[15]. The two different materials that will be in the calculations is polypropylene and steel alloys.

After researching [15], the two processes that are the most relevant for these materials are injection moulding and shell moulding. This is an easy and low-cost processes, suitable for a low or medium production volume.

$$\begin{cases} M_c = \text{material cost} \\ V = \text{volume} \\ C_{mt} = \text{material cost per unit volume} \\ W_c = \text{waste coefficient} \\ R_c = \text{relative cost coefficient} \\ C_c = \text{relative cost associated with producing different geometries} \\ C_{mp} = \text{relative cost associated with material-process compatibility} \\ C_s = \text{relative cost associated with achieving a section reduction/thickness} \\ C_{ft} = \text{relative cost associated with obtaining a specified tolerance/surface finish} \end{cases} \tag{1}$$

$$M_c = V \cdot C_{mt} \cdot [W_c] \tag{2}$$

$$R_c = C_c \cdot C_{mp} \cdot C_s \cdot [C_{ft}] \tag{3}$$

With the information from [15] the total process cost had be calculated using equation (2) and equation (3).
The result of the calculation for both of the brewers was that the budget version would cost 166 SEK and premium version 188 SEK.

4.5.2 Assembly cost

With the assembly cost calculated though [15] by using equation (4):

$$C_{ma} = C_l(F + H) \tag{4}$$

Where F is a 'fitting' index and H is a 'Handling' index, C_l is labor rate which is 0,11 SEK/s. With the given assembly time though the DFA for both the budget version and the premium version, this gives that the budget assembly price would be 5,214 SEK and the premium assembly price would be 4,532 SEK.

4.5.3 Total manufacturing cost and discussion

With both the process cost and assembly cost calculated, the final cost for the brewers can be compiled. The budget version would have a manufacturing cost at 171,5 SEK and the premium one at 192,4 SEK.

With the total cost calculated, it is important to keep in mind that this is just an estimations from the CAD-models, the real coffee brewer will have several parts inside the frame that is needed for brewing coffee. With those components added, the manufacturing cost would increase.

5 Material selection

In this part of the report the selection of material will be made for two different components for the coffee brewers produced in the previous section. A discussion for requirements, desires and why the requirements are set will also be held. The material selection was done for for the heating plate and the filter holder. Material selection is done to be able to select the most suitable material for a component in regards to functionality and environment.

5.1 Heating plate

The heating plate on the already existing coffee brewer was analysed to make it clear which material it was made out of. This was done to see if the material needs to be changed after the material selection or not. For example a test was done to see if it was magnetic or not, which it was. After this analyse a conclusion was made that the material was some kind of low alloyed steel.

To see which material that was the most suitable for the heating plate Granta EduPack was used. To start of this method different criteria to the material were made to make it work functionally. These criteria can be seen below.

1. Should heat up and cool down quickly ⇒ low DENSITY * Specific heat capacity
2. Transfer heat quickly to the coffee pot ⇒ High thermal conductivity
3. The heat plate must be able to withstand water and coffee spills. Coffee has a pH of 4.85-5.10 and is treated as a weak acid.[10] ⇒ Water (fresh) and weak acids: Acceptable

The following points are desires and not requirements.

1. Prioritising low cost over exceptional performance
2. Low CO2 footprint
3. Can be manufactured as sheet metal, stampable, and bendable
4. Low cost

From the requirements and desires a chart was put up by choosing thermal conductivity for the y-axis and specific heat capacity and density for the x-axis as a suitable material should have highest possible thermal conductivity with acceptable density and heat capacity. The other desires and requirements limited the selection by ruling out the materials that do not meet these criteria. The metal does not need to be food safe because the carafe separates the coffee from the the heat plate. Prioritising low cost over low specific heat capacity we get low alloy steel, stainless steel is very durable and will handle water and coffee stains exceptionally but costs four times as much as low alloy steel. A price limit of 20 SEK/kg was set to sort out metals that have an unnecessarily high quality. Along those all possible aluminium choices disappear because of their high price. If the budget was higher it might have been a viable option. Comparing CO2 footprints to find that low alloy steel has an acceptable and similar value as its contenders. In conclusion the most suitable material for the heating plate was Low alloy steel 16Mo3 which was the same as the previous selected material for the existing product and does not need to be changed.

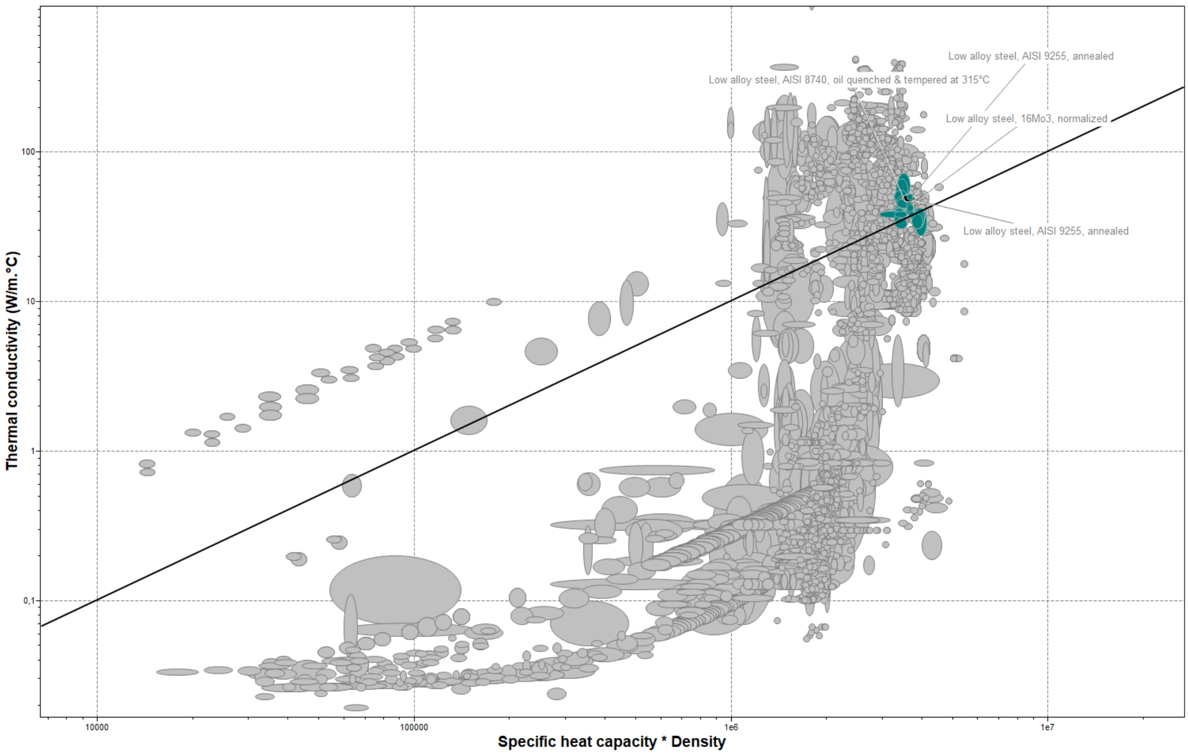


Figure 29: Granta EduPack material selection for heating plate

5.2 Filter holder

For the filter holder the used material for the existing coffee brewer was a PP polymer. This was concluded by a marking on the component. The same method to selecting a suitable material for the filter holder was done, as for the heating plate.

When choosing the material for the filter holder, the same axes for x and y were chosen as seen in Figure 30. This choice was made because the filter holder needs have a low thermal conductivity and relatively low density and still have a specific heat capacity that to withstand the hot coffee flowing through. Low thermal conductivity will lead to less heat losses. Low density will make the structure sturdy as the filter holder is placed in the top left corner. To sort out non suitable materials different constraints were also made. The filter holder needs to withstand water, weak acids and food at a high range as it is in contact with the coffee and grounds throughout the whole process. It has to be able to be injection moulded because of the complex design and that the production method is cheap and easy when producing a high amount of products. After the sorting an analysis of the remaining options were made. In this part price, service temperature and CO2-footprint were compared to get a material as cheap and environmental friendly as possible as well as withstand the temperature from the coffee without plastic deformation. After a carefully done analysis Group 10 chose PP (homopolymer 10% talc) as one of the best suitable material for the filter holder. As the previous material used for the component were a PP polymer just as the one that was selected, there will be no need to change the material.

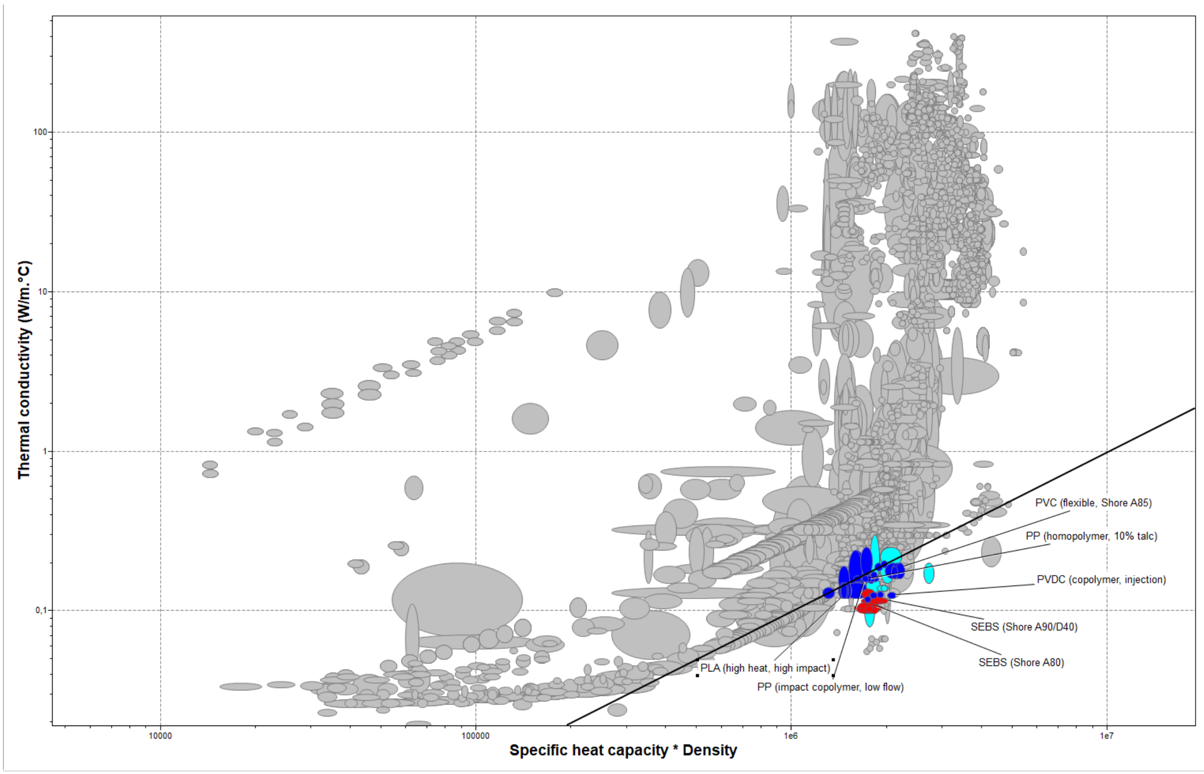


Figure 30: Granta EduPack material selection for filter holder

6 Verification

After constructing two new products by redesigning an already existing coffee brewer, it is important to verify if the improvements made the brewers better or worse. This step will be done by looking at the goals set for the project and products. Verifying changes made to the product is important to see if the changes are worth doing or if they could be further optimised. The verification can be done in many different ways depending on what is analysed.

Verification of the aesthetic design can be hard to measure due to the fact that it is a subjective opinion. Thus no numerical measures can be done to verify this. A possible verification method would therefore be based on the customers´ opinion. A survey asking a broad range of potential customers can be done to get their opinions. For relevant data, the survey would be aimed at the intended market segments to gather the potential buyers' opinion. Another feature of the coffee brewer that is subjective, is the taste of the brewed coffee. This can be verified after the new products are fully constructed, by testing both the new brewers and the already existing one. With the same measurements for all brewers, a taste test can be done by both the designer group and potential customers. During this verification, the simplicity and ease of the brewing process can also be assessed by the tester. You can also measure the extracted amount, but this is not a very specific test as the same amounts of extraction can differ in taste. Only because you have good extraction, it does not directly mean you have great coffee. A method that could be used is measuring total dissolved solids or TDS in short. This is when a refractometer is used to measures the refraction and the concentration can be calculated. This could be used to see if the new brewers reaches a higher extraction than the old brewer. It should be taken into account that greater extraction is not synonymous with greater taste. [4]

To verify if the new products are more environmental friendly, the Granta EDU-pack can be used to see the different materials´ carbon dioxide footprint both in the production and extraction phase. By determining the amount of material and which production method had been used, a comparison of the old and new coffee brewers can be done. The amount of products being produced also affects these numbers. This only verifies the production phase of the brewers. During usage of the brewers the electricity used will matter in the environment perspective. This can be done by measuring the electricity usage for the same amount of coffee brewed in all the brewers. Lastly the end of life phase of the product also play a part in the environmental footprint. When a component no longer works it preferably needs to be recycled or if not possible, discarded. By comparing the materials in Granta EDU-pack, it is possible to see the carbon dioxide footprint. The modularity of the product can prolong the lifespan of the product due to every component being replaceable, thus making this phase harder to verify.

Another requirement was to make the product modular. The brewers designed in this project are more modular than the given example - the carry-over that has been done between the two different brewers, is proof of their modularity. The most clearly modular part of the coffee brewer is the heating plate. This can easily be removed and exchanged for a plastic piece, which instead acts as a guide for the positioning of the thermos. Further, modularity is hard to test without the assembled product.

7 Conclusion and recommendation

When the final coffee brewers design were completed and analysed, several possible points of improvements occurred. Even though the brewers are fully functional and meet high standards, some minor adjustments can be made to improve the models.

In the design model, as previously mentioned in section 4.3, some attachment points positioned higher up on the water tank will improve the stability of the coffee brewer. Further improvement could be done by redesign the coffee filter holder, mainly by creating a slot in the top of the filter so that the filter could slide in and out easily.

After analysing the existing brewer, it was obvious that several highly-prioritised improvements were needed for the new brewers. The most general problem our group identified was the lack of consistent water temperature, the need for the shower head to evenly distribute the water onto the coffee grounds, an ineffective anti-drip function, and a more appealing design. Working with those problems had some impact on how the design outcome, but one issue that needs the most attention was to keep the temperature of the water consistent. If the coffee brewer would be produced and sold on the market, a more detailed overview of how the functional structure should be created and implemented inside of the coffee brewer with details of the components. This may have an impact on the current design of the coffee brewers.

The manufacturing cost analysis provides a good overview and understanding of the potential costs for the coffee brewers. A more detailed examination of all the individual parts in the new designed coffee brewers would provide a more precise analysis. It is important to note that the current analysis primarily focuses on the frame of the coffee brewers. To determine the total cost for the coffee brewers, a calculation on the functional structure inside the coffee brewers is required. This has not been done in this report, but is needed in the future for further development. Also, a more profound knowledge on how a thermos is made and what type of material that is best suited for a thermos would specify the costs further.

At the start of this project the main goals was to lower the manufacturing cost, clear improvement of the performance, clear environmental profile and a design that meets the given requirements. With those goals guiding the project, it all resolved in well designed coffee brewers. Reviewing the outcome, it is evident that almost all goals were fulfilled. The manufacturing cost is below 200 SEK, which was the given limit of manufacturing cost. The performance has a high likelihood of improving and the design is better suited for the targeted segments. However, the element that did not have significant improvement was the environmental aspect, the LCA in particular. The premium brewer has a higher impact than the original brewer, and that is due to materials used to make the thermos. The budget brewer has a lower environmental impact than the given brewer, which were the intended goal.

To improve the coffee brewers for further development, a few things can be consider to be analysed. One of them being the industrial design part, with the two different coffee brewers aiming to two different markets with the least amount of changes. Further research can be made to identify more variance between the coffee brewers. Exploring these differences can lead to improvements to the coffee brewers and potentially increase their values. It is important that those improvements are made, so the value increases without significantly raising the manufacturing cost. With more functionalities and a more luxury appearance, the premium version has the potential to create an even better impression compared to the budget version. The goal was to reach two different markets with the least amount of changes, and the outcome after this period of time is good, but with ongoing analysing and development in this section can lead to further improvements and increase the value of the coffee brewers.

8 Discussion on the methodology

The methodology used has been mainly based on reverse engineering (Otto & Wood, 1996)[14]. This methodology is an easy-to-follow, step by step guide on how to reinvent a product and create value. It demands certain things from the developers, group 10 in this case. These requirements are for example a deep understanding of the product in question.

The work began with the existing brewer, analysing its functions and trying to understand how a coffee brewer works. This was realised by first doing a black box model and hypothetical functional structure of a coffee brewer. Creating the black box model was quite straight forward but the functional structure required some discussion and thinking in the group. Later on a test and then disassembly of the brewer occurred which enabled the group to understand the brewing process more in detail and see the relations between different components and their role in the brewing. This process gave thoughts on how a great coffee brewer should work and what types of functions it should have as well as the what could be better with the functions the existing brewer already had. This lead to the establishment of mutual functions in the group for the developed coffee brewers and the individual brewers were later complemented with functions tailored for their market segment. There was no market research done during this report, instead the market segments were based on the group members and their experiences, diversity and different wishes. A proper market research would have been useful to ensure that there is indeed a market demand for the two developed brewers. With that being said, the brewers are not unique nor revolutionary, but they might attract customers from outside the set market segments with proper marketing.

In the current production market, every penny counts, especially as with the case in this report with group 10 being a less established company with a less established and proven product in a well saturated market. With the intention to reuse as many parts as possible for both of the brewers as an aim to satisfy two different markets, this approach will reduce the production cost and enable group 10 to maximise the profit from the investment. A modular design, which was one of the requirements in the assignment given to group 10, and the groups decision to reuse the maximum amount of parts between the brewers, resulted in a promising design.

The design was developed by one of the authors of this report and was a result of a clear requirement specifications set upon the products. No specific method was used to come up with the requirement specification, it was purely developed by brainstorming and discussing within group 10. This was made easier with having distinct market segments and differential between them. A consequence of the market segments being based on the members of group 10 also simplified the process of choosing the requirements - the authors just asked themselves what they would like to receive from their coffee brewer. This resulted in both requirements and wishes set upon the brewers, the difference between the two was that wishes were things that group 10 would like to fulfil, while the requirements were an absolute must to fulfil.

The next step was then to solve the requirements and wishes set upon the brewers. This step were also solved by brainstorming, the resulting ideas were a compote of prior experiences from both the existing brewer, other coffee brewers as well as arbitrarily machines with similar functions. The ideas generated in this brainstorming session were later inserted into a Morphological matrix, this matrix enabled easy exclusion of the ideas that did not solve all of the requirements. The remaining ideas were then put in a Pugh matrix, which is a matrix to compare different solutions to find the best one. This method is simple, candid and useful to easily visualise the best candidates of the solutions. The problematic thing with this method is its dependency of the users input, it is the user that decides if a solution is better than another. If the user have a favourite solution prior to this method it may affect the judgement of each comparison and by that the whole method, which may result in the method output different results given different users. With that said, numerous steps and methods in this project and others depend on the users input, given an experienced and open minded user a good result should be obtained.

As mentioned earlier the design was developed by one of the authors, but it was first at this stage with all of the above completed that the first design concepts were generated. The concepts were all based on the existing brewer regarding their main structure but with new features and functions incorporated. With some internal feedback within group 10, the final design concepts were finalised which enabled the project to continue with its upcoming steps, the analyses.

The first analysis performed in this project was the Design for Assembly analysis, the goal of DFA is to analyse how hard it is to assemble the final product. The analysis was done using a software tool called AVIX and the analysis itself purely consisted of questions regarding the assembly process of the product. The strength of this analysis is the unique point of view of the product, in this project, there was a minimal amount of thought spent on the idea of how hard the product is to assemble upon this analysis. After having completed the DFA the amount of thought spent on the assembly process had increased, while performing the DFA multiple questions were answered, and the questions themselves created new questions and ideas within the group. These questions and ideas were a consequence of answering questions regarding how a non-physical product is supposed to be assembled. This is also the difficulty with this analysis, to understand how the assembly process of the finished physical product will be when you merely have a CAD model. The output of the analysis is a percentage of how easy the assembly process will be, the goal set for the project-developed products was 70%. It is this output that can be seen as the analysis weakness, the output is diffuse and the definition of it is unknown, at least to the authors of the report.

Following the DFA being finalised, a Life-cycle analysis was done to understand the effect the product has on the environment during its whole lifespan. The different choices of materials used in the product during its production and use phase, the use of different energy alternatives, and how much of the product is recycled in the end-of-life phase are clearly reflected in the output of the analysis. The output is given in a unit called ELU which makes it easy to compare different choices with each other. The LCA was quite easy to perform and gives an estimate of the environmental impact the product has. A potential downside or weakness of the analysis is the lookup table from which each environmental load is taken, if it is wrong then the whole analysis is wrong. Another possible cause of the inaccuracy might be the lack of knowledge, of what materials each component is made out of and how much of it has been used. It is very time-consuming to correctly research it, especially without the original data sheets

The next analysis performed was the RD&T analysis. This was done to investigate the robustness of the design and variations in the final assembly given various tolerances of the components. The advantages of this analysis are all of the data that can be collected after the simulation has been run. The disadvantage is locating each mounting point between the components which is not always that obvious. Overall the analysis is beneficial to perform due to the visualisation of variation in gaps, flush surfaces, and position of components. These variations are due to different mounting alternatives and tolerances set upon the components, decreasing the tolerances of each component is expensive and it is therefore important to investigate the mounting alternatives.

The last analysis performed according to the methodology was the FMEA. This was done to explore possible failures in the design, their frequency, and effects. A surely important analysis to perform but a possible problem with it is that a developer of a product might be blind to some of the problems that could occur while using it. Presumably, all of the main functions are implemented in the design at this stage of the project and they are implemented in a way that the developer believes will be safe and functional. This could result in the developer coming up with some minor failures or more major failures with a small possibility, but the real possible failures might be missed. This could be solved with an unbiased third-party user doing the analysis, who could also grade the possibility and severity of the failure more accurately. With that said the analysis displays an important result, what the developer believes is the most critical to further work on.

Overall the methodology results in a product that step by step evolves into a better version of its predecessor. The whole method could be seen as iterative, the product is updated with feedback from each analysis and when the last analysis is finished the process is restarted. In this project, there was only one iteration made due to limited time, but with more iterations and some well-balanced compromises should result in a well-designed product.

9 References

References

[1] apple. https://store.storeimages.cdn-apple.com/4668/as-images.apple.com/is/affordability-facebook-og?wid=1200hei=630fmt=jpegqlt=95.v=1600376390000. Accessed on December 4, 2023.

[2] Books-coffee. https://latium.org/service?id=67763. Accessed on December 4, 2023.

[3] Coffee mug. https://www.whittard.co.uk/tea/tea-equipment/all-tea-equipment/nova-double-walled-mug-354175.html. Accessed on December 4, 2023.

[4] Comparing methods for measuring extraction yield in espresso. https://towardsdatascience.com/comparing-methods-for-measuring-extraction-yield-4fd4da584be1. Accessed on January 4, 2024.

[5] drip-brewer. https://designmaven.co.uk/products/kinto-brewer-stand-set-black-4-cups. Accessed on December 4, 2023.

[6] Fork. https://ombiaombia.wordpress.com/2016/05/11/design-319/. Accessed on December 4, 2023.

[7] grinder. https://www.epicurious.com/expert-advice/the-best-coffee-grinders-article. Accessed on December 4, 2023.

[8] home-office. https://www.realestatepropertiessantafe.com/eco-lifestyle-and-home-news-march-2023/home-office/. Accessed on December 4, 2023.

[9] house. https://twitter.com/fireclaytile/status/999778719207079936. Accessed on December 4, 2023.

[10] is coffee acidic. https://www.healthline.com/nutrition/is-coffee-acidic. Accessed on December 6, 2023.

[11] kitchen. https://www.themuse.com/advice/best-accessories-things-you-need-to-work-from-home. Accessed on December 4, 2023.

[12] Nyc-morning. https://www.flickriver.com/photos/dickie-d/2356166640/. Accessed on December 4, 2023.

[13] opener. https://worldflairassociation.com/product/steel-bar-blade/. Accessed on December 4, 2023.

[14] Wood K. & Otto, K. *A REVERSE ENGINEERING AND REDESIGN METHODOLOGY FOR PRODUCT EVOLUTION.* The 1996 ASME Design Engineering Technical Conferences and Design Theory and Methodology Conference, (1996).

[15] Booker J. & Swift, K. *Process selection.* Butterworth-Heinemann, (2003).

A Appendix A: Market investigation and product analysis

A.1 Black-box model

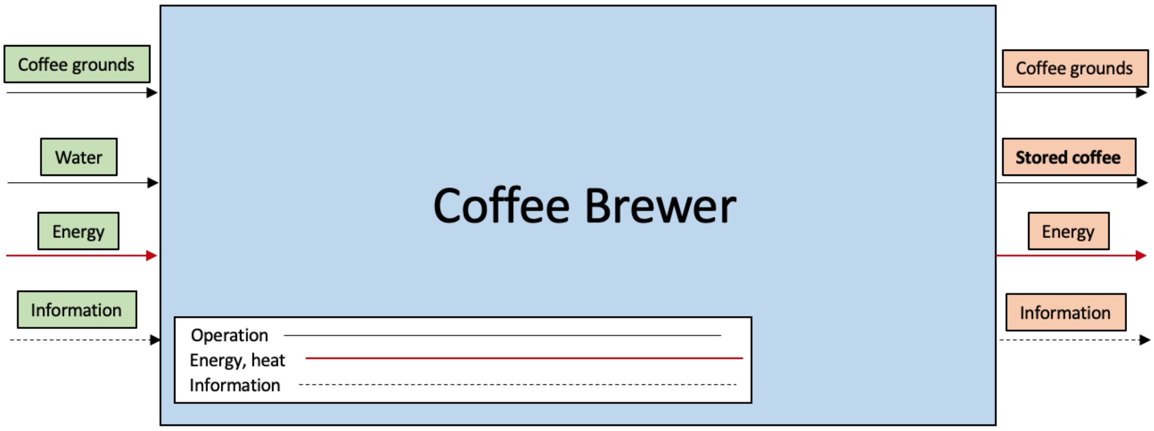


Figure 31: Black box of hypothetical coffee brewer

A.2 Function structure

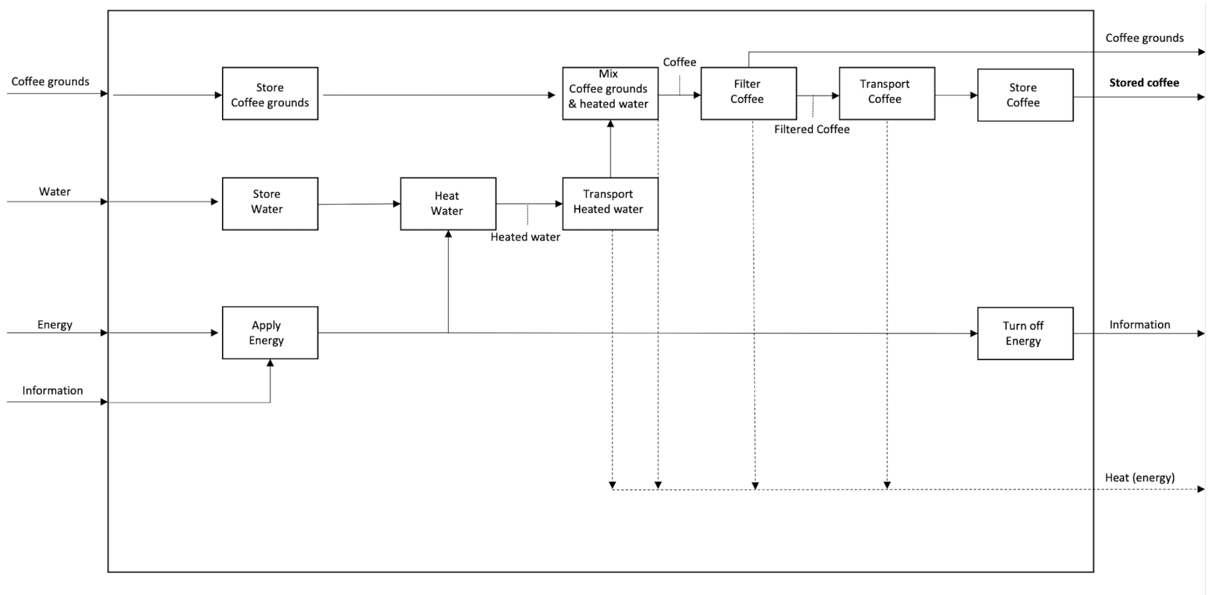


Figure 32: Function structure

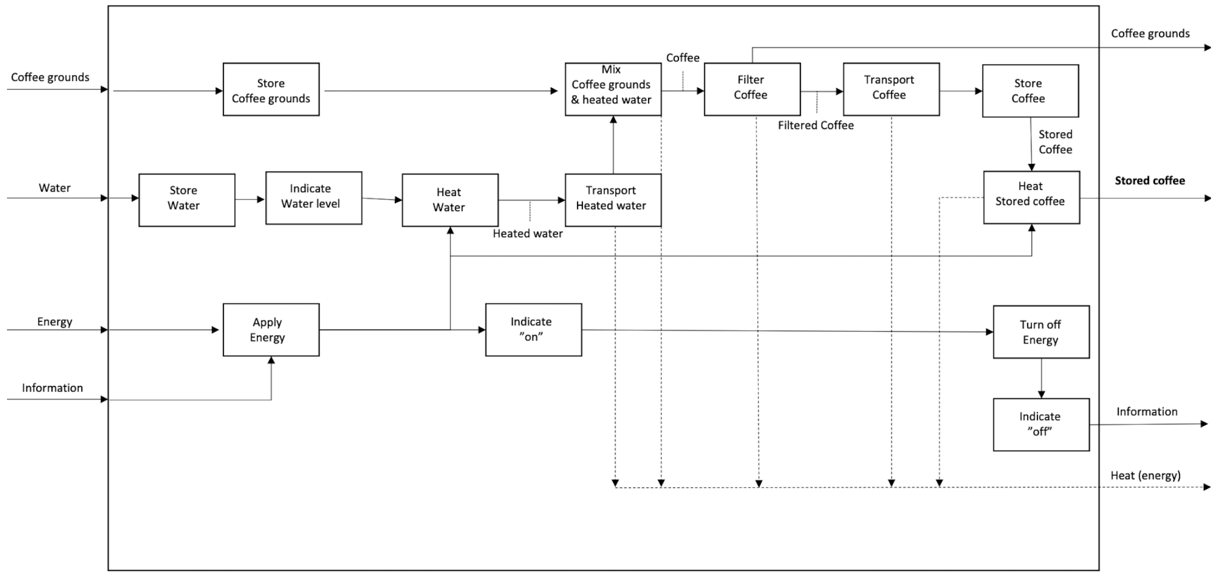


Figure 33: Function structure

A.3 Pughs Balloon's Matrix

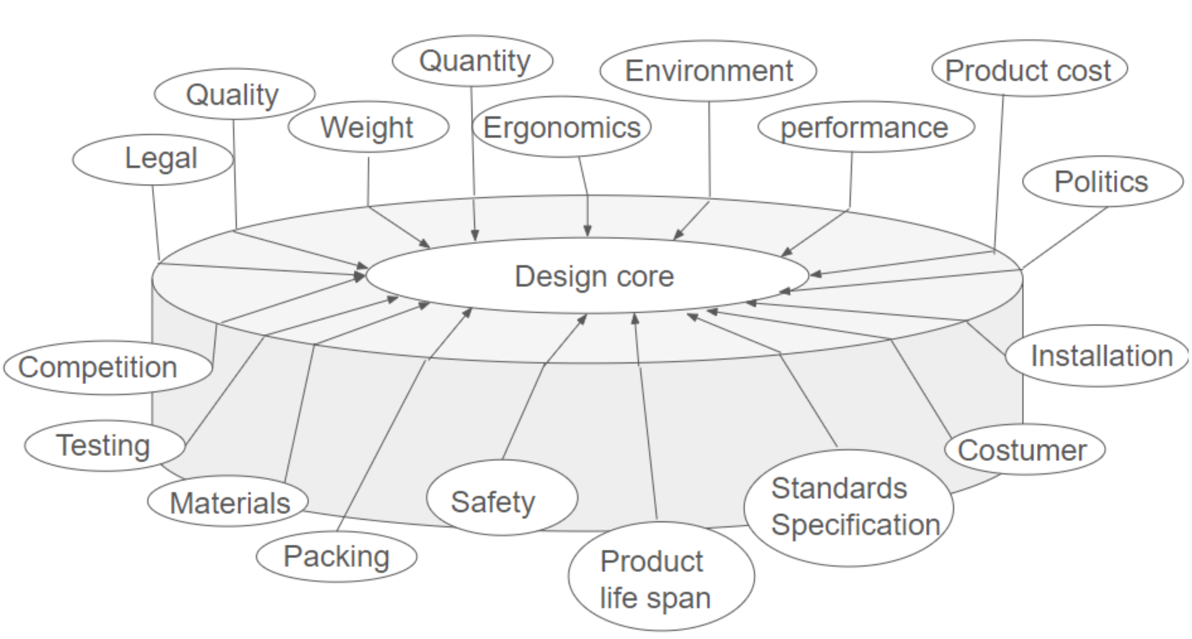


Figure 34: Pugh's Balloon's matrix before consideration

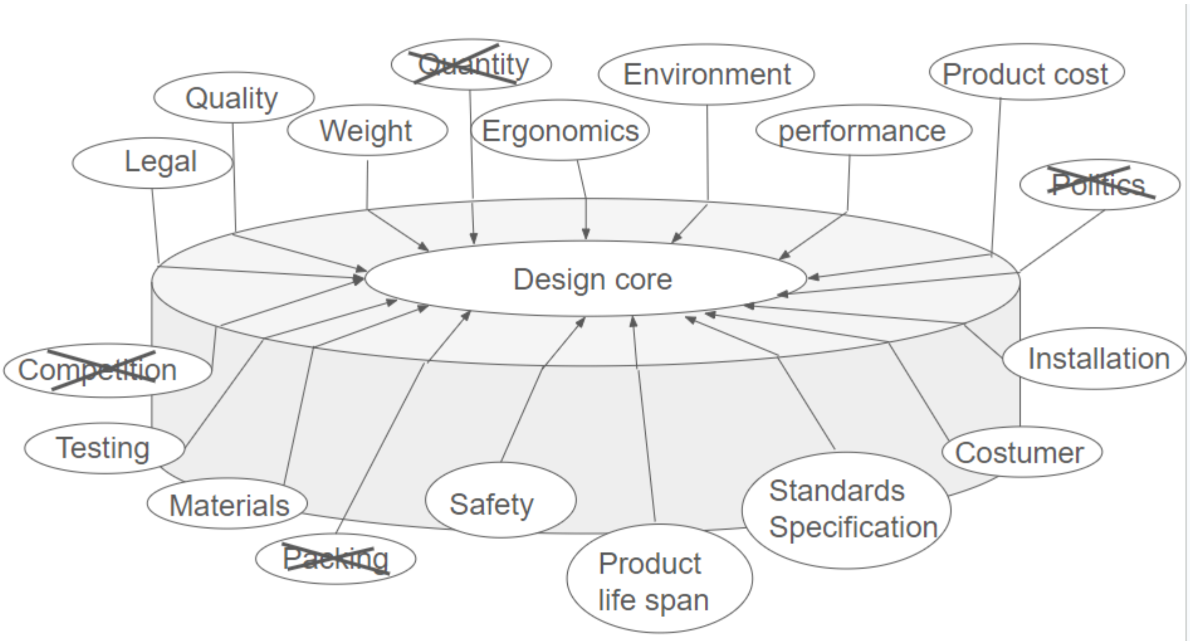


Figure 35: Pughs Balloon's matrix after consideration

A.4 Requirement specification

Group 10			Requirement specification				
MMF092		*Project*	Coffee brewer				
	Criteria		***Target Value***	***R/D***	***Importance***	***Verification method***	***Referens (Verifier)***
	Functions						
	Store coffee grounds			R		Testing	What a coffee machine does
	Store water			R		Testing	What a coffee machine does
	Apply energy			R		Testing	What a coffee machine does
	Heat water			R		Testing	What a coffee machine does
	Transport heated water			R		Testing	What a coffee machine does
	Mix coffegrounds and heated water			R		Testing	What a coffee machine does
	Filter coffee			R		Testing	What a coffee machine does
	Transport coffee			R		Testing	What a coffee machine does
	Store coffee			R		Testing	What a coffee machine does
	Turn off energy			R		Testing	What a coffee machine does
1.	**Performance**						
	1.1	Brew 4 cups in 5 minutes		R		Timer	Customer
		The priority is good coffee which has an optimal time					
	1.2	*Brew 4 cups in 3 minutes*		D	3	Timer	Customer
		The priority is good coffee which has an optimal time tha					
	1.3	Avoid under/over extracted coffee		D	4	Testing	Customer
2.	**Environment (ambient)**						
	2.1	Temperature in sorrounding enviroment +5 °C -- +50 °C		R		Thermometer	Product
		Indoor use only					
3.	**Lifespan**						
	3.1	Longevity	> 6000 cycles (10 years, 3 brewings/day)	R		Stress test	SIS Standard XXX
	3.2	Longevity	> 9000 cycles (15 years, 5 brewings/day)	D	2	Stress test	Produktplanering
4.	**Size**						
	4.1	Max height, width and depth (0.5,0.5,0.3) [m]		R		Calculated based on CAD model	
		Usual size of cabinets and countertops					
	4.2	Max height, width and depth (0.4,0.4,0.2) [m]				Calculated based on CAD model	
5.	**Wheight**						
	5.1	Max 3 kg		R		Calculated based on CAD model	Planning division
	5.2	Max 1 kg		D	1	Calculated based on CAD model	Product planning
6.	**Ergonomics**						
	6.1					Testing	
		Weight is a big factor aswell as shape.					

Figure 36: Requirement Specification

6.	**Ergonomics**					
	6.1				Testing	
		Weight is a big factor aswell as shape.				
7.	**Safety**					
	7.1	Highest possible score accepted by FMEA	R		FMEA Score	
	7.2	A better score by FMEA	D	5	FMEA Score	
8.	**Aesthics and finish**					
	8.1	Fingerprint resistant finish	D	4	Visual inspection	
	8.2	Materials maching target customer	D	4	Visual inspection	
9.	**Material**					
	9.1	Using non toxic material	R		Material documentation	
	9.2	Using no forever chemicals	R		Material documentation	
10.	**Quality and reliability**					
	10.1	Should not break under normal usage	R		Testing	
9.	**Manufacturing costs**					
	9.1	1/3 of MSRP	R		Calcualtion	
	9.2	1/5 of MSRP	D	2	Calcualtion	
		Depending on the version, premium version will be more expensive but it will have a bigger margin				
10.	**Manufacturing facility**					
	10.1	Production volume 10 000 units/year	R		Simulation	Planning division
11.	**Packaging**					
	11.1	Enviromentally freindly material			Material documentation	
		Lower ELU than previous	R		Calculation	
	11.2	Lower ELU than "certain value"	D	3	Calculation	
12 .	**Operation**					
	12.1	Being efficient	R		Test	Produktplanering
13 .	**Maintenance**					
	13.1	Only need decalcification one time per year	D	2	Test	Product planning
14 .	**Recycle / destruction**					
	14.1	Modular design of brewer	R		Product design	Product planning
	14.2	Enviromentally friendly material	R		Product design	Customer / Laws
	14.3	Single material components	D	4	Product design	
15 .	**Standards and legal obligation**					
	15.1	To be continued...				
16 .	**Time schedule**					
	16.1	Projected time				

Figure 37: Requirement Specification, continuation

A.5 Differentiationplan

Figure 38: Render of both brewers

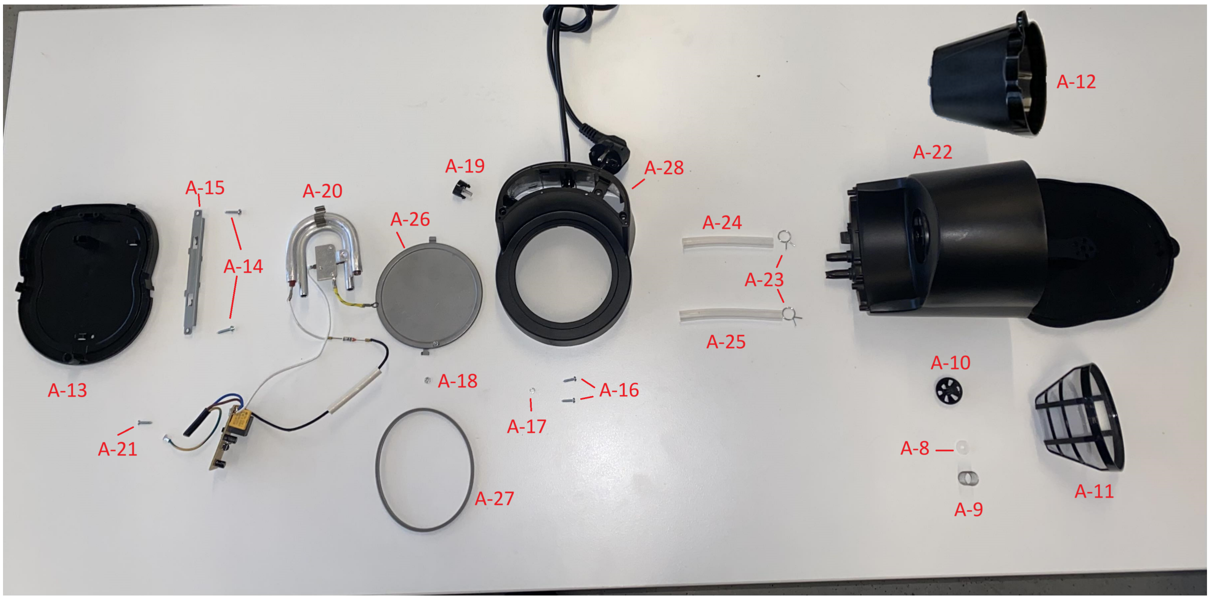
Shared components:
- Water tank
- Base
- Coffee filter
- Middle tower
- On / Off button

All of these components are shared between the two brewers. The middle towers are basically the same, the difference between the two are the stamped holes in the luxury brewer for the gauges and the knobs.
Individual components:
Budget:
- Glass jug
- Budget base extension
- Heating plate

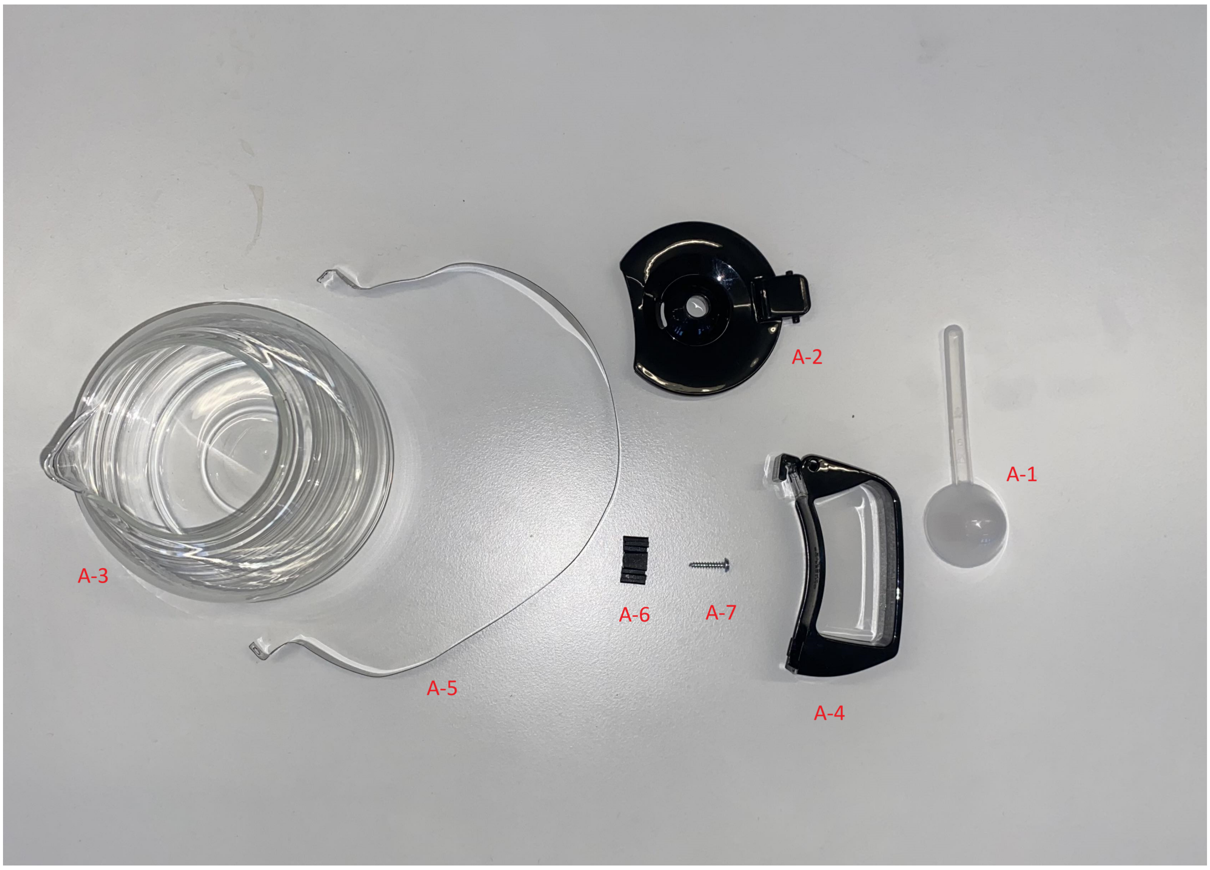
Luxury:
- Thermos jug
- Luxury base extension
- Gauges
- Knobs

B Appendix B: Product analysis

B.1 Exploded view



(a) Exploded view - Part 1



(b) Exploded view - Part 2

Figure 39: Exploded view on existing coffee brewer

B.2 Ishikawa diagram

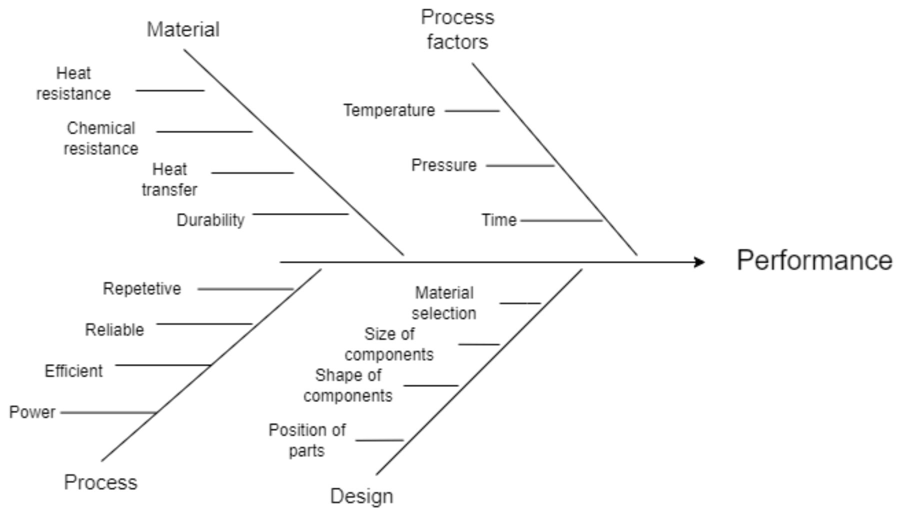


Figure 40: Ishikawa diagram describing causes behind performance

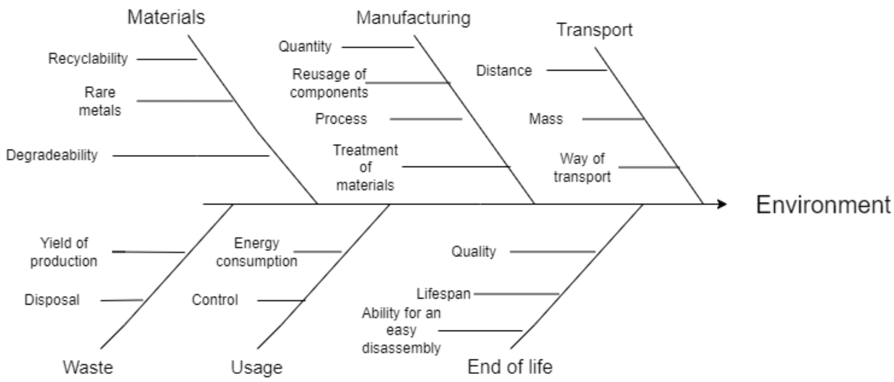


Figure 41: Ishikawa diagram describing causes environmentally friendly product

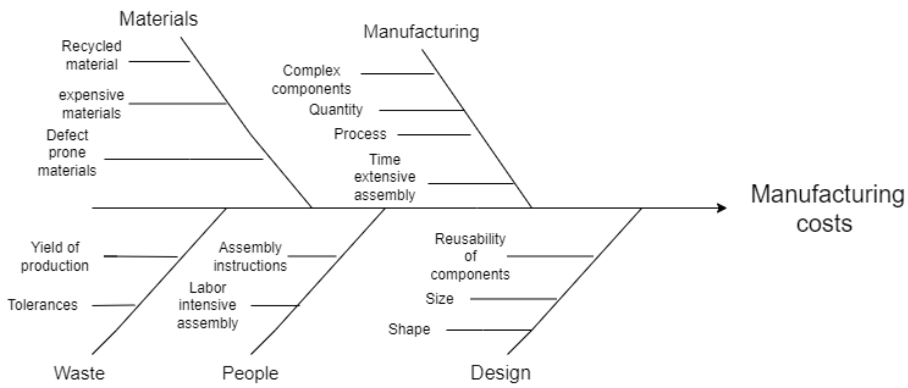


Figure 42: Ishikawa diagram describing causes behind manufacturing costs

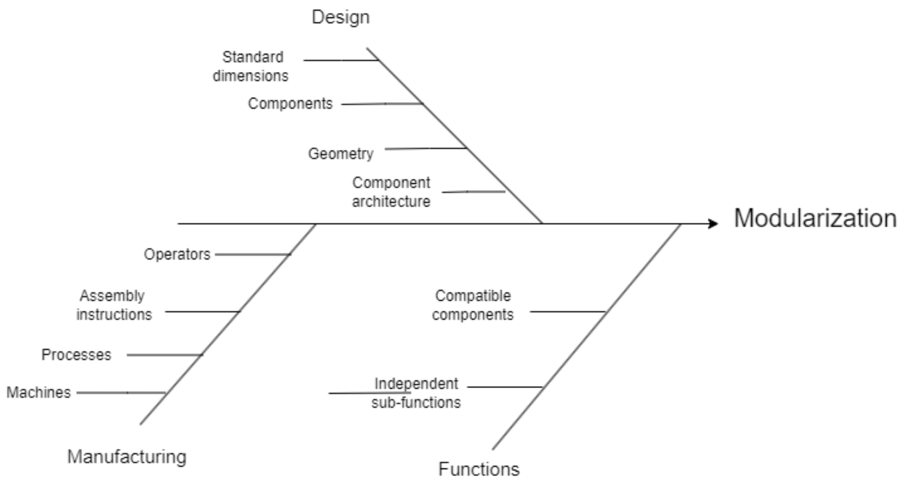


Figure 43: Ishikawa diagram describing causes behind modular design

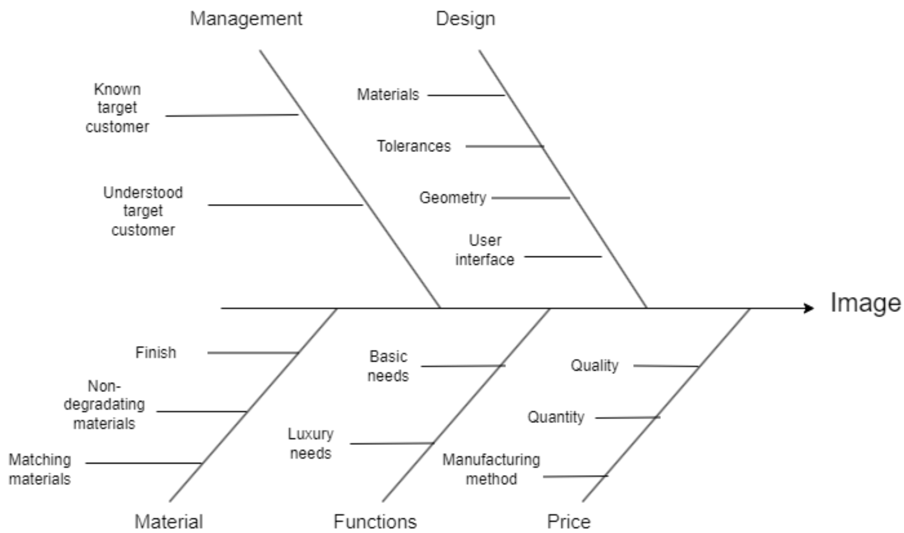


Figure 44: Ishikawa diagram describing causes behind image of the product

C Appendix C: LCA

C.1 LCA old brewer

Functional unit: Coffee brewer for 10 000 times

Materials & Processes		Pre-Use			Use			Post-Use																		Sum
		Production			Life			Reuse - Component			Reuse - Material			Energy recovery - combustion			Incineration - no energy recovery			Landfill			Other			
		E cost	Amount	Impact	index	Amount	Impact	index	Amount	Impact	index	Amount	Impact	index	Amount	Impact	index	Amount	Impact	index	Amount	Impact	index	Amount	Impact	Impact
	Unit	[ELU/ unit]		[ELU]	[ELU/ unit]		[ELU]	[ELU/ unit]		[ELU]	[ELU/ unit]		[ELU]	[ELU/ unit]		[ELU]	[ELU/ unit]		[ELU]	[ELU/ unit]		[ELU]	[ELU/ unit]		[ELU]	[ELU]
Glass	kg	0,279	0,161	0,0449			0			0	-0,223	0,161	-0,0359			0			0			0			0	0,04491621
Polypropylene (PP)	kg	0,959	0,5181	0,4969			0			0	-0,479	0,5181	-0,2482			0			0			0			0	0,49687708
Silicone rubber	kg	2,8	0,0154	0,0432			0			0			0	0	0,0154	0			0			0			0	0,043232
Steel. sheet metal	kg	1,21	0,1104	0,1336			0	0	0,011	0	-1,18	0,0331	-0,0391			0			0	4,21E-07	0,0662	3E-08			0	0,13355378
Alumin. Cast	kg	1,748	0,0376	0,0657			0	0	0,0038	0	-0,946	0,0113	-0,0107			0			0	1,05E-06	0,0226	2E-08			0	0,06573356
Tap water	kg	8,2E-05		0	8,2E-05	6250	0,5119			0			0			0			0			0			0	0,511875
Coffee	kg			0	2	300	600			0			0			0			0			0			0	600
Electricity	kWh			0	0,076	606,48	46,092			0			0			0			0			0			0	46,09248
				0			0			0			0			0			0			0			0	0
				0			0			0			0			0			0			0			0	0
				0			0			0			0			0			0			0			0	0
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				0			0			0			0			0			0			0			0	0
				0			0			0			0			0			0			0			0	0
SUM				0,7843			646,6			0			-0,3338			0			0			5E-08			0	647,388668

Figure 45: LCA existing coffee brewer

C.2 LCA budget brewer

Functional unit:	New budget Coffee brewer for 10 000 times																									
Processes		Pre-Use			Use			Post-Use																		Sum
		Production			Life			Reuse - Component			Reuse - Material			Energy recovery - combustion			Incineration - no energy recovery			Landfill			Other			
		E cost	Amount	Impact	index	Amount	Impact	index	Amount	Impact	index	Amount	Impact	index	Amount	Impact	index	Amount	Impact	index	Amount	Impact	index	Amount	Impact	Impact
	Unit	[ELU/ unit]		[ELU]	[ELU/ unit]		[ELU]	[ELU/ unit]		[ELU]	[ELU/ unit]		[ELU]	[ELU/ unit]		[ELU]	[ELU/ unit]		[ELU]	[ELU/ unit]		[ELU]	[ELU/ unit]		[ELU]	[ELU]
Glass	kg	0,279	0,2623	0,07318			0			0	-0,223	0,2	-0,0446			0			0			0			0	0,0731817
Polypropylene (PP)	kg	0,959	0,9352	0,89686			0			0	-0,479	0,9	-0,4311			0			0			0			0	0,8968568
Silicone rubber	kg	2,8	0,01544	0,04323			0			0			0	0	0,01544	0			0			0			0	0,043232
Steel. sheet metal	kg	-1,18	1,467	-1,7311			0	0	0,15	0	-1,18	0,45	-0,531			0			0	4,21E-07	0,9	3,8E-07			0	-1,73106
Alumin. Cast	kg	1,748	0,03761	0,06573			0	0	0,00376	0	-0,946	0,01128	-0,0107			0			0	1,05E-06	0,02257	2,4E-08			0	0,0657336
Tap water	kg	8,2E-05		0	8,2E-05	6250	0,51188			0			0			0			0			0			0	0,511875
Coffee	kg			0	2	300	600			0			0			0			0			0			0	600
Electricity	kWh			0	0,076	606,48	46,0925			0			0			0			0			0			0	46,09248
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				0			0			0			0			0			0			0			0	0
				0			0			0			0			0			0			0			0	0
SUM				-0,652			646,6			0			-1,017			0			0			4E-07			0	645,9523

Figure 46: LCA budget brewer

C.3 LCA premium brewer

Functional unit:	New Premium Coffee brewer for 10 000 times																									
Materials & Processes		Pre-Use			Use			Post-Use																		Sum
		Production			Life			Reuse - Component			Reuse - Material			Energy recovery - combustion			Incineration - no energy recovery			Landfill			Other			
		E cost	Amount	Impact	index	Amount	Impact	index	Amount	Impact	index	Amount	Impact	index	Amount	Impact	index	Amount	Impact	index	Amount	Impact	index	Amount	Impact	Impact
	Unit	[ELU/ unit]		[ELU]	[ELU/ unit]		[ELU]	[ELU/ unit]		[ELU]	[ELU/ unit]		[ELU]	[ELU/ unit]		[ELU]	[ELU/ unit]		[ELU]	[ELU/ unit]		[ELU]	[ELU/ unit]		[ELU]	[ELU]
Glass	kg	0,279	0,4687	0,13077			0			0	-0,223	0,2	-0,0446			0			0			0			0	0,1307673
Polypropylene (PP)	kg	0,959	0,9352	0,89686			0			0	-0,479	0,9	-0,4311			0			0			0			0	0,8968568
Silicone rubber	kg	2,8	0,01544	0,04323			0			0			0	0	0,01544	0			0			0			0	0,043232
Steel. sheet metal	kg	-1,18	1,467	-1,7311			0	0	0,15	0	-1,18	0,45	-0,531			0			0	4,21E-07	0,9	3,8E-07			0	-1,7310596
Stainless steel, sheet	kg	33,11	0,763	25,2629			0			0	-30,47	0,6867	-20,924			0			0	6,32E-07	0,0763	4,8E-08			0	25,26293
Alumin. Cast	kg	1,748	0,03761	0,06573			0	0	0,00376	0	-0,946	0,01128	-0,0107			0			0	1,05E-06	0,02257	2,4E-08			0	0,0657336
Tap water	kg	8,19E-05		0	8,2E-05	6250	0,51188			0			0			0			0			0			0	0,511875
Coffee	kg			0	2	300	600			0			0			0			0			0			0	600
Electricity	kWh			0	0,076	448,8	34,1088			0			0			0			0			0			0	34,1088
				0			0			0			0			0			0			0			0	0
				0			0			0			0			0			0			0			0	0
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				0			0			0			0			0			0			0			0	0
				0			0			0			0			0			0			0			0	0
SUM				24,668			634,62			0			-21,94			0			0			5E-07			0	659,28914

Figure 47: LCA premium brewer

D Appendix D: RD&T

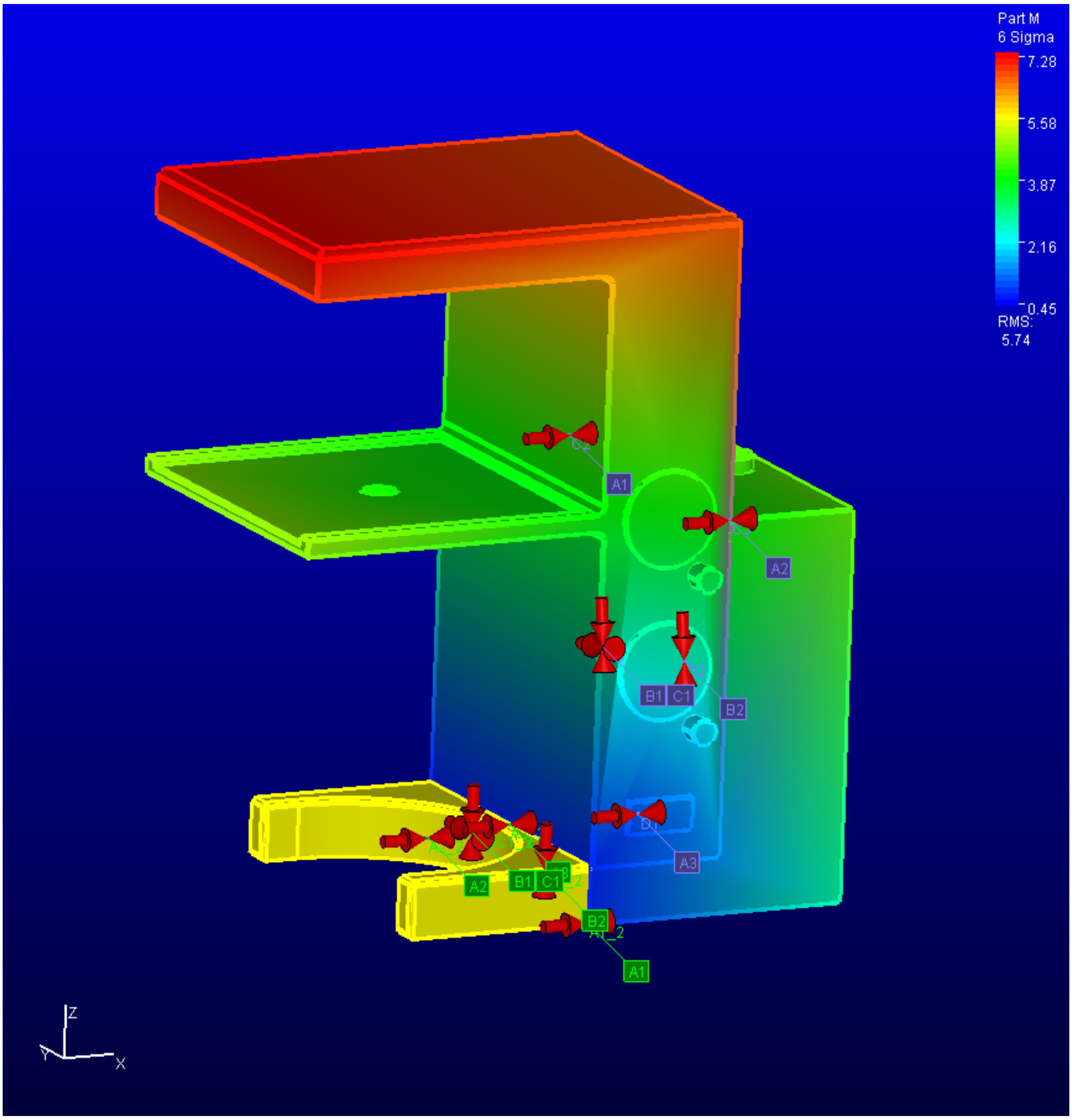

Figure 48: Robust Design and Tolerances v.1

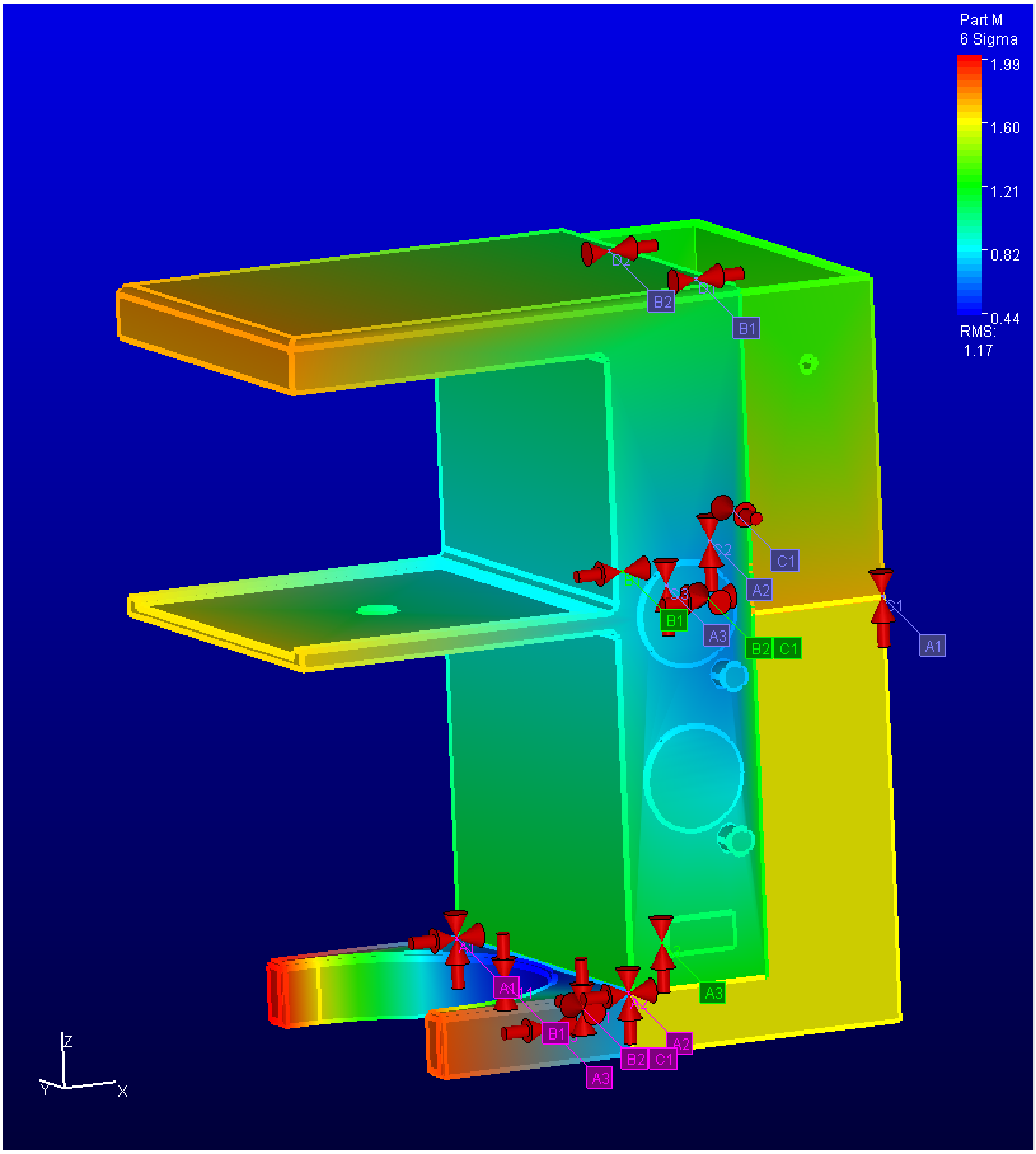

Figure 49: Robust Design and Tolerances v.2

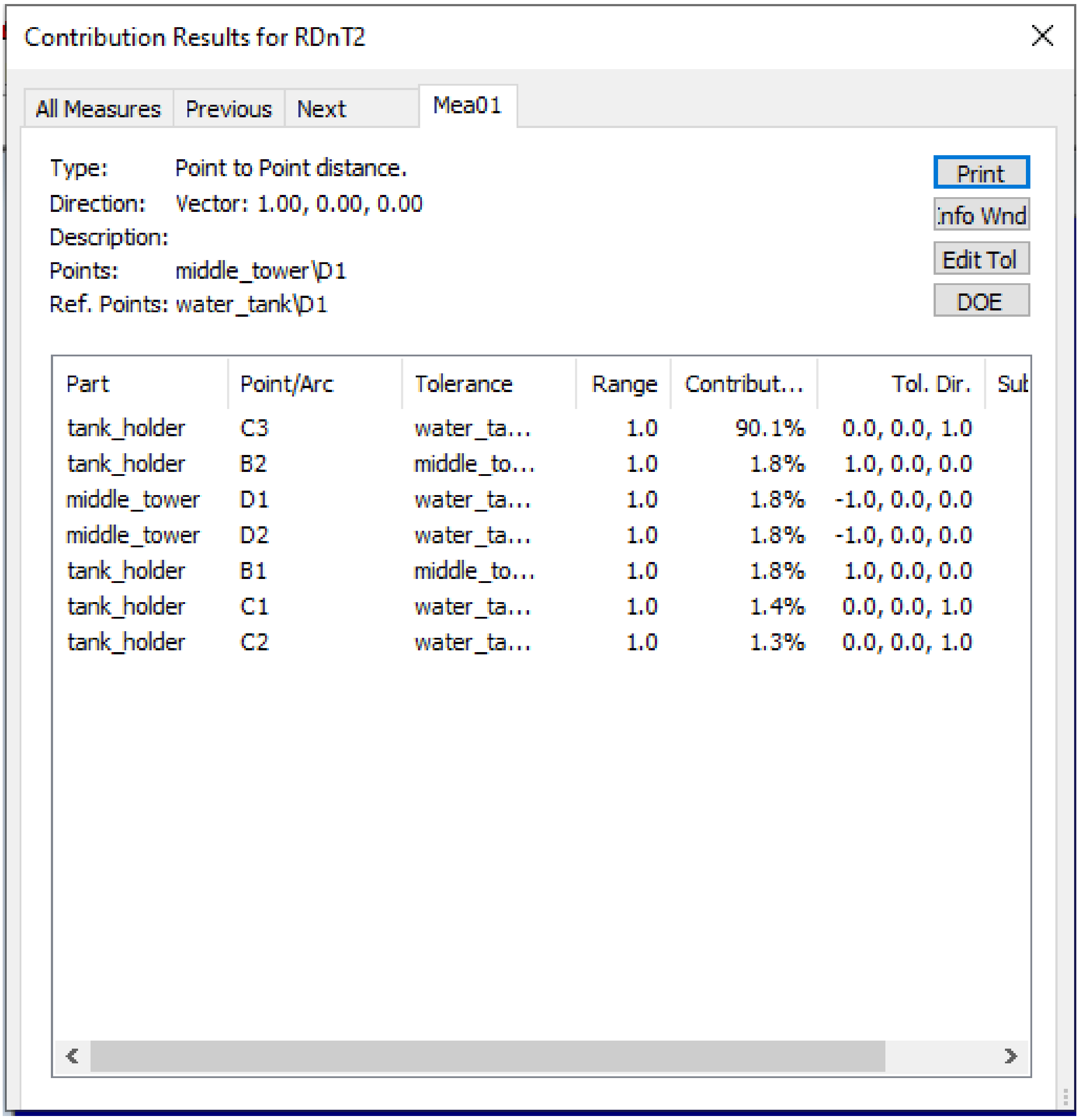

Figure 50: Contribution analysis gap 1

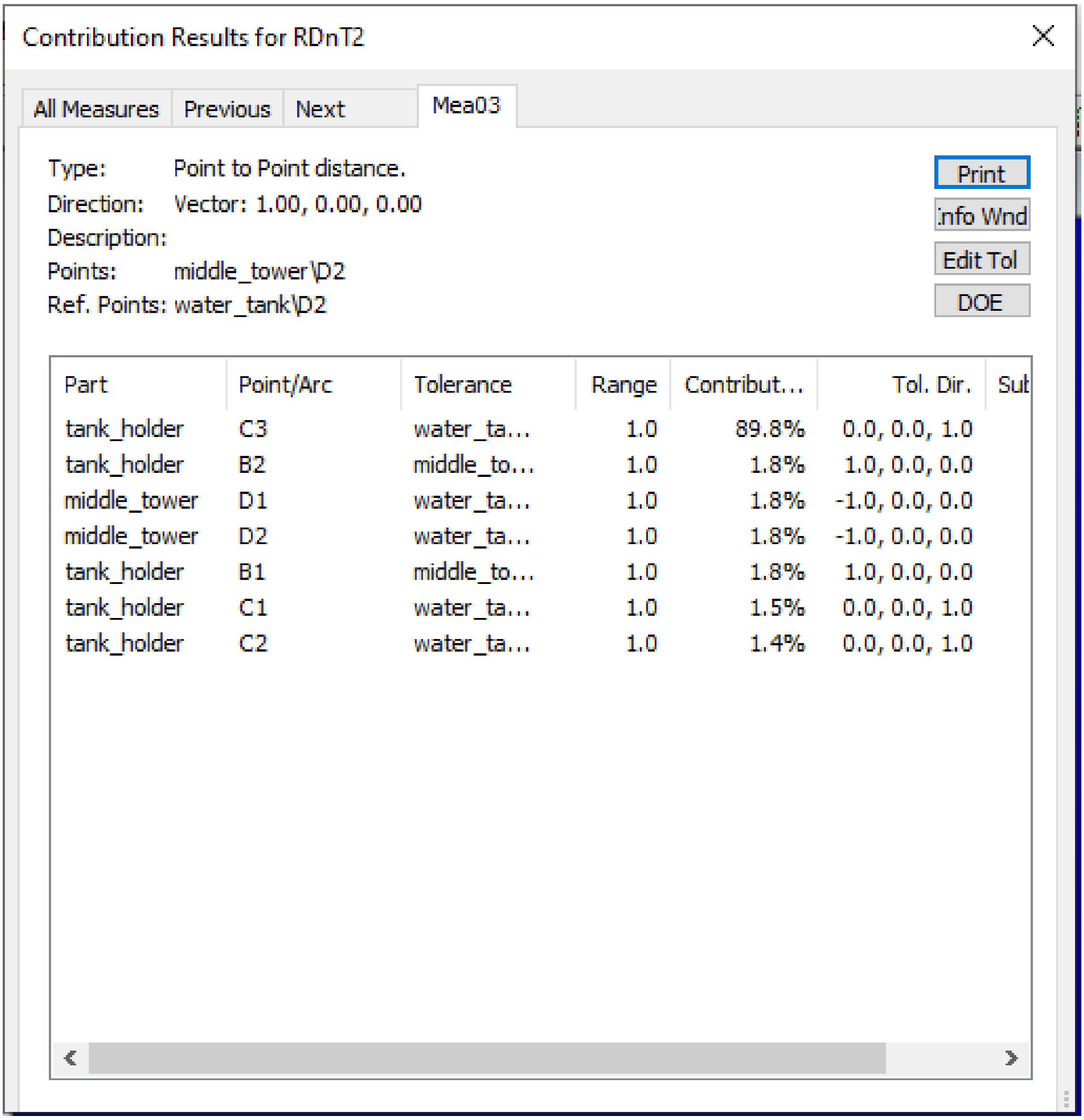

Figure 51: Contribution analysis gap 2

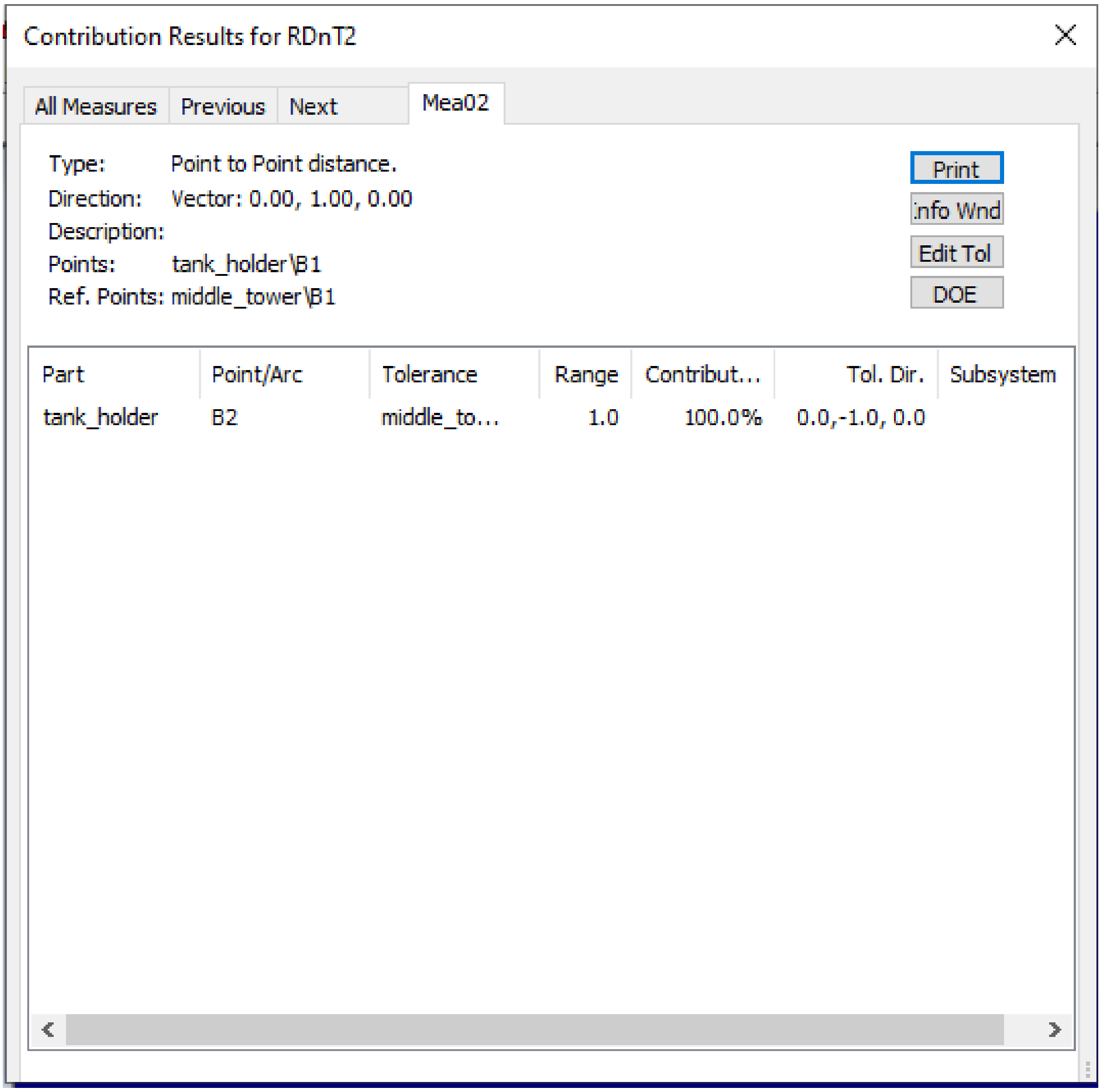

Figure 52: Contribution analysis flush 3

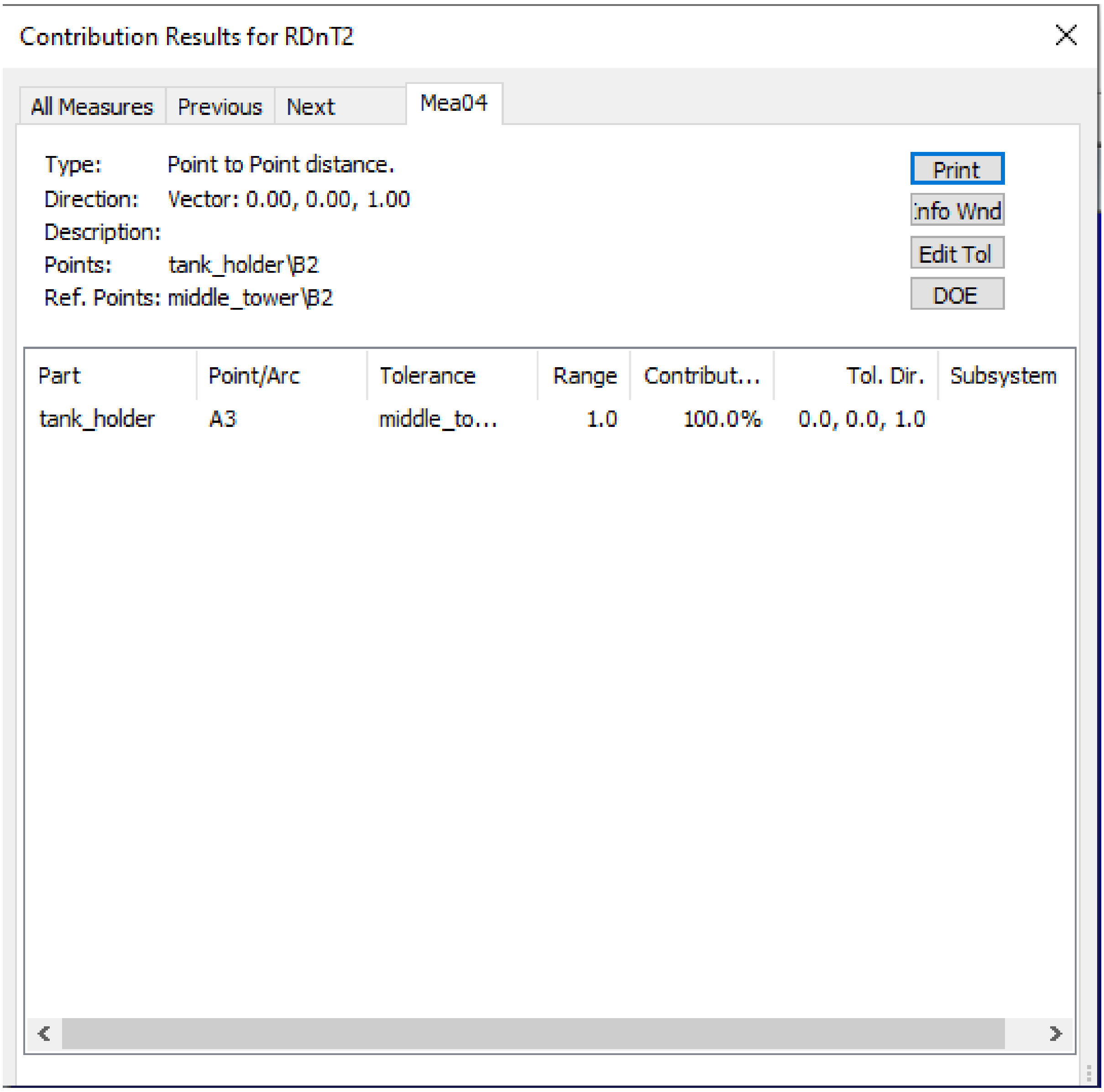

Figure 53: Contribution analysis flush 4

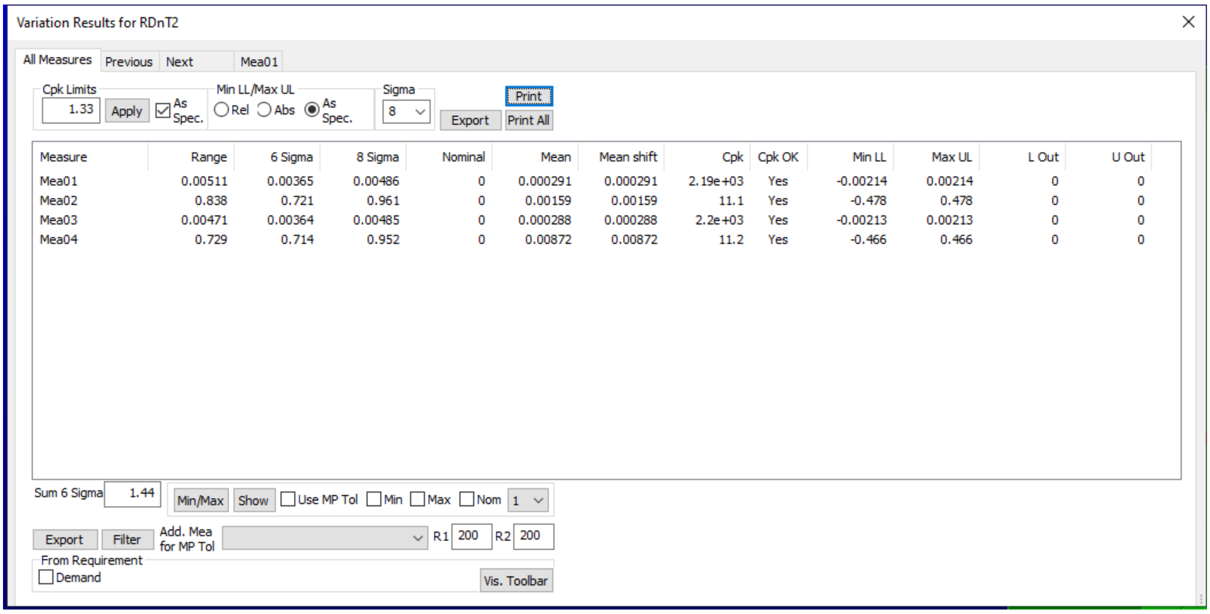

Figure 55: Variation analysis

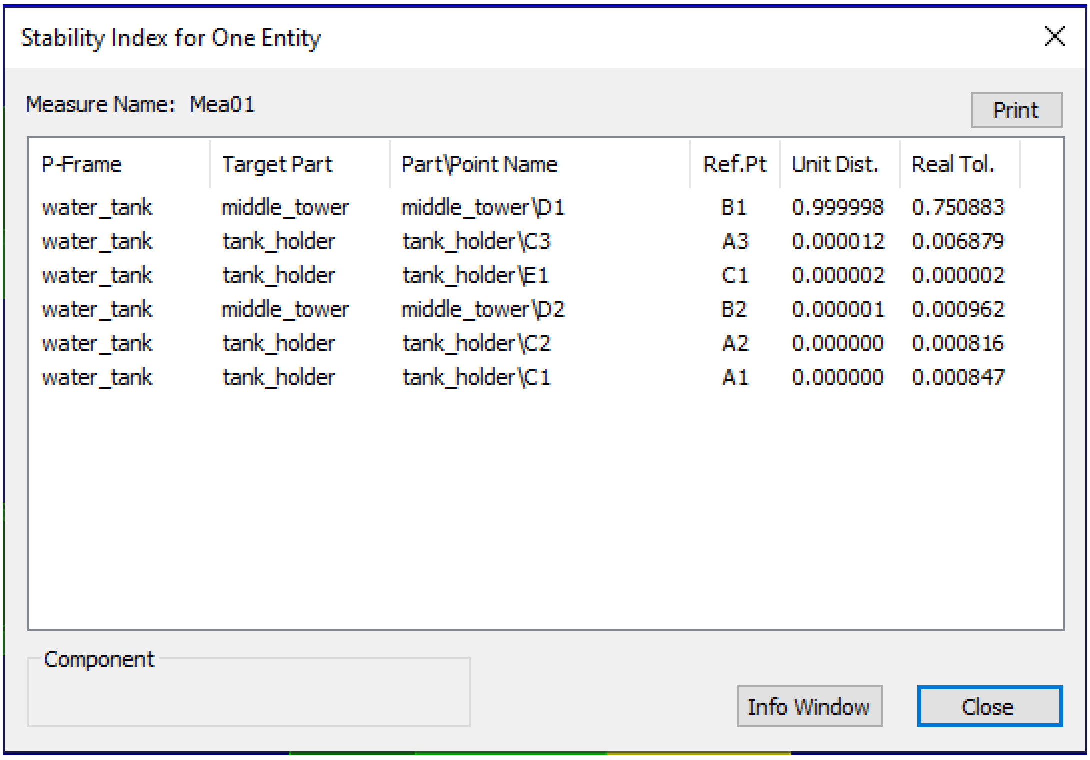

Figure 54: Stability analysis measure 1

E Appendix E: Drawings

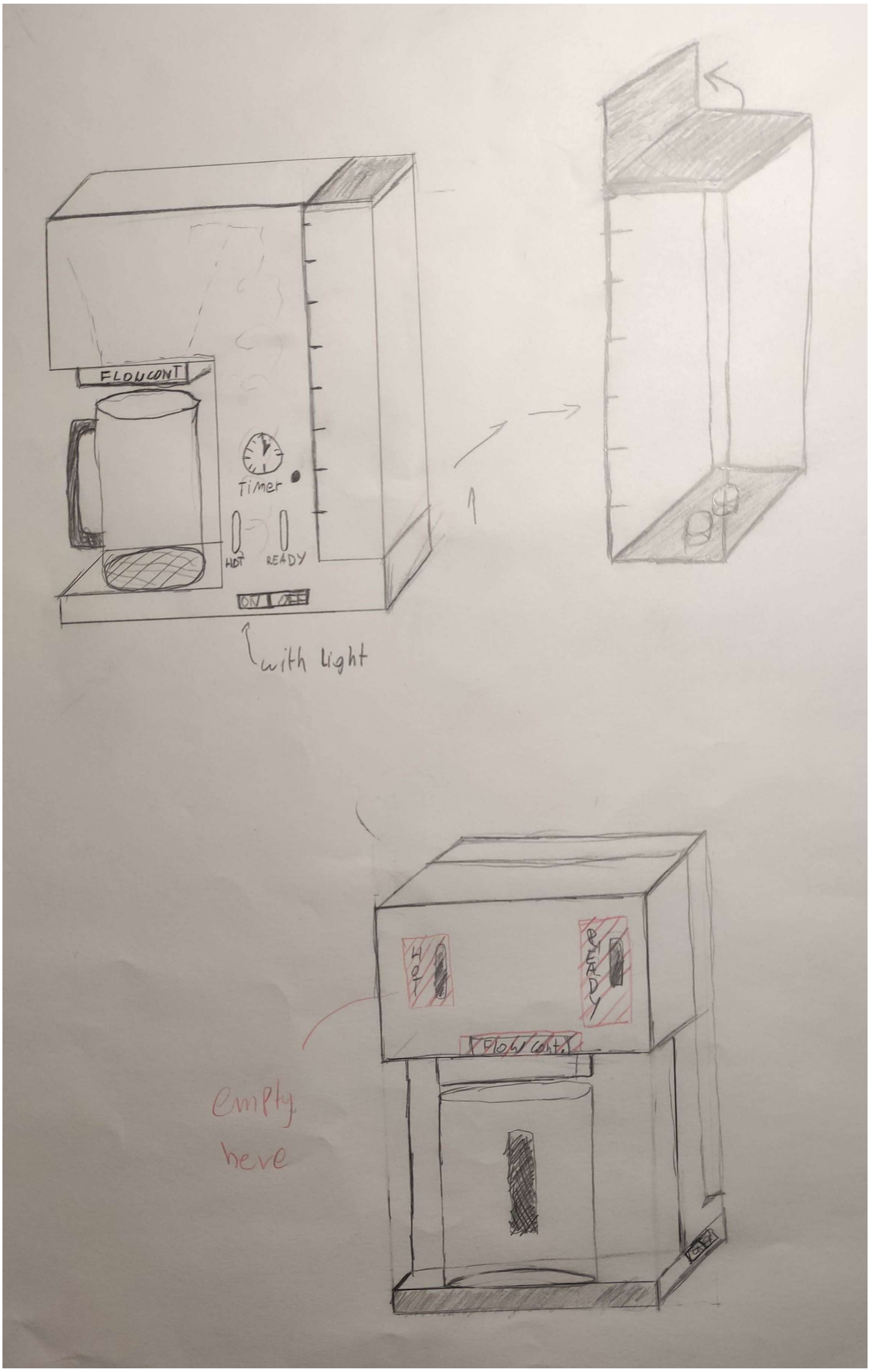

Figure 56: Initial sketch of the basic brewer

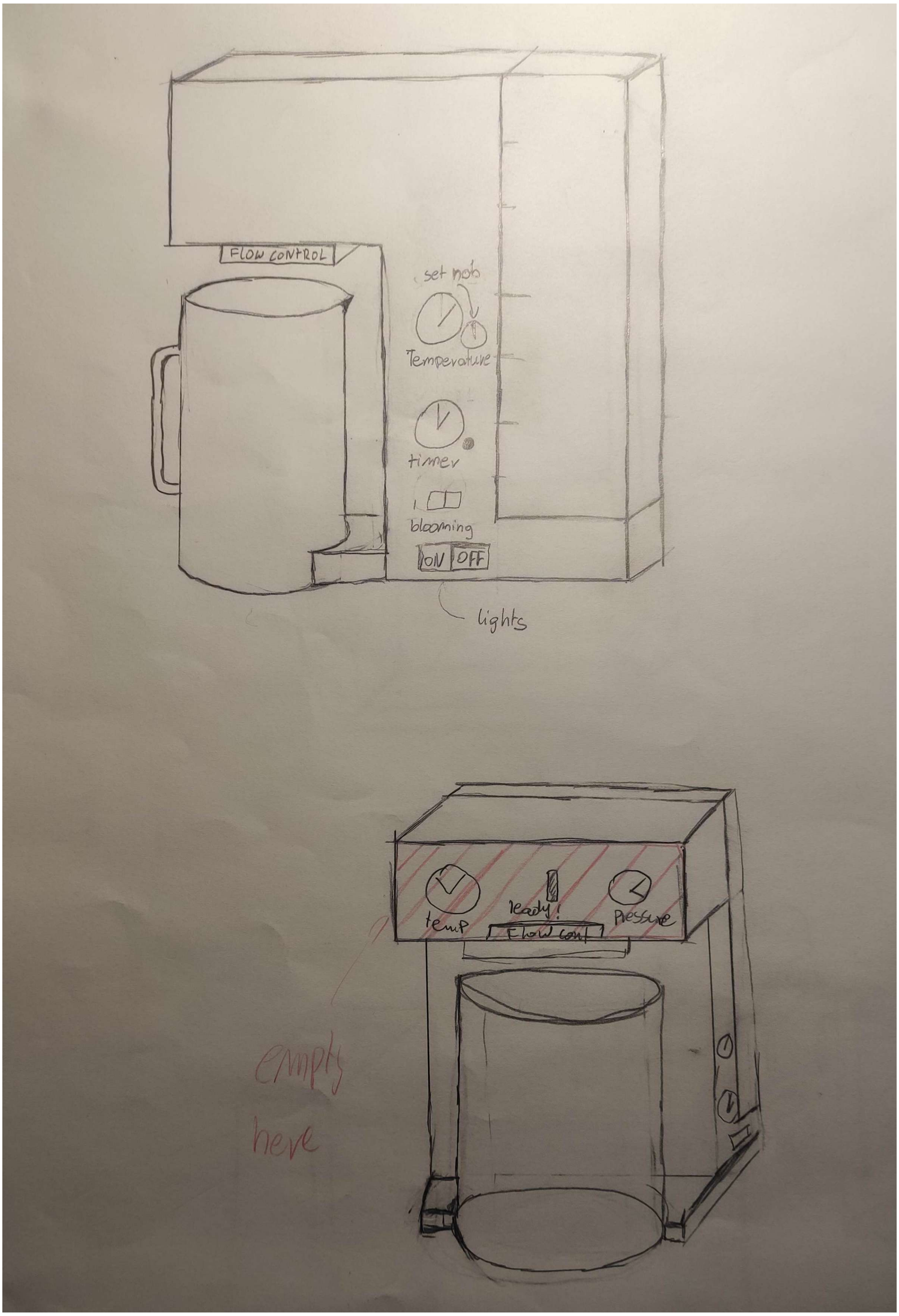

Figure 57: Initial sketch of the premium brewer

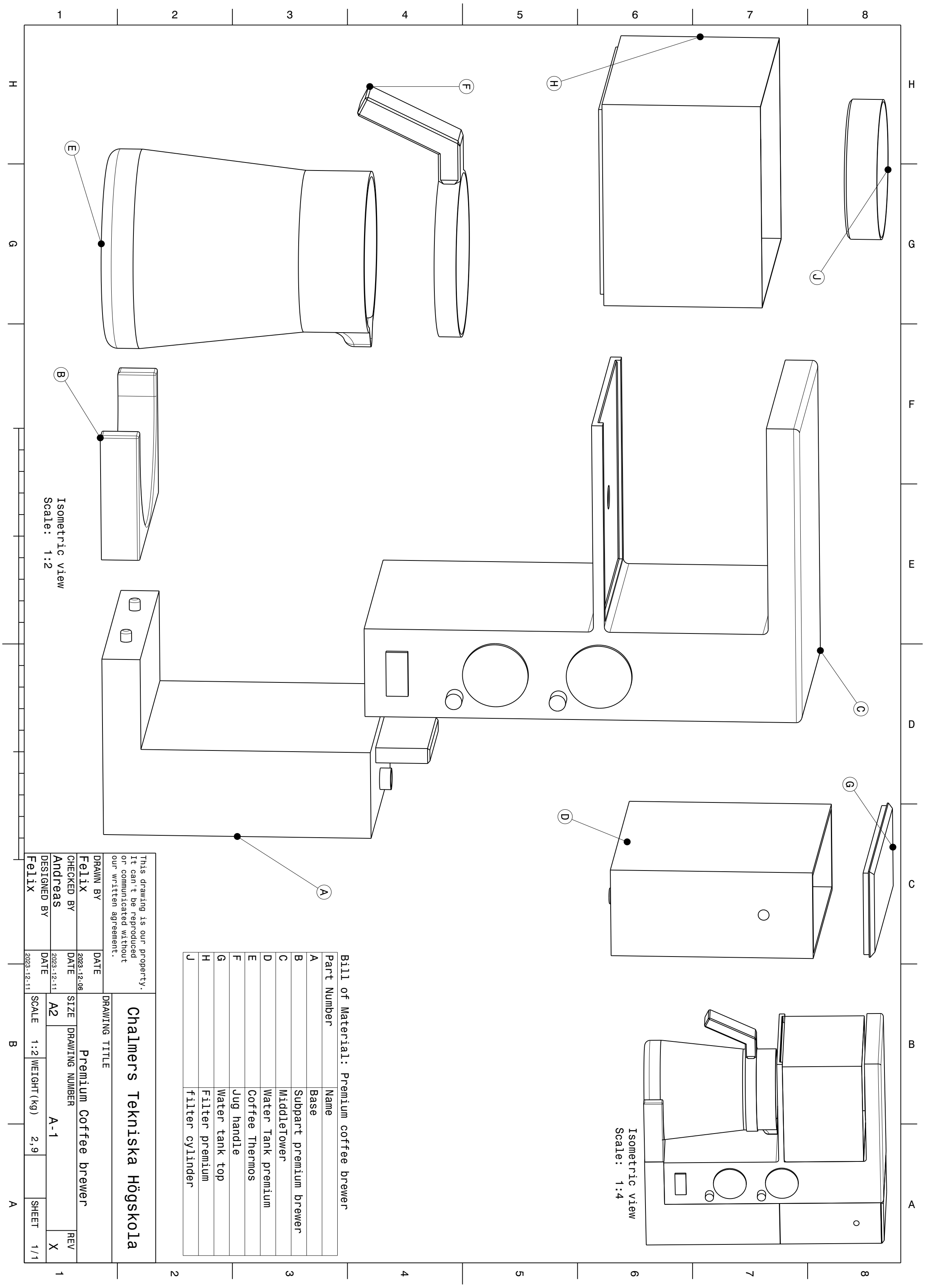

Figure 58: Exploded view drawing

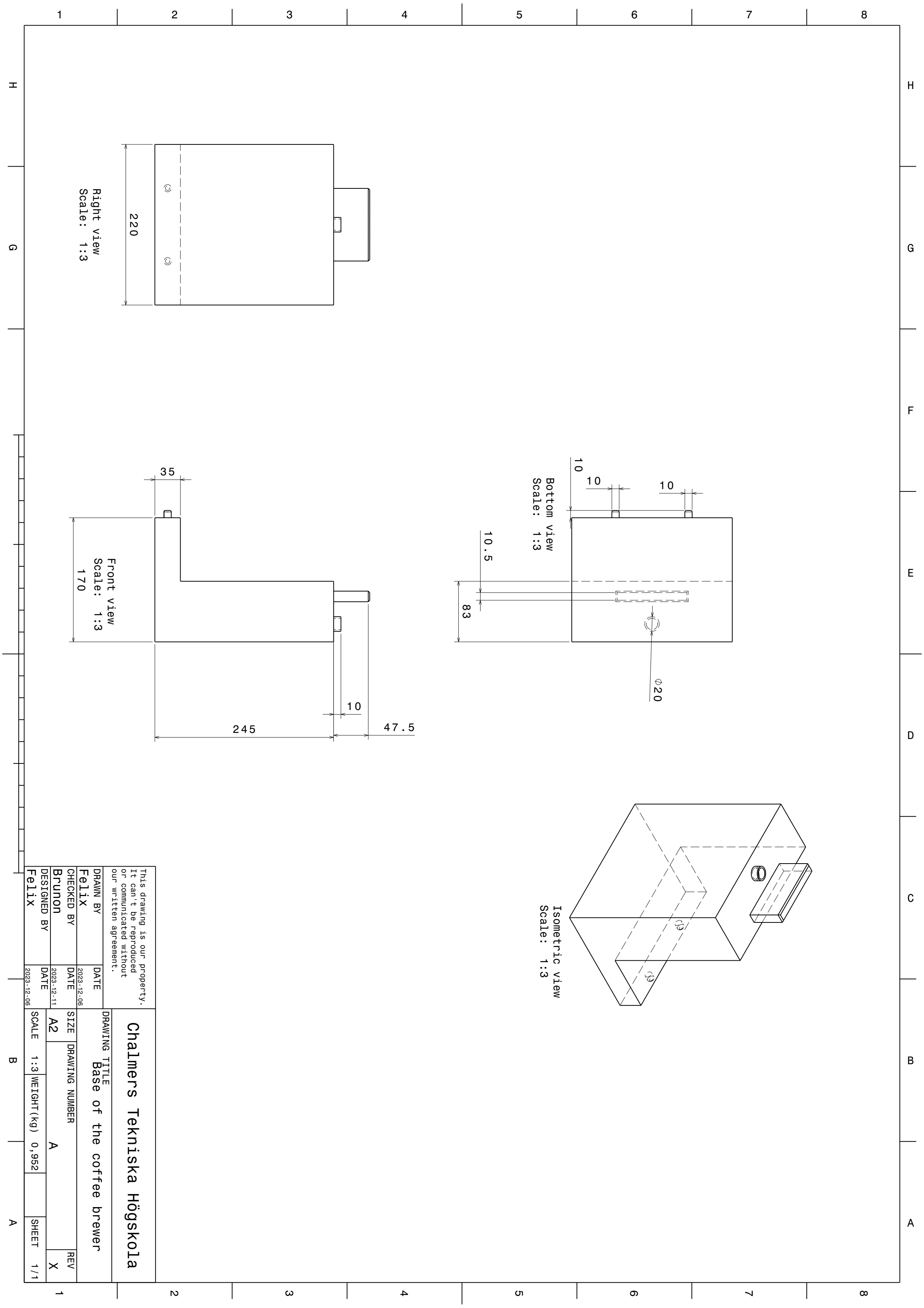

Figure 59: Drawing of the base

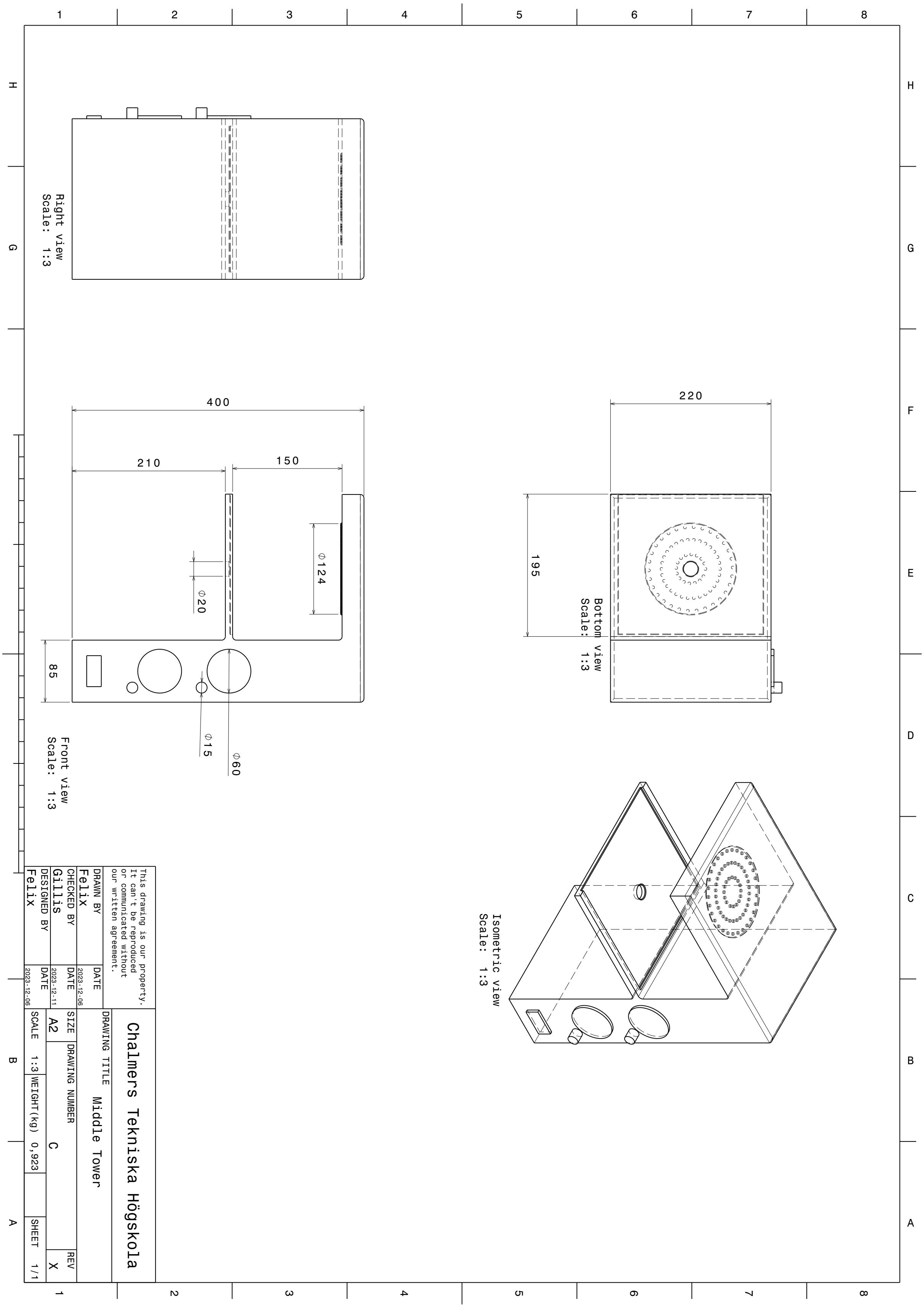

Figure 60: Drawing of the middle tower

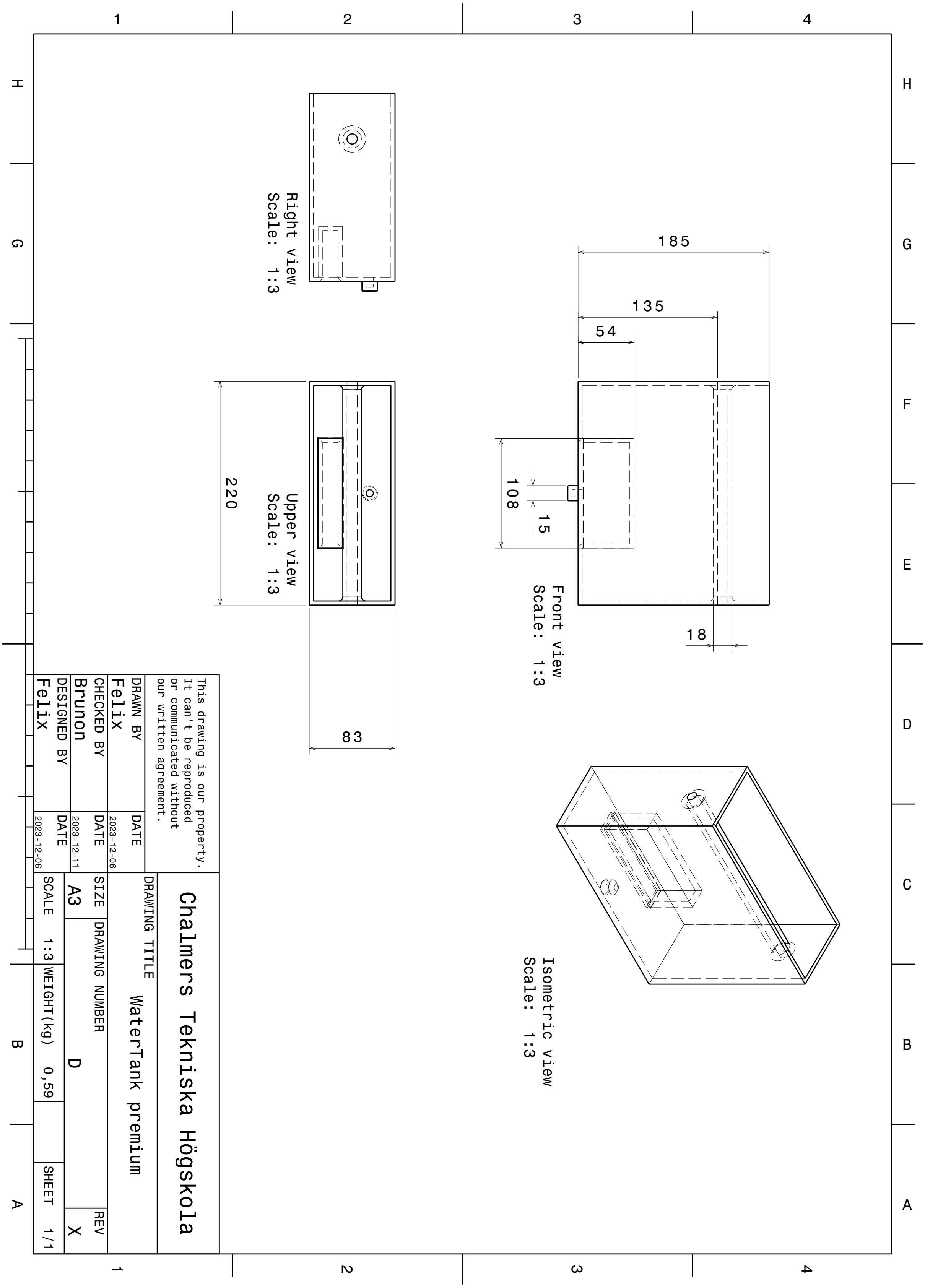

Figure 61: Drawing of the water tank