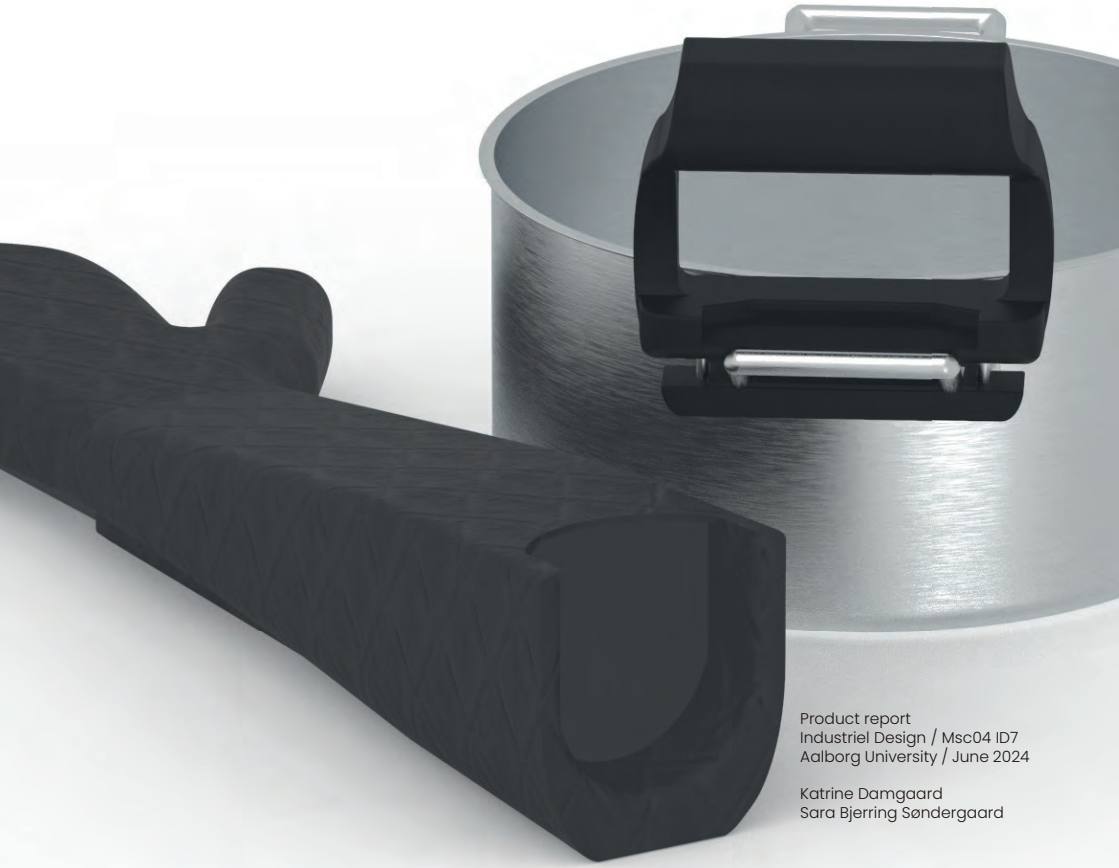
Eac

enable arm care



Product report
Industriel Design / Msc04 ID7
Aalborg University / June 2024

Katrine Damgaard
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Title Page

Project title:	Eac
Report type:	Product report
Project group:	MSc4-ID7
University:	Aalborg University
Main supervisor:	Linda Nhu Laursen
Technical supervisor:	Matin Afshar
Project period:	01/02/2024 - 30/05/2024
Total pages:	23

Abstract

The following report outlines the proposal for Eac, a medical assistive device created by two Industrial Design engineering students. Eac is designed to assist individuals with arm amputations by enabling them to use a pot while cooking independently without the need for external assistance. This aims to promote a sense of independence in the kitchen. Eac was developed in consultation with arm amputees and medical specialists to address various aspects of their needs.

The need for Eac arises from the fact that over 50% of upper limb amputees do not use their prosthetics due to limitations in functionality. With only one arm left, they end up lifting twice as much weight, which can lead to overuse and, in the worst-case scenario, being unable to use their arm for a period of time. Therefore, Eac is designed to prevent overuse of the healthy arm, ensuring continued functionality.

Eac distinguishes itself by addressing functional challenges while also considering aesthetic appeal, thereby reducing the stigma associated with assistive devices. It includes a pot attachment with a secure grip handle and an arm attachment for additional support, significantly improving the user's ability to cook independently.

This innovative design represents a significant step towards restoring independence for arm amputees. It showcases the potential of thoughtful design to make a meaningful difference in the lives of its users.

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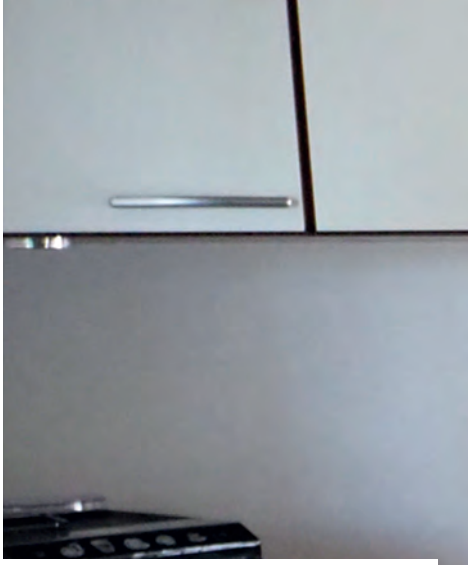


Eac

Eac is more than just a typical assistive device on the market. It is specifically designed to be an integrated part of the user's existing kitchen routine and prioritize their needs. Eac is functional and visually appealing, blending in with the kitchen environment. Additionally, Eac comes in multiple sizes to ensure a perfect fit for the user.

Eac is designed to support arm amputees throughout their lives. It enables them to use their muscles, maintain strength, and build more strength.

Eac is not designed for arm amputees to carry more than they are able to. Instead, it is designed to ensure that they do not overuse their arms while building strength. When both attachments are used together, lifting a pot may feel lighter, but this is not meant to encourage lifting more than they are capable of. Rather, it is intended to make it easier for them to test their strength and lift what they can without using all of their energy while cooking.

It can be psychologically difficult to go through an amputation. Although EAC does not directly address this aspect, it will help amputees focus on their psychological reaction by making it more tangible for them to continue cooking while going through the rehabilitation process.

By allowing independent use of pots during cooking, Eac goes beyond being just a device. It brings the reality of independence in the kitchen closer to the user.

Pot Attachment

The pot attachment is permanently mounted onto the pots handle, ensuring that the arm amputee always has a handle on the pot to provide a firm grip while transporting it around the kitchen.

The handle is shaped to fit the palm of the hand, ensuring that the handle lies securely in the palm while lifting the pot.

The attachment is designed to suit different types of pots to ensure that arm amputees can use the attachment with their pots, thereby not having to replace their existing interior as other assistive devices require.

The pot attachment do not limit family members or guests without an arm amputation to not use the pot, they can either use the same handle as the arm amputee, or for more support use both handles on the pot.

Arm Attachment

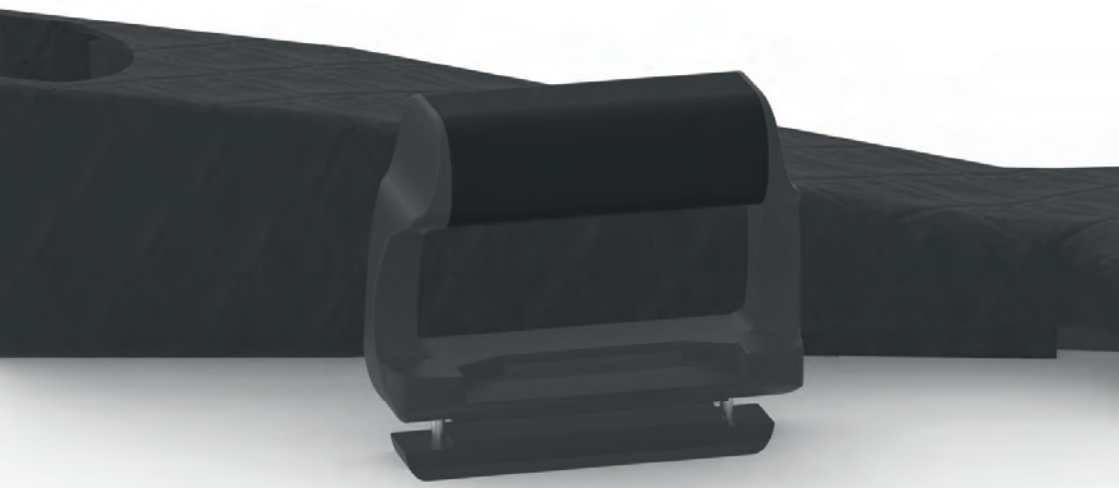
The arm attachment is designed to support the user when transporting a pot around the kitchen, distributing the load onto the lower arm. This prevents arm amputees from overusing their healthy arm.

The arm attachment can be quickly put on and taken off.

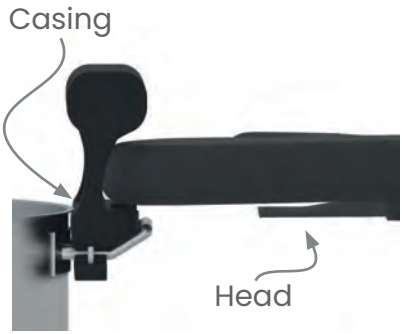
The user just needs to lay the arm attachment on the counter and slide their arm into it. Silicone on the bottom ensures that the arm attachment stays in place. To remove the arm attachment, the user simply lays their arm on the counter and slides it out of the attachment.

Used Together

The two attachments can be used together by inserting the head of the arm attachment into the casing on the pot attachment.



To do this, the user first put on the arm attachment and then grip onto the handle by following the bottom of the handle with their hand.



While doing this, the head will automatically slide into the casing...

...and the user will know it is placed correctly when the head hits the back wall of the casing.

Eac comes in five sizes to ensure it fits the different users. When the attachments are not in use, they will be stored where the user already stores their pots and oven mitts.

Eac also supports the arm when draining the content in the pot.

Visual Expression

Eac is designed with the kitchen environment in mind. The arm attachment's shape and quilted material are inspired by the design of an oven mitt, providing a heat-resistant layer for added safety and comfort.

This innovative attachment seamlessly integrates into the kitchen setting, empowering arm amputees to confidently and comfortably participate in cooking activities, even when entertaining guests.

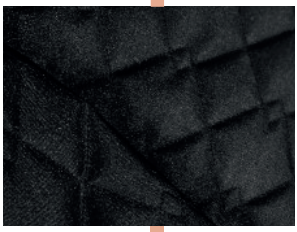
The pot attachment is are carefully designed to complement the kitchen ambiance. Deliberately selected colors ensure that Eac caters to a diverse range of users, promoting inclusivity and accessibility.

What truly distinguishes Eac is its harmonious fusion of practicality and visual appeal. By valuing both aesthetics and functionality, Eac aims to challenge the stereotypes often associated with assistive devices, fostering a sense of pride in its users. Experience the ultimate kitchen journey with Eac, where innovation harmonizes with comfort and style.

Materials

Quiltet fabric

The fabric is quilted, which is often found in oven mitts. This choice was made for its visual appeal and to ensure the user's comfort when using the arm attachment near hot areas in the kitchen. A diamond pattern has been chosen to keep the cost down.

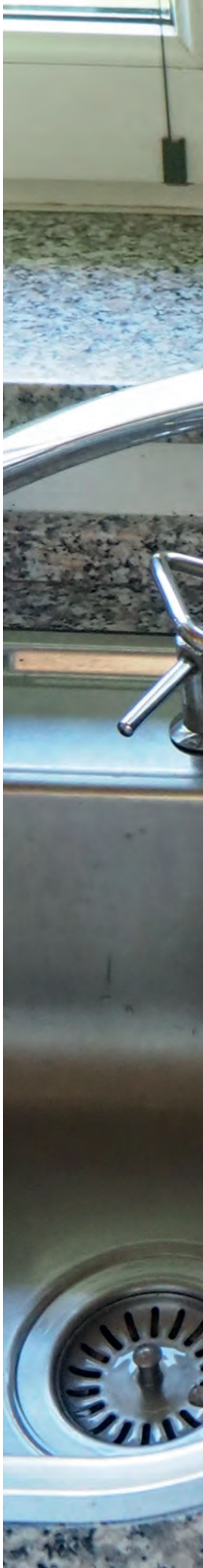


Nylon 66

The pot attachment and arm support are produced in nylon 66. To gain more strength in the arm support it has been reinforced with 60% glass.
Nylon is a durable material that can be disinfected and can be cleaned in the dishwasher, so the user can feel comfortable using it near food.

Silicone

Silicone has been used in three different areas of the product: on the handle to create a firm grip, on the area of the pot attachment where it will be mounted onto a pot's handle to ensure no scratching will occur, and lastly on the bottom of the fabric to ensure the user can easily attach and detach the arm attachment.



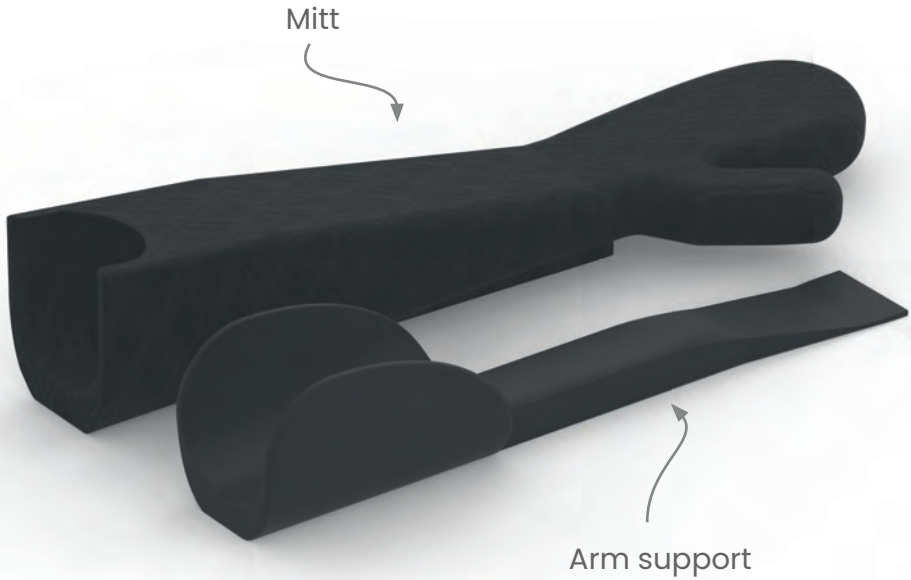
Construction

The arm attachment consists of an arm support and a shape-sewn fabric that slides onto the arm support.

The pot attachment consists of a top and bottom part that connect around a pot handle using blots.
Both the top and bottom parts have silicone on the area that touches the pot handle to prevent scratching.

The attachment is mounted by the employer from the municipality that will deliver Eac to the citizen.
This provides reassurance to the user that the device is correctly mounted.

The pot attachment and arm support will be produced through injection molding.




Pot attachment top
Pot attachment bottom
Bolts

Arm support

Mitt

Pot attachment

Cost & Investment

Denmark experiences approximately 30-35 arm/hand amputations each year suggesting a potential market for around 35 units of the product sold annually. Although specific data on the current number of arm amputees in Denmark is not available, it's important to consider that they could also be potential purchasers of the product.

Retail price: 5000 DKK

Break even: 263 units sold in 8 years

Implementation

The following steps are four of the steps from the implementation plan. The rest of the implementation plan can be found in the process report.

Funding

To propel our Eac forward, it is estimated that a minimum of 1,300,050 DKK is required for molds and materials, with additional expenses to follow. Therefore, enthusiastic investors will be found to help kickstart Eac.

Partnership

Eac will be granted to the arm amputees by the municipalities who therefore will be the customers. A partnership with Aabentoft, who already has the municipalities of Denmark as customers, will create a sales challenge and thereby reach the municipalities.

Testing & Optimization

Eac will undergo further testing and optimization to prepare for a 0-series, where the required tests for Eac to be classified as a medical device Class I can be conducted.

Expanding the Market

After achieving success in the Danish market, it is imperative to expedite the expansion to other countries to boost sales.

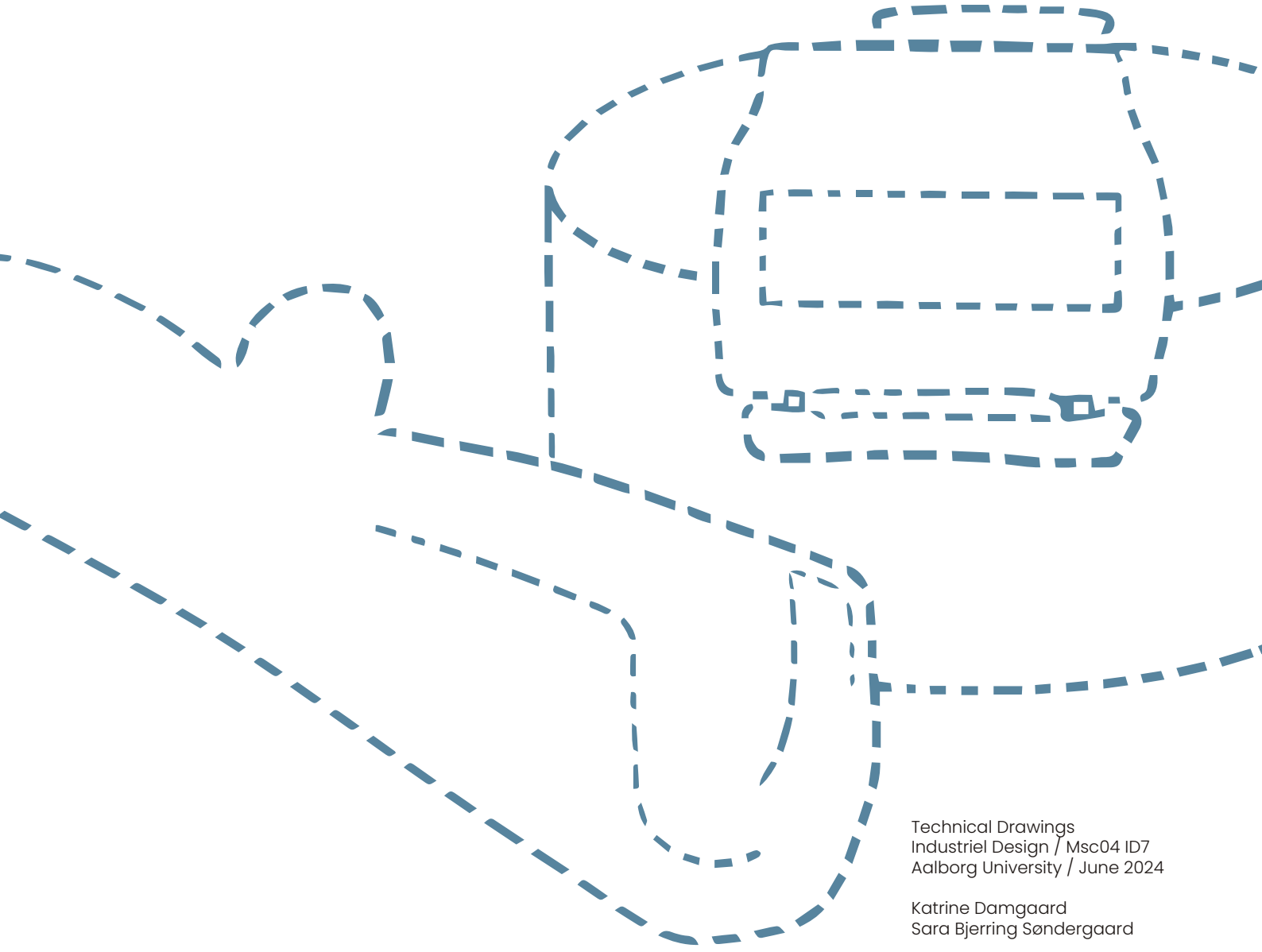
Eac brings arm amputees a step closer to the independence they had pre-amputation.

Eac

enable arm care

Technical Drawings

Eac



Technical Drawings
Industriel Design / Msc04 ID7
Aalborg University / June 2024

Katrine Damgaard
Sara Bjerring Søndergaard

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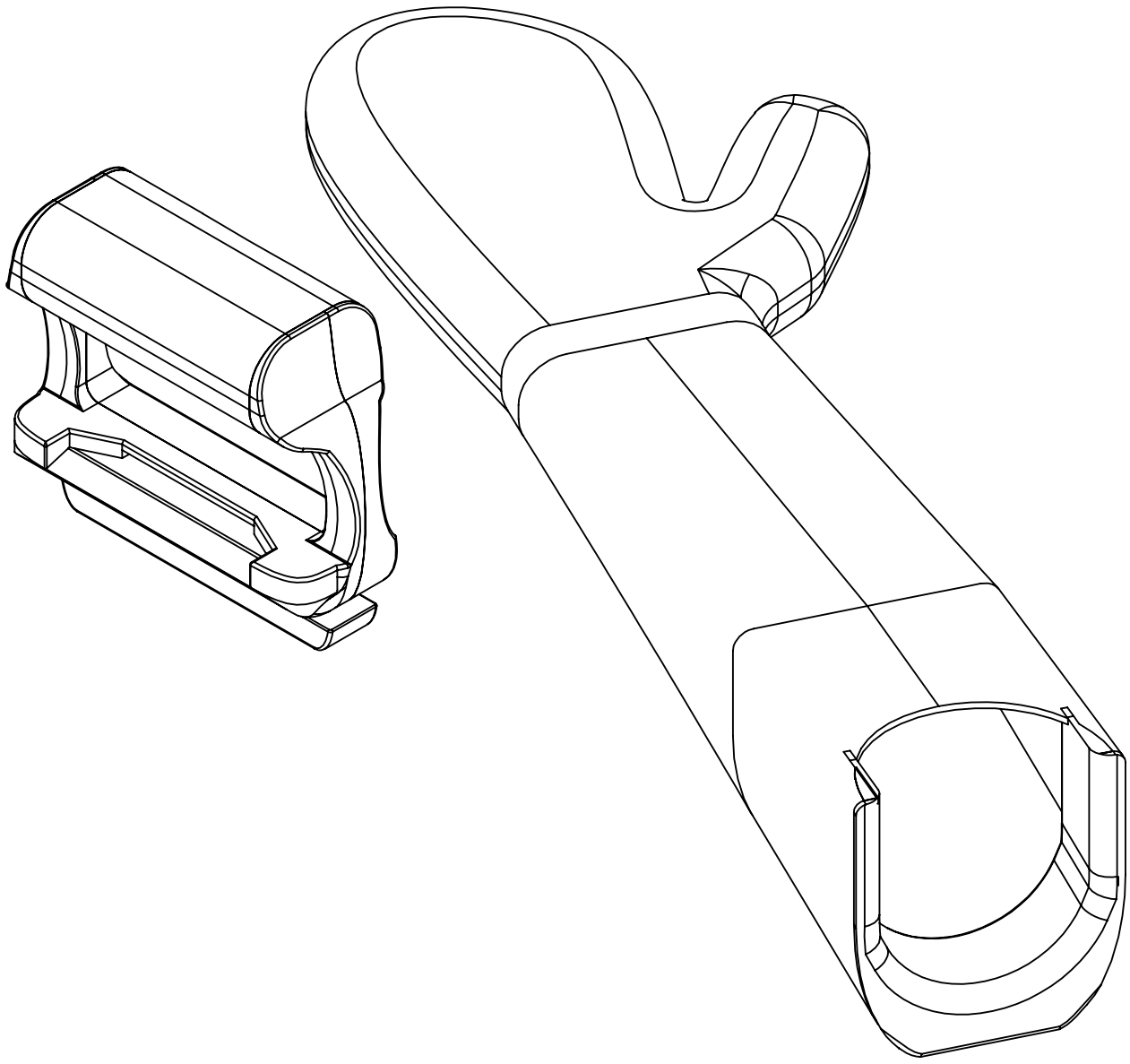
Disclamer

The technical drawings have been prepared for Eac in size medium.

The Arm Support Part and the Pot Attachment Top front part have been selected for specific tolerance adjustments, as these are the most critical components. It is crucial that the head of the Arm Support fits into the casing on the Pot Attachment Top front part.

To finalize the technical drawings for Eac's production, it is essential to consult with the manufacturer to ensure they have all the necessary data from the drawings.



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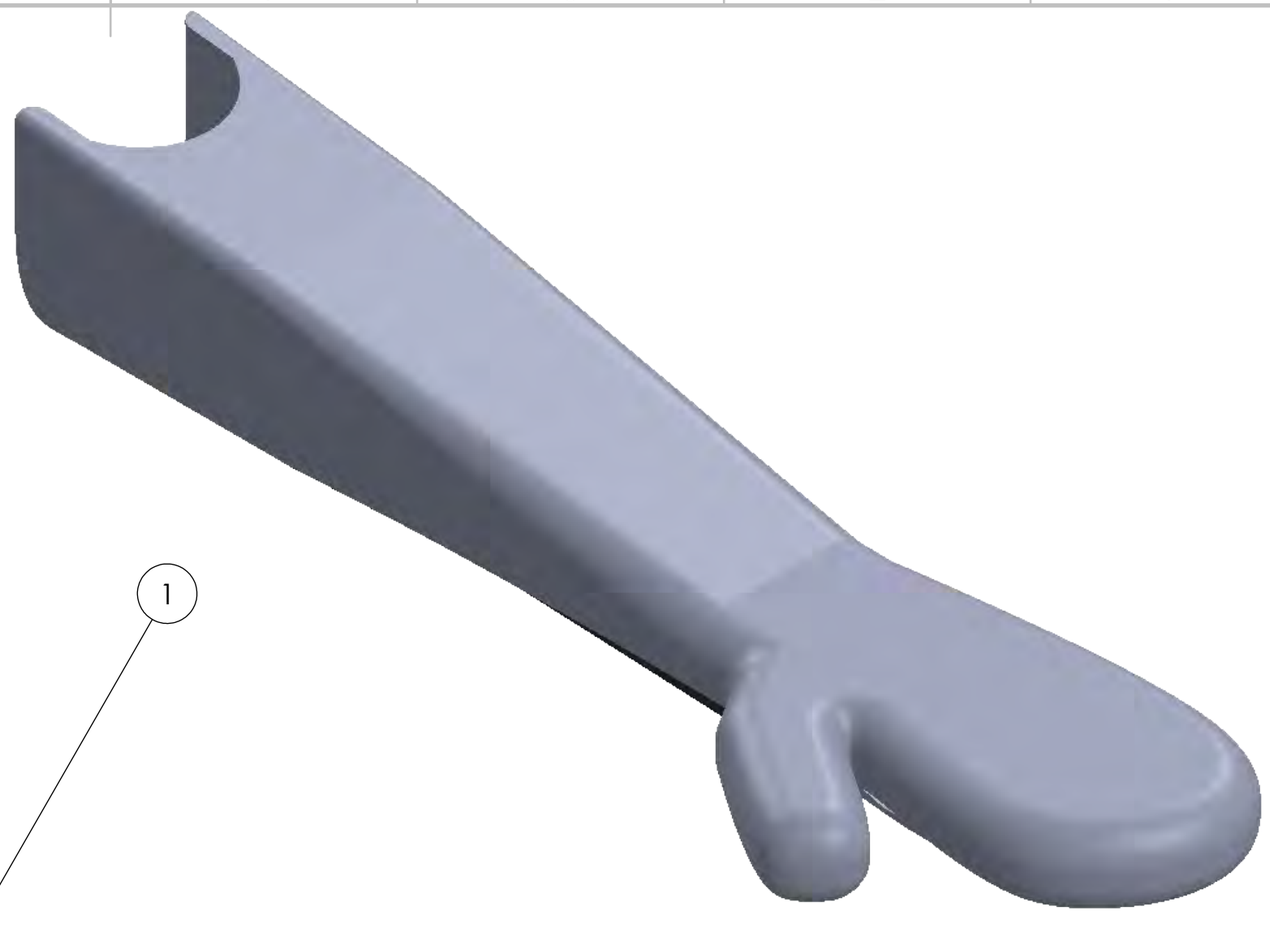
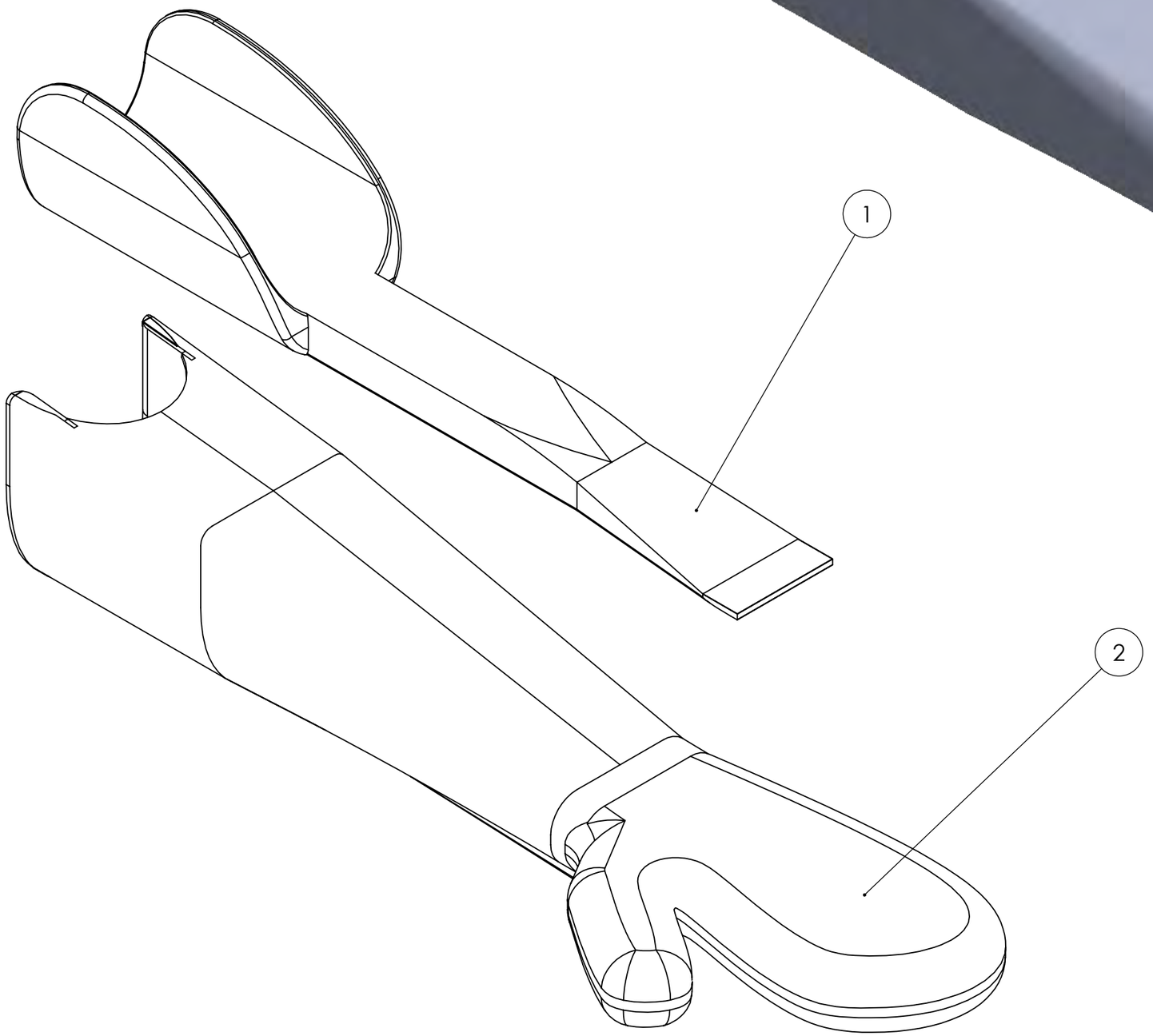
SHEET SIZE: A4	SHEET: 1 OF 17
	DATE: 28/05-2024





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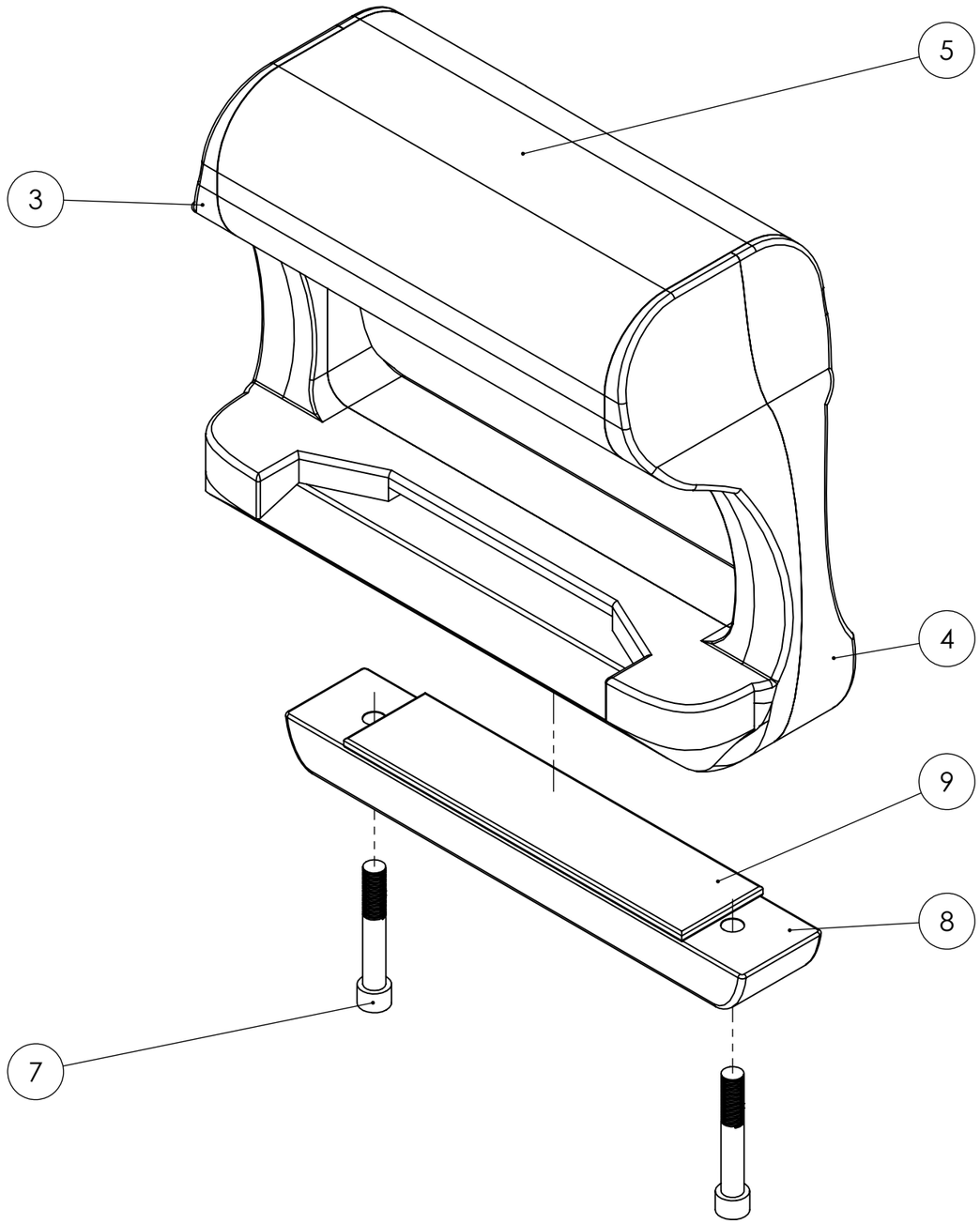
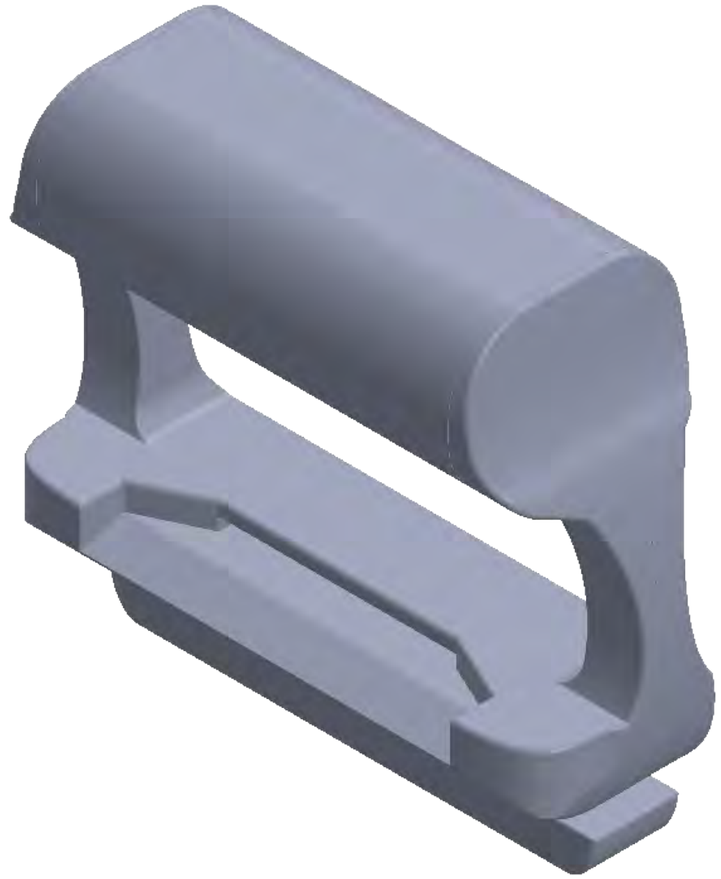
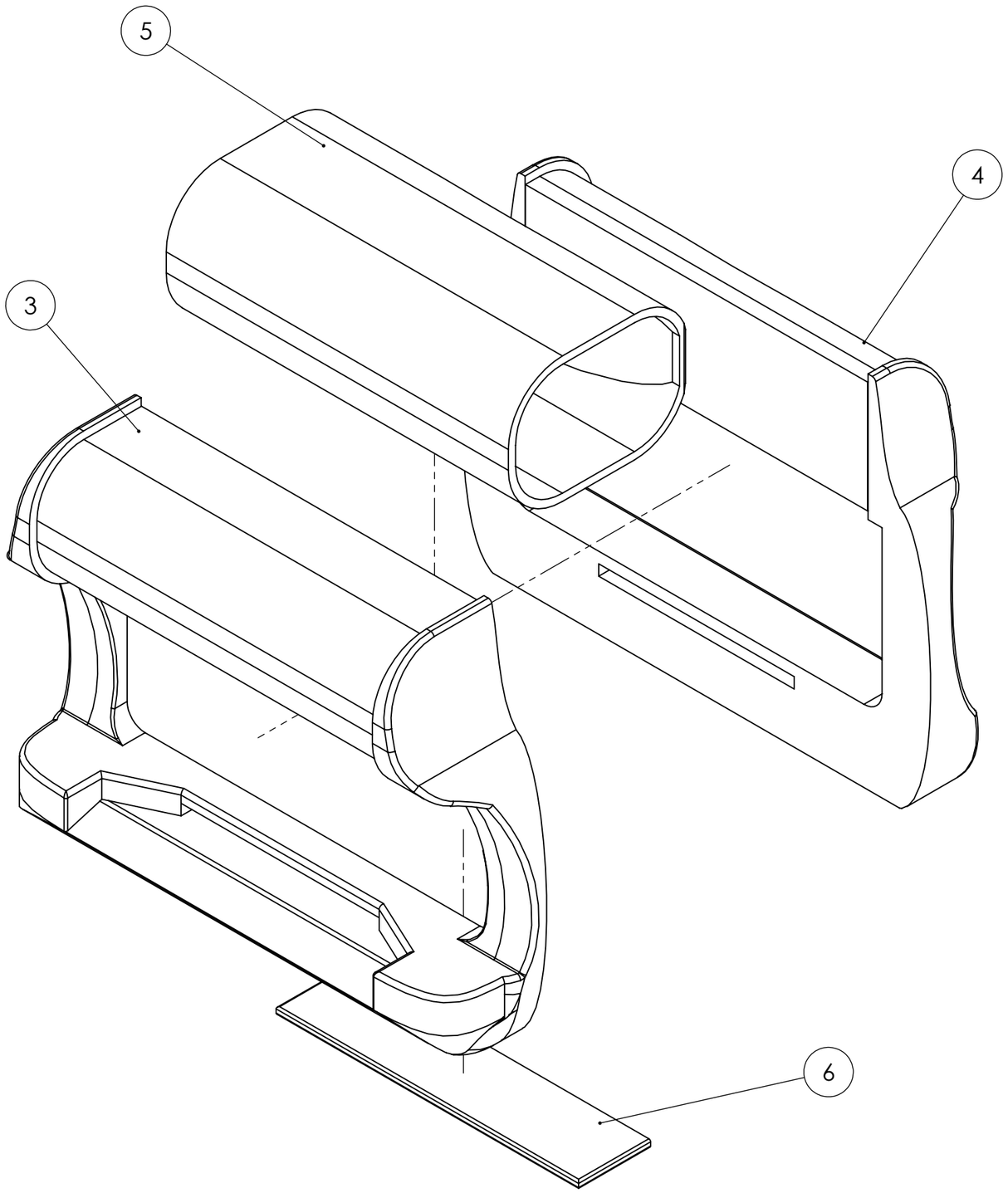
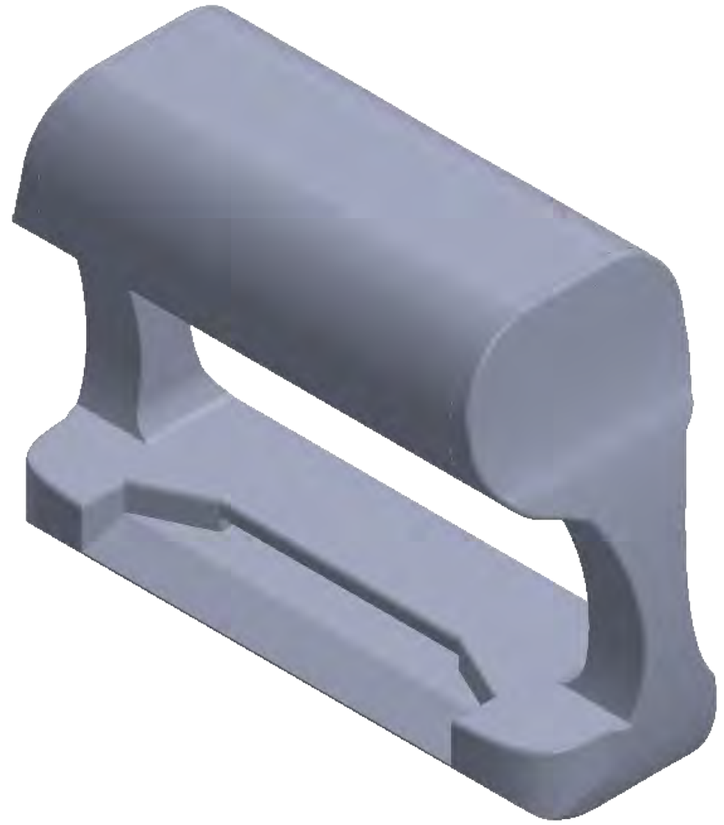
COMPONENT NAME: Arm Attachment exploded	
SCALE:1:2	CREATOR: MSc4-ID7
SHEET SIZE: A3	SHEET 2 OF 17
	DATE: 28/05-2024





PRODUCT NAME: Eac	
COMPONENT NAME: Pot Attachment Exploded	
SCALE:1:1	CREATOR: MSc4-ID7
SHEET SIZE: A3	SHEET 3 OF 17
	DATE: 28/05-2024





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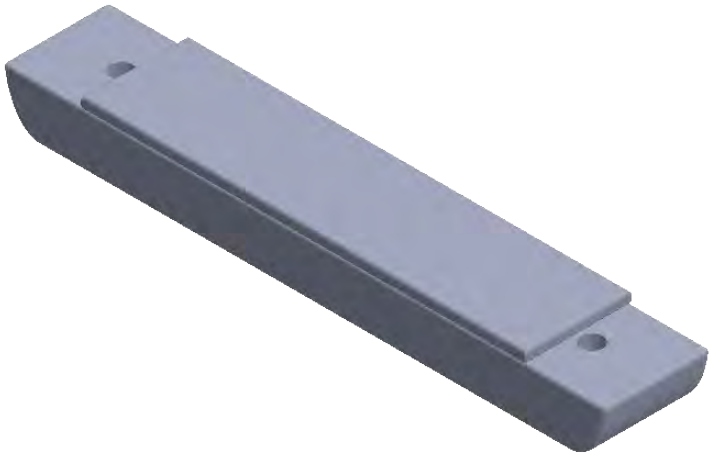
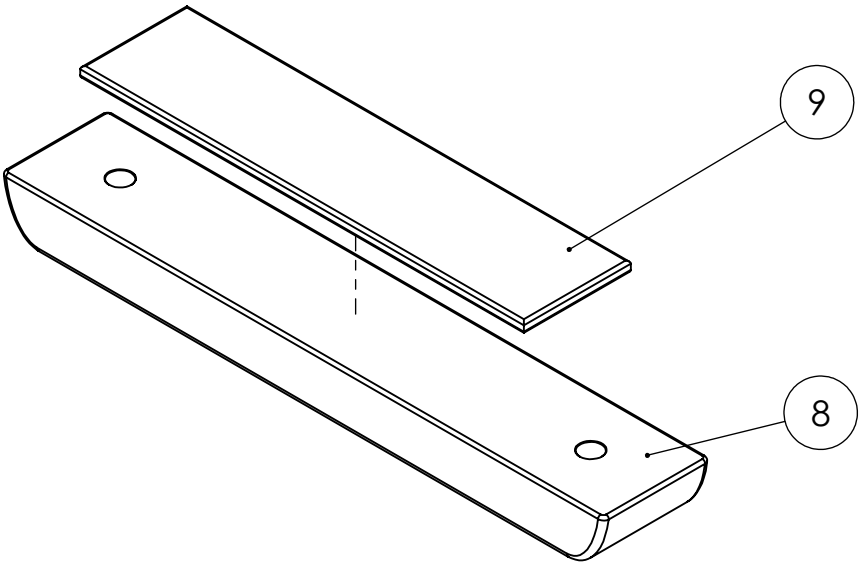
COMPONENT NAME: Pot Attachment Top Exploded	
SCALE:1:1 SHEET SIZE: A3	CREATOR: MSc4-ID7 SHEET 4 OF 17 DATE: 28/05-2024





PRODUCT NAME: Eac	
COMPONENT NAME: Pot Attachment Bottom Exploded	
SCALE:1:1	CREATOR: MSc4-ID7
SHEET SIZE: A4	SHEET 5 OF 17
	DATE: 28/05-2024

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Arm support part	Nylon 66 - 60% Glass Fibre Reinforced	1
2	Mitt part	Quilted fabric and silicone	1
3	Pot attachment top front part	Nylon 66	1
4	Pot attachment top back part updated	Nylon 66	1
5	Pot attachment top silicone handle	Silicone	1
6	Pot attachment top silicone bottom	Silicone	1
7	Bolt	Stainless Steel	2
8	Pot attachment bottom part	Nylon 66	1
9	Pot attachment bottom silicone top	Silicone	1

PRODUCT NAME: Eac

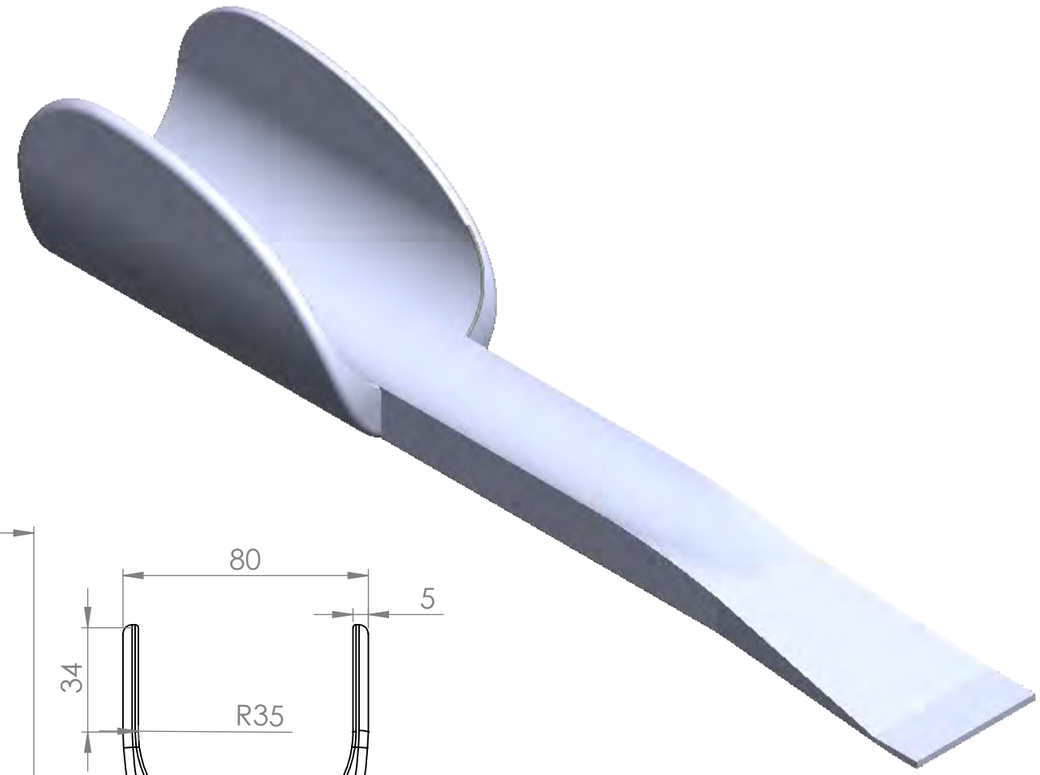
COMPONENT NAME: Bill of Materials

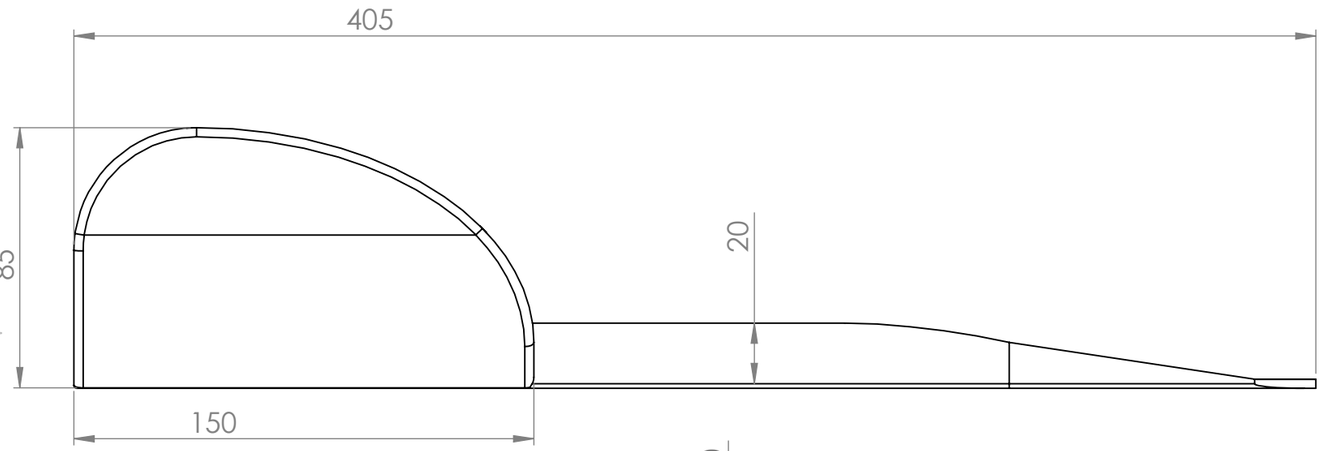
SHEET SIZE: A4

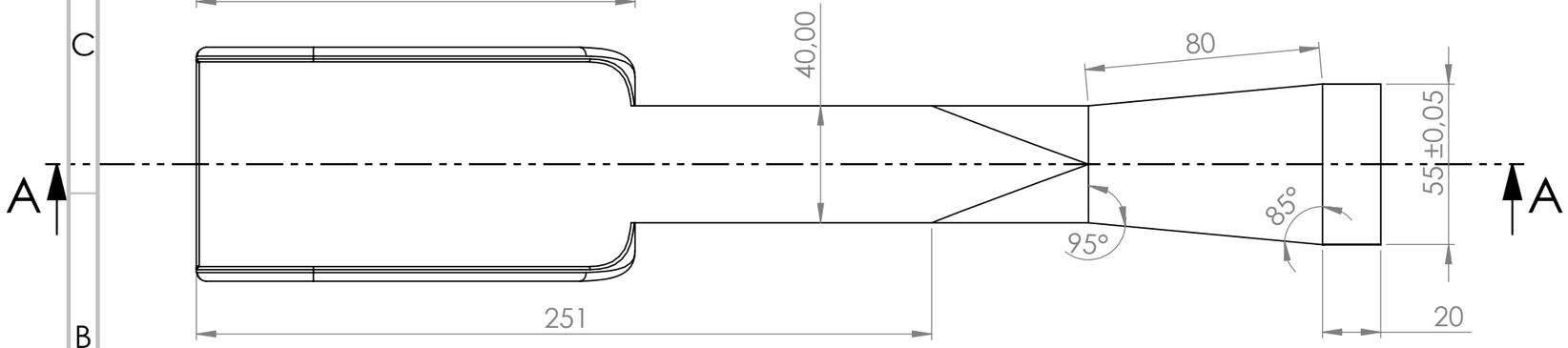
CREATOR: MSc4-ID7

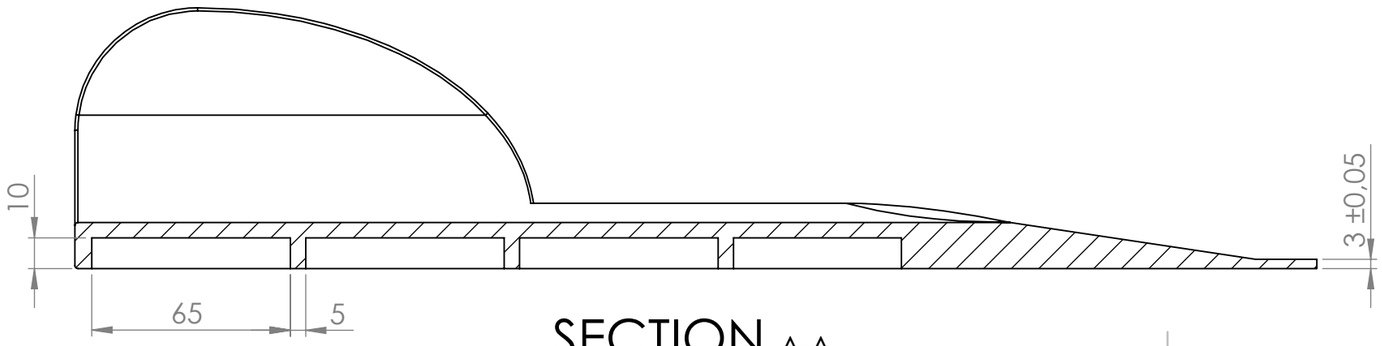
SHEET 6 OF 17

DATE: 28/05-2024









SECTION A-A

SCALE 1 : 2

PRODUCT NAME: Eac	
COMPONENT NAME: Arm Support Part	
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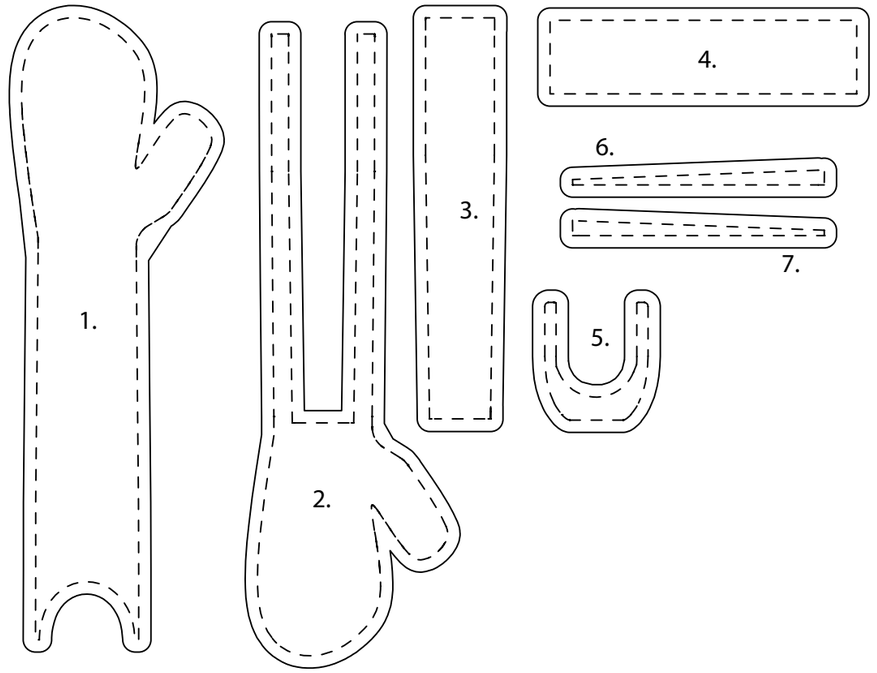
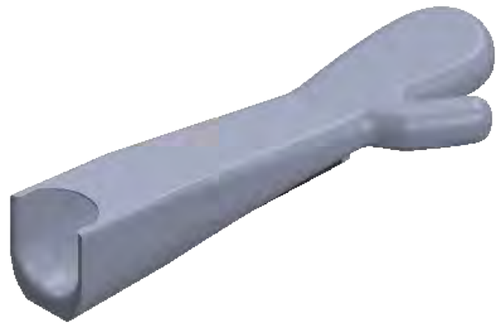
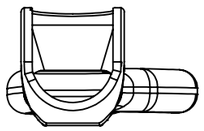
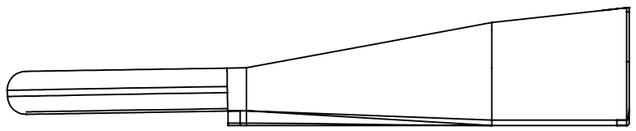
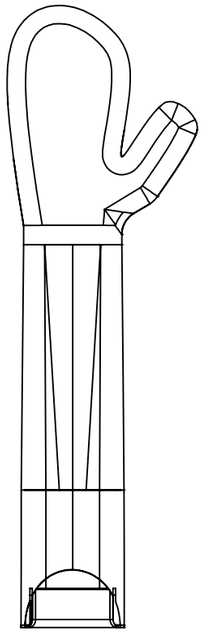
SCALE:1:2	UNIT: mm
SHEET SIZE: A3	SHEET 7 OF 17
	DATE: 28/05-2024











Materials:

Bias bound seam

Silicone

Quilted fabric

1: Top mitt
2: Bottom mitt
3: Silicone piece
4: Inside patch
5: End patch
6: Side piece
7: Side piece

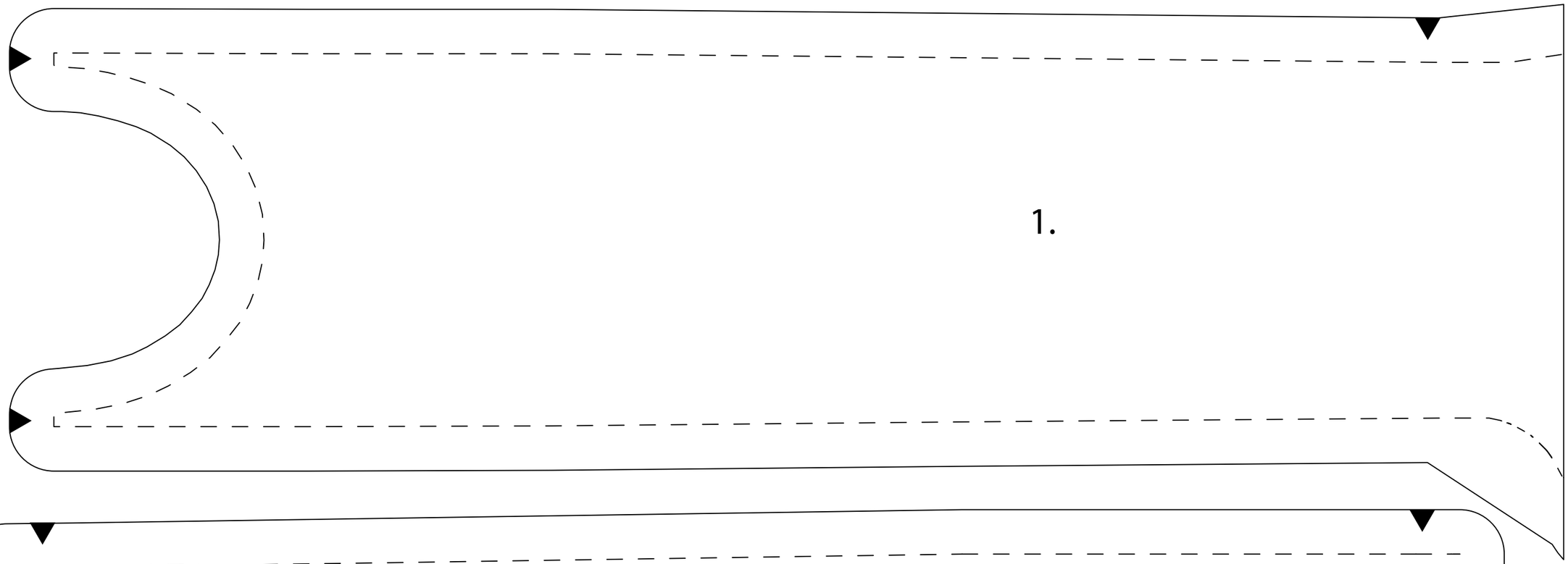
▲ = triangle

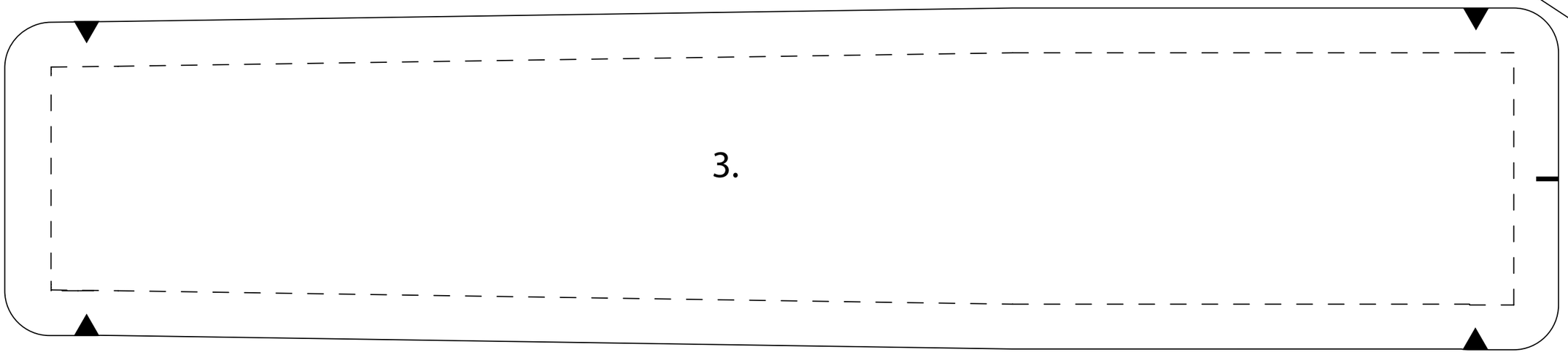
▌ = notch

Sewing Guide

1. Assemble the pattern of top mitt (1) and bottom mitt (2) by attaching the two parts.
2. Cut all pieces.
3. Sew the two side pieces (6+7) to the silicone piece (3), fit triangle over triangle.
4. Sew on bias bound seam on both shortest sides of this piece (3+6+7).
5. Sew this piece (3+6+7) to bottom mitt (2), fit notch over notch
6. Sew inside patch (4) to end patch (5), fit triangle over triangle.
7. Sew piece 4+5 to top mitt (1), fit triangle over triangle.
8. Sew piece 1+4+5 to piece 2+3+6+7, fit triangle over triangle.
9. Turn the mitt inside out.

PRODUCT NAME: Eac	
COMPONENT NAME: Mitt part	
ITEM NO.: 2	CREATOR: MSc04-ID7
SCALE:1:5	UNIT: mm
SHEET SIZE: A3	SHEET 8 OF 17
	DATE: 28/05-2024



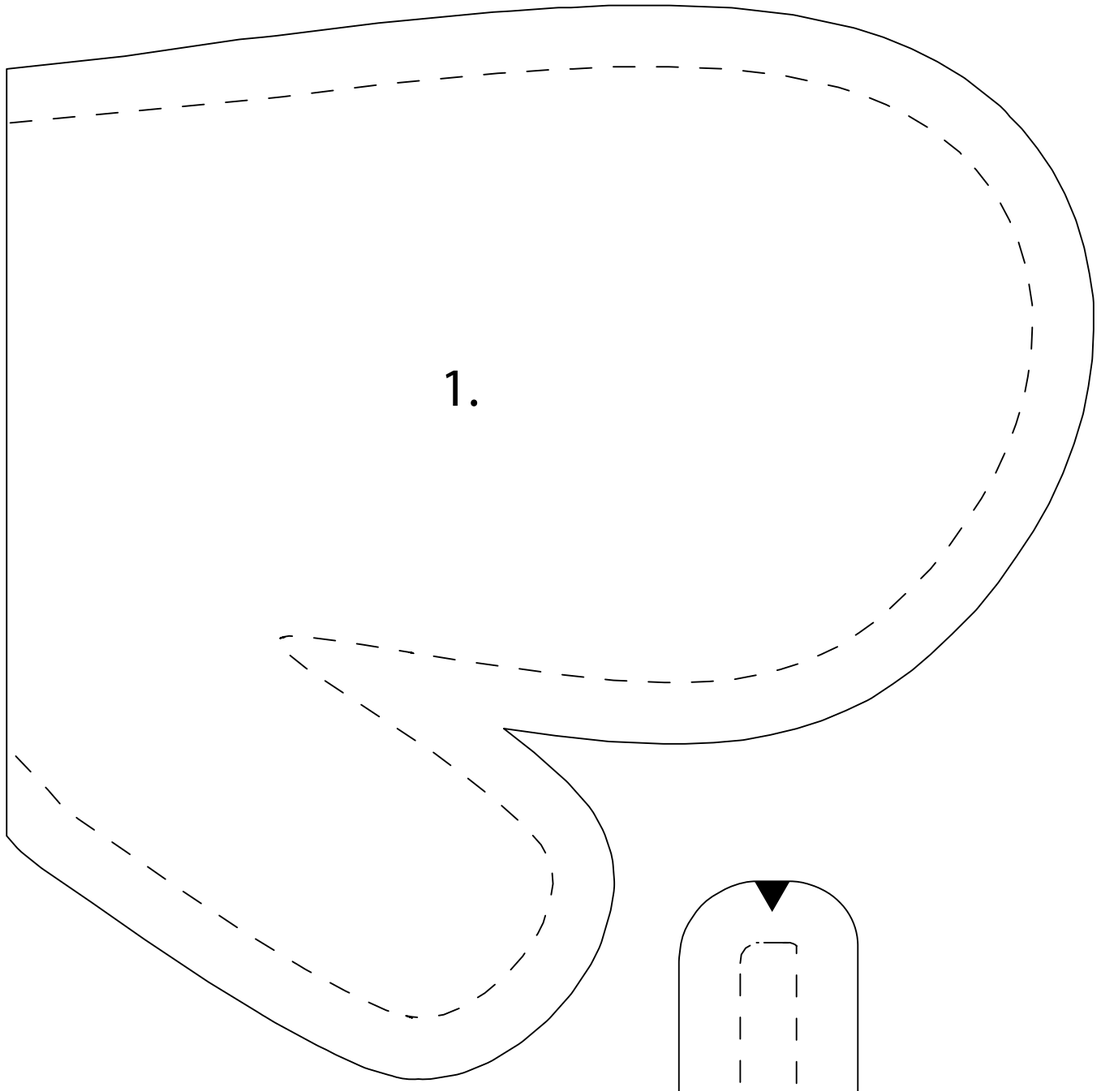


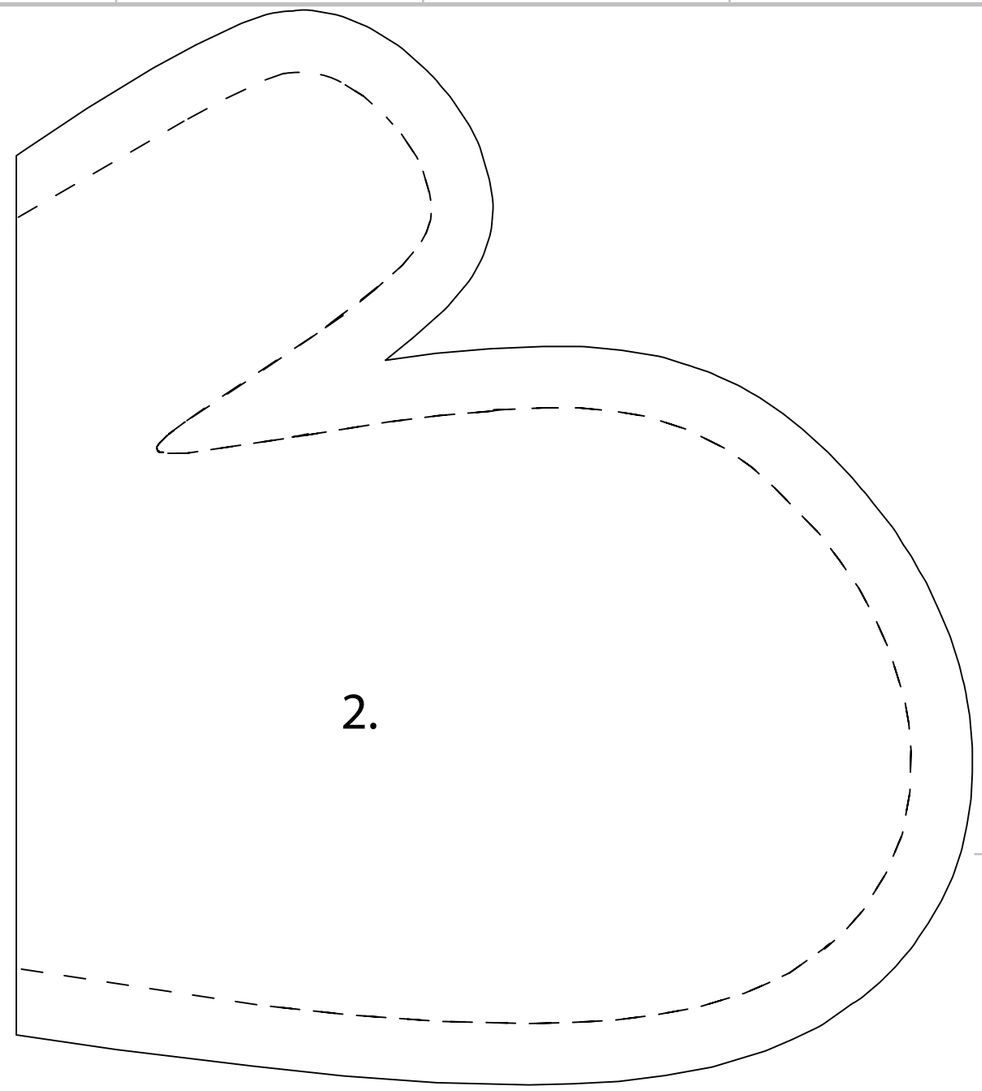
PRODUCT NAME: Eac	
COMPONENT NAME: Mitt part	
ITEM NO.: 2	CREATOR: MSc04-ID7
SCALE:1:1	UNIT: mm
SHEET SIZE: A3	SHEET 9 OF 17
	DATE: 28/05-2024

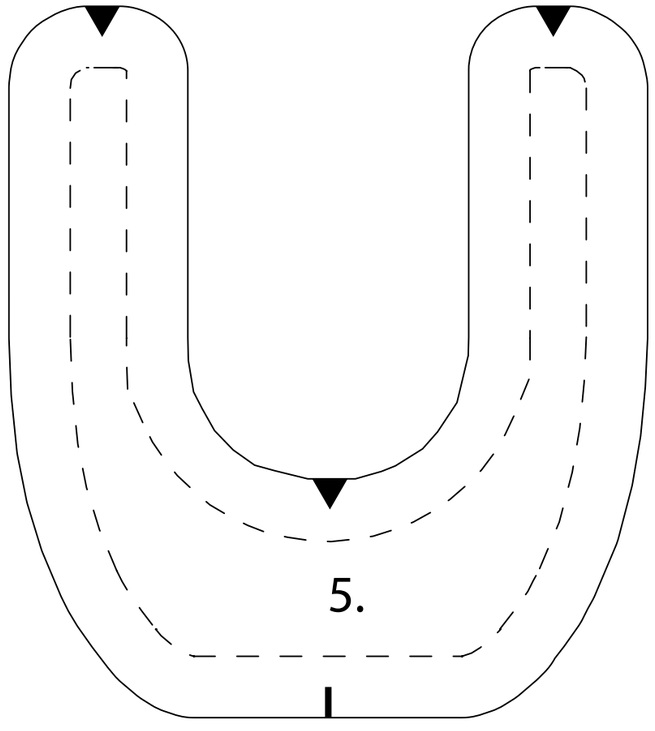
B

A

2 1





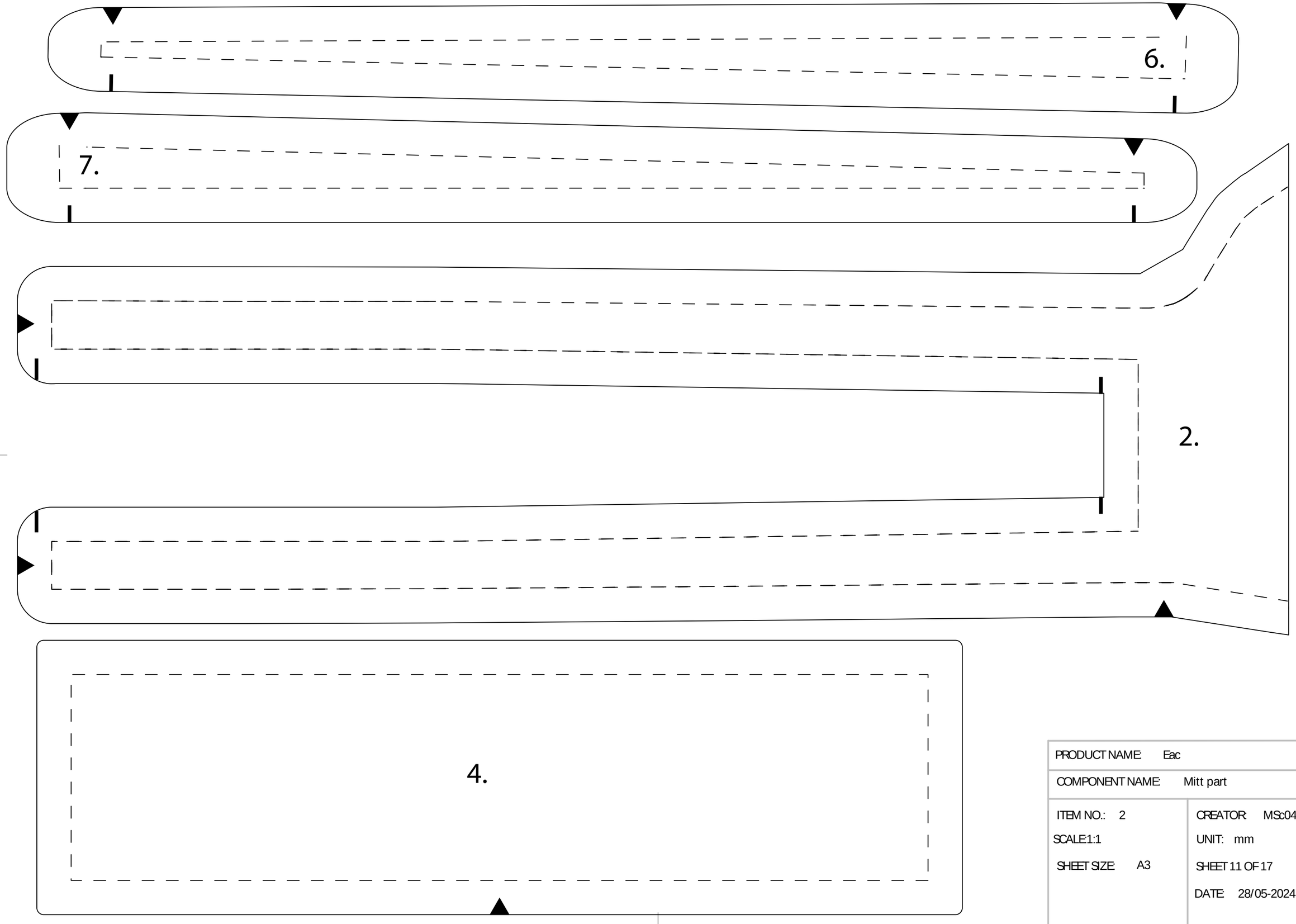


PRODUCT NAME: Eac	
COMPONENT NAME: Mitt part	
ITEM NO.: 2	CREATOR: MSc04-ID7
SCALE:1:1	UNIT: mm
SHEET SIZE: A3	SHEET 10 OF 17
	DATE: 28/05-2024

B

A

2 1

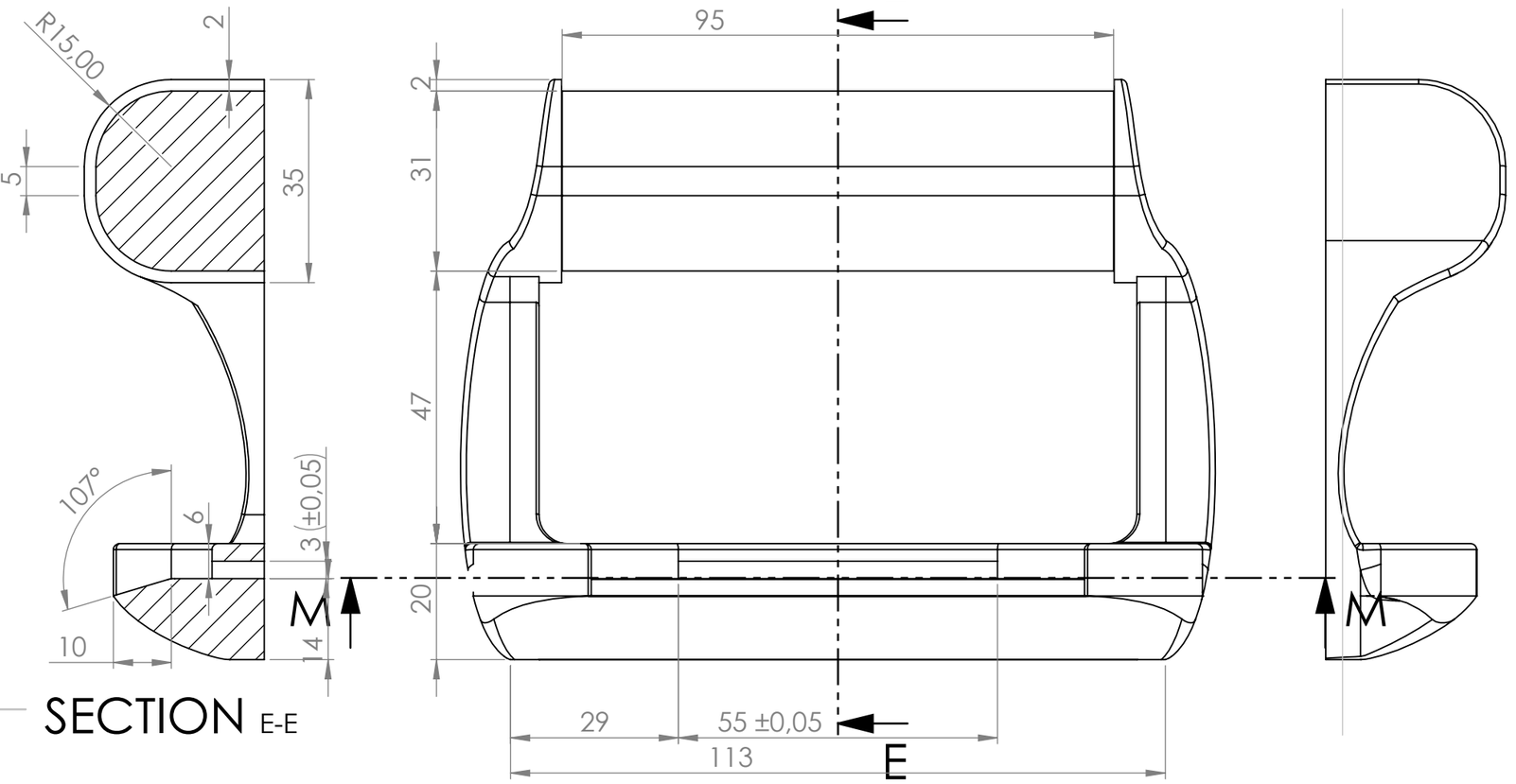


PRODUCT NAME: Eac	
COMPONENT NAME: Mitt part	
ITEM NO.: 2	CREATOR: MSc04-ID7
SCALE:1:1	UNIT: mm
SHEET SIZE: A3	SHEET 11 OF 17
	DATE: 28/05-2024

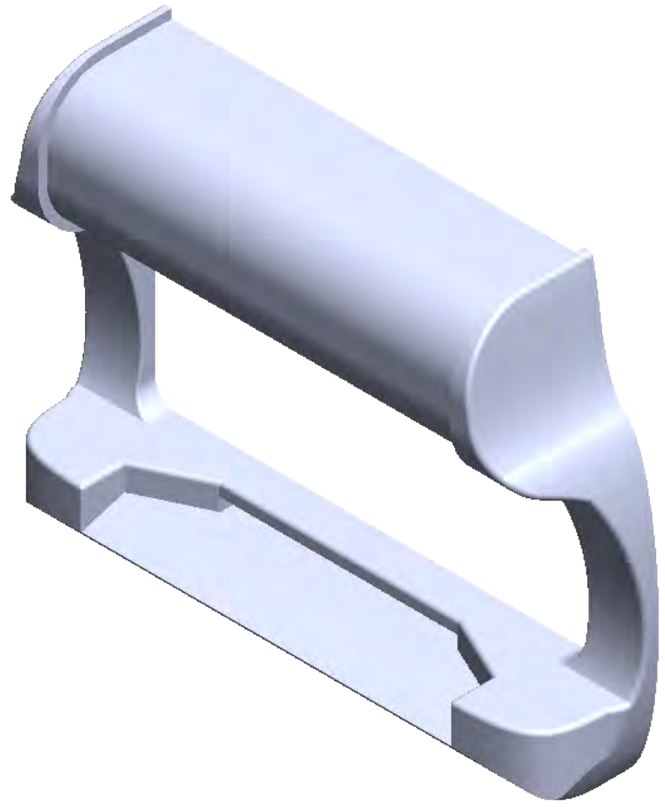
B

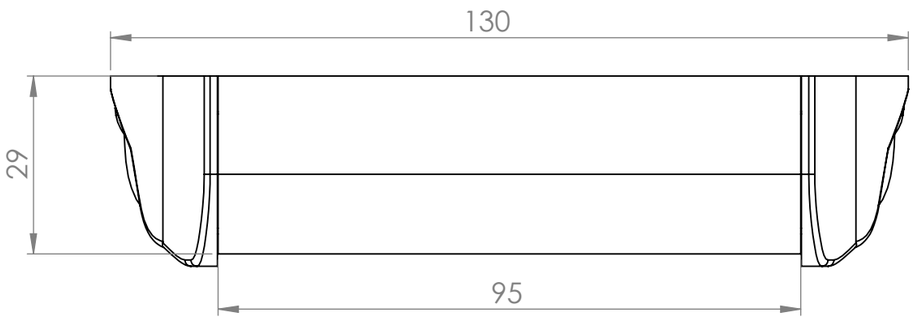
A

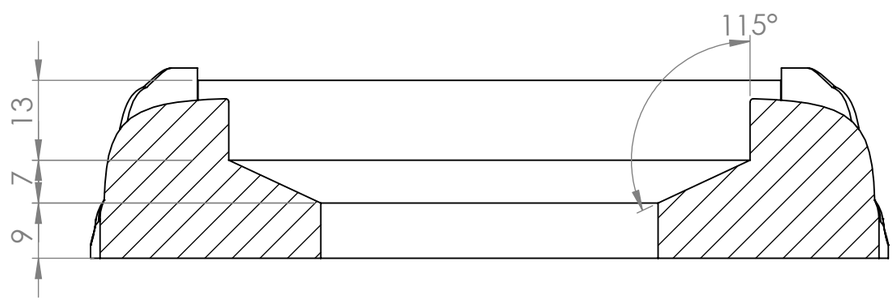
2 1



SECTION E-E

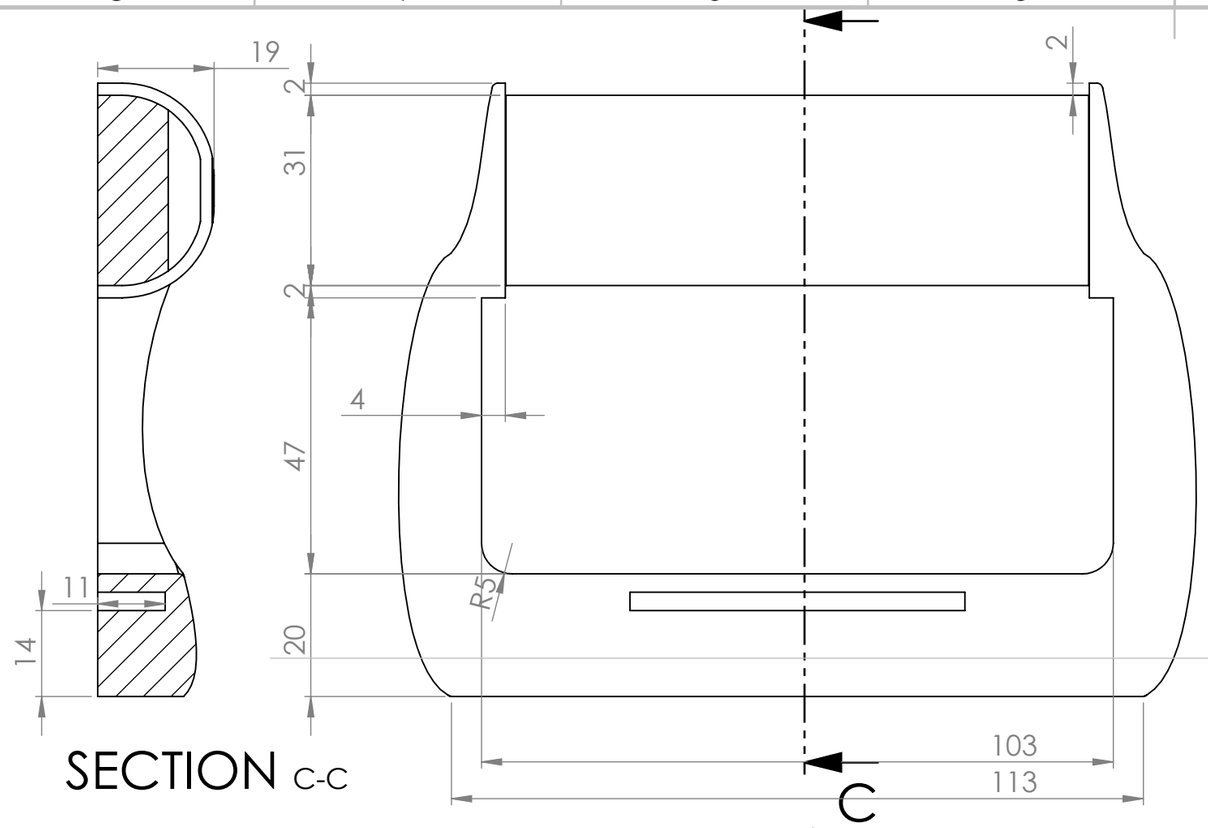




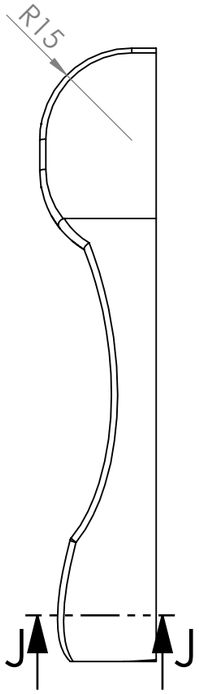


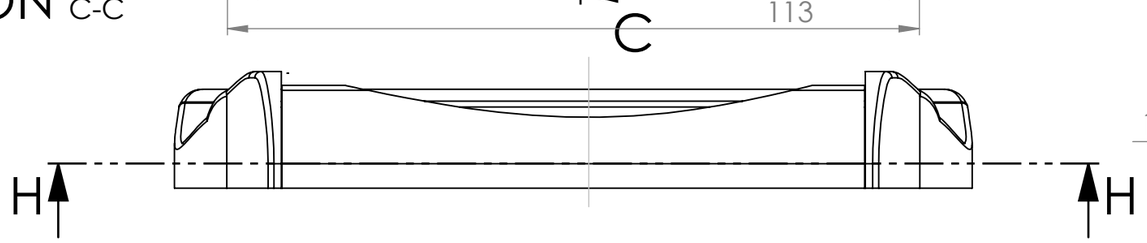
SECTION M-M

PRODUCT NAME: Eac	
COMPONENT NAME: Pot Attachment Top front part	
ITEM NO.: 3	CREATOR: Msc4-ID7
SCALE:1:1	UNIT: mm
SHEET SIZE: A3	SHEET 12 OF 17
NOTE: Wall thickness 4 mm, w. ribs	DATE: 28/05-2024



SECTION C-C





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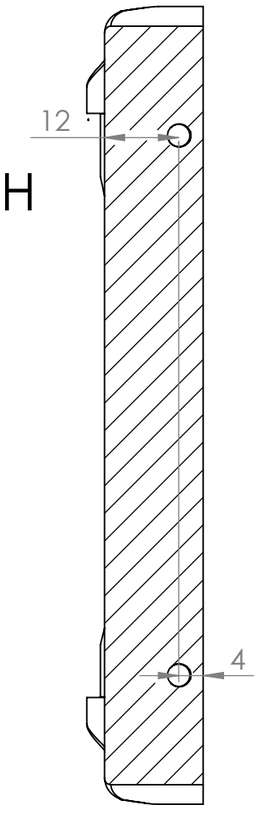
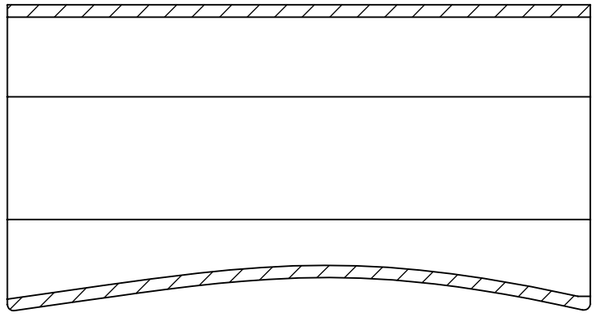
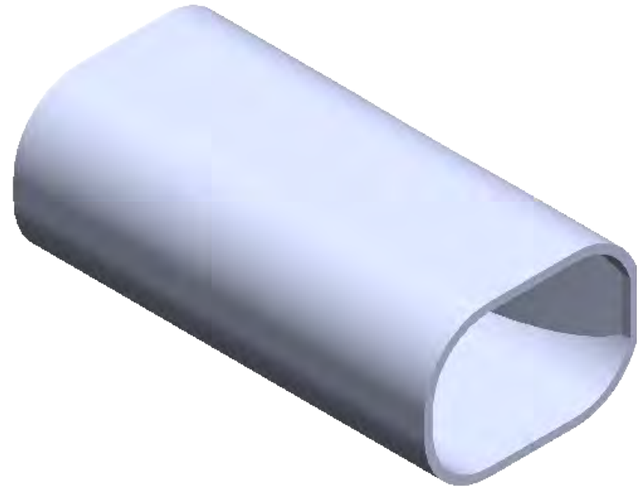


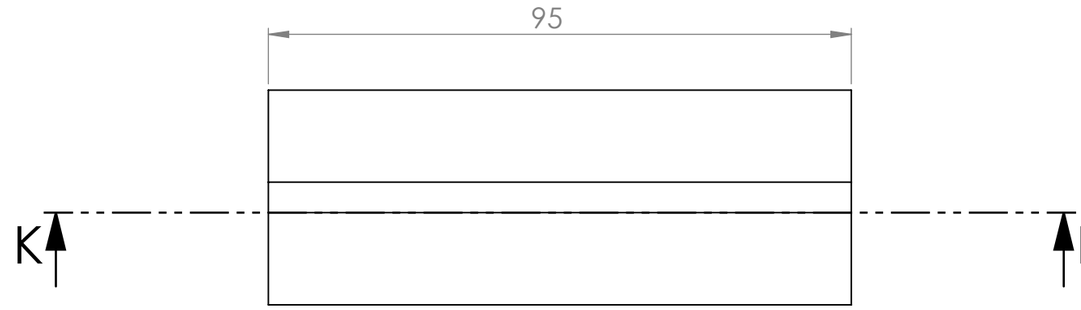
SECTION J-J

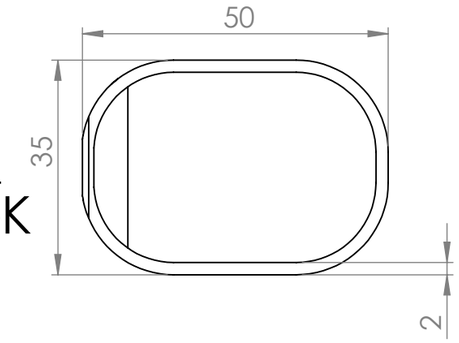
PRODUCT NAME: Eac	
COMPONENT NAME: Pot Attacment Top back part	
ITEM NO.: 4	CREATOR: MSc4-ID7
SCALE:1:1	UNIT: mm
SHEET SIZE: A3	SHEET 13 OF 17
NOTE: Wall thickness 4 mm, w. ribs	DATE: 28/05-2024

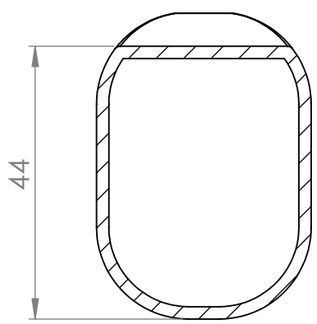


SECTION K-K









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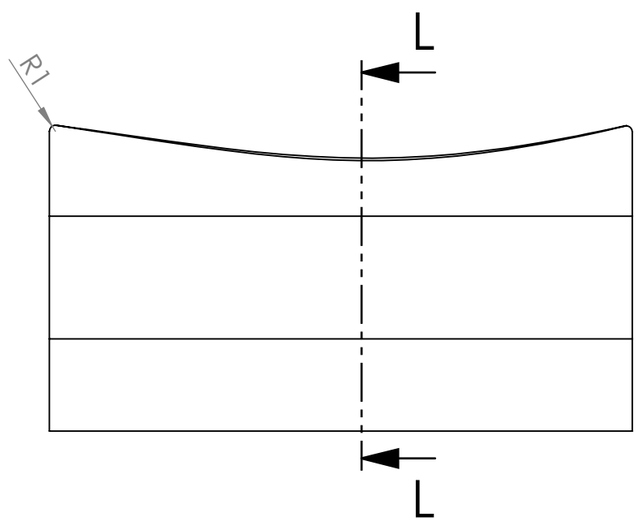
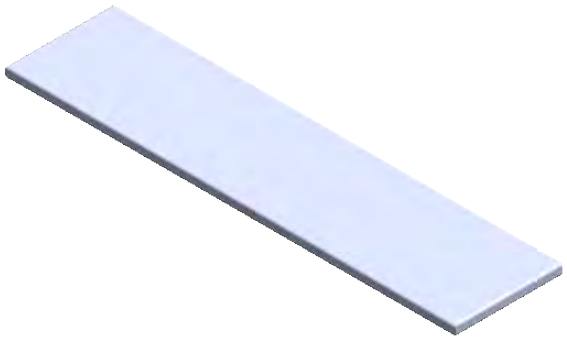
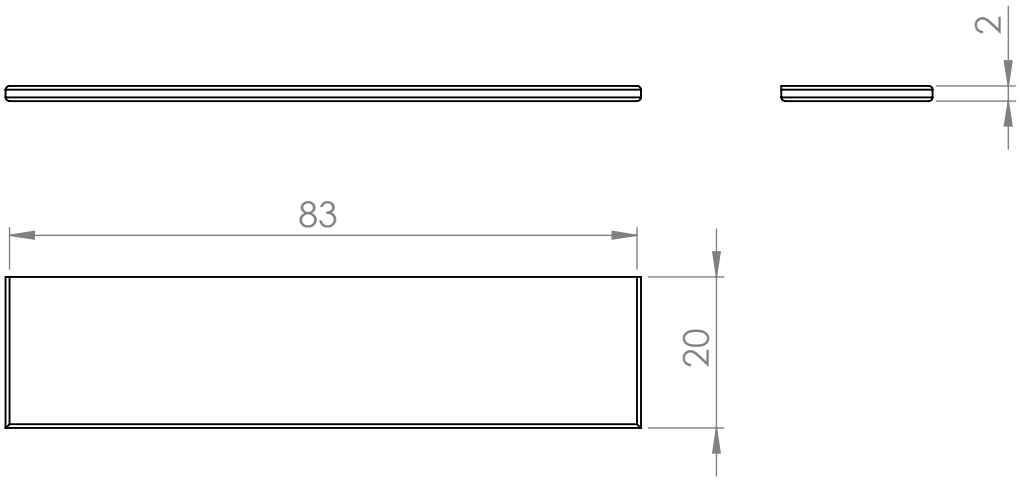
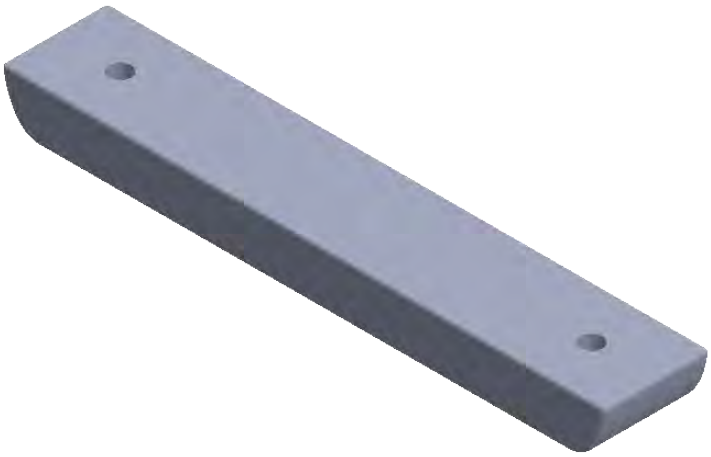


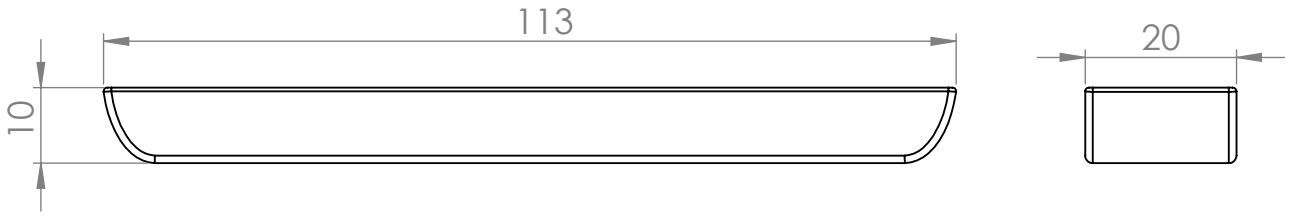
PRODUCT NAME: Eac	
COMPONENT NAME: Pot Attachment Top silicone handle	
ITEM NO.: 5	CREATOR: MSc4-ID7
SCALE:1:1	UNIT: mm
SHEET SIZE: A3	SHEET 14 OF 17
	DATE: 28/05-2024

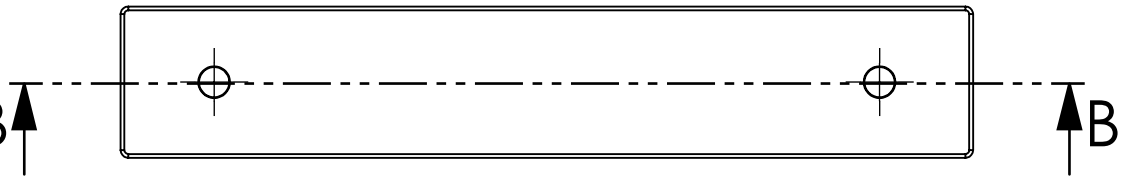


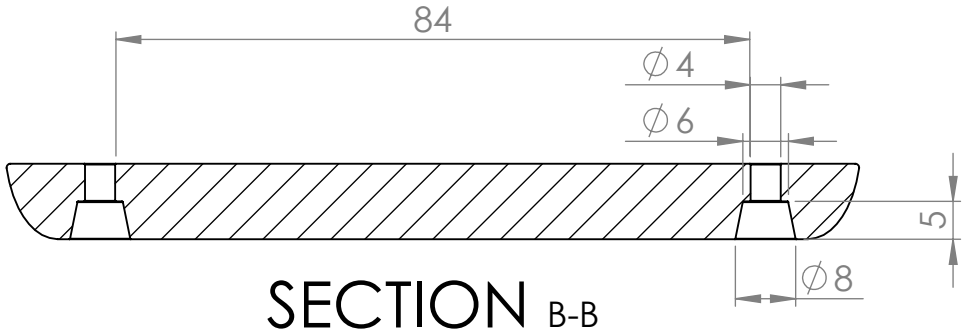


PRODUCT NAME: Eac	
COMPONENT NAME Pot Attachment Top silicone bottom	
ITEM NO.: 6	CREATOR: MSc4-ID7
SCALE:1:1	UNIT: mm
SHEET SIZE: A4	SHEET 15 OF 17
	DATE: 28/05-2024



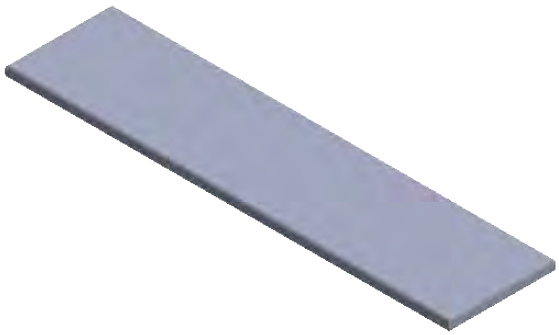


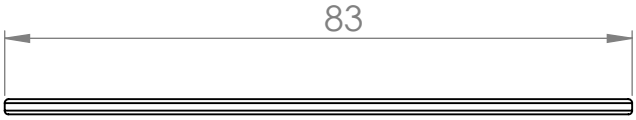


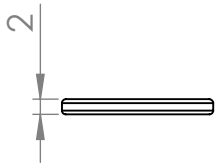


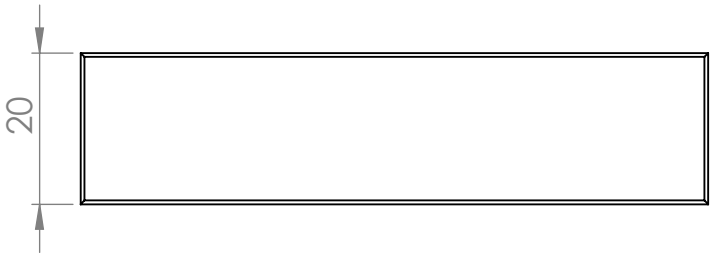
SECTION B-B

PRODUCT NAME: Eac	
COMPONENT NAME:Pot Attachment bottom part	
ITEM NO.: 8	CREATOR: MSc4-ID7
SCALE:1:1	UNIT: mm
SHEET SIZE: A4	SHEET 16 OF 17
	DATE: 28/05-2024









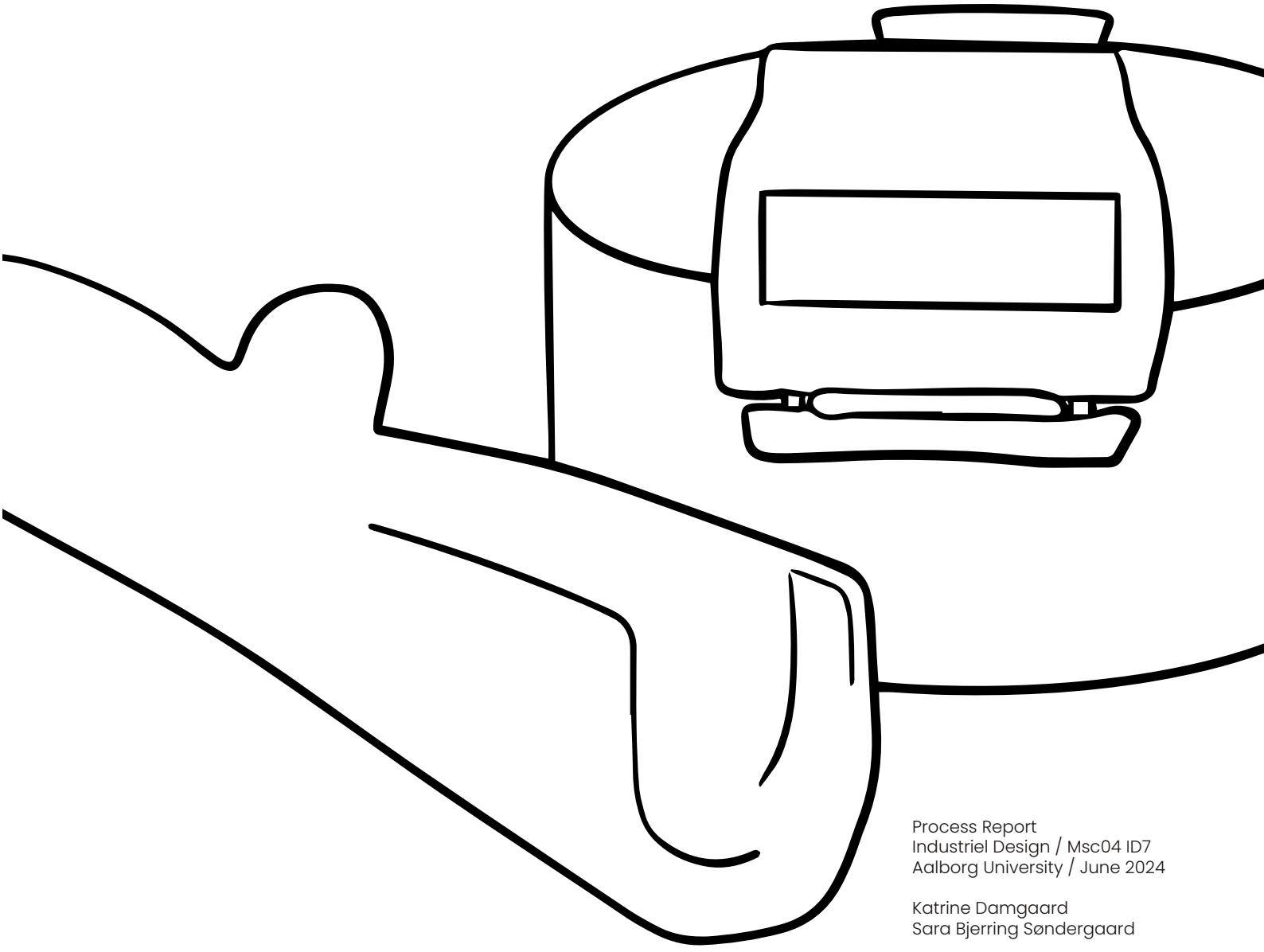
PRODUCT NAME: Eac	
COMPONENT NAME: Pot Attachment bottom silicone top	
ITEM NO.: 9	CREATOR: MSc4-ID7
SCALE:1:1	UNIT: mm
SHEET SIZE: A4	SHEET 17 OF 17
	DATE: 28/05-2024

Eac

enable arm care

Process Report

Eac



Process Report
Industriel Design / Msc04 ID7
Aalborg University / June 2024

Katrine Damgaard
Sara Bjerring Søndergaard

Title Page

Project title:	Eac
Report type:	Process report
Project group:	MSc4-ID7
University:	Aalborg University
Main supervisor:	Linda Nhu Laursen
Technical supervisor:	Matin Afshar
Project period:	01/02/2024 - 30/05/2024
Total pages:	93

Abstract

This master's thesis will outline the design process of two Industrial Design engineering students from Aalborg University, Denmark, as the product proposal Eac is developed. The project aims to create an assistive device for arm amputees that will enable them to use a pot while cooking without needing help from others, making them feel more independent in the kitchen. Despite the availability of prosthetics, many arm amputees choose not to use them due to their impracticality when used in daily tasks.

The design of Eac emerged from a collaborative process involving end-users and specialists. Interview, shadowing, and product testing were some of the methods incorporated to ensure a user-centered approach. Further insight into manufacturing was obtained through consultation with a company specializing in injection molding.

Eac distinguishes itself by addressing arm amputees' functional challenges while simultaneously appealing to aesthetic sensibilities, thereby reducing the stigma associated with assistive devices. It features a pot attachment with a handle for a secure grip and an arm attachment for additional support, improving the user's ability to cook independently.

This innovative design represents a significant step toward restoring their independence pre-amputation, demonstrating the potential of thoughtful design to make a meaningful difference in the lives of those it serves.

Acknowledgement

We would like to express our gratitude to our main supervisor, Linda Nhu Laursen, for her guidance, support, and encouragement throughout the process. We would also like to thank our technical supervisor, Matin Afshar, for his knowledge and guidance.

This project has involved collaboration with arm amputees, an occupational therapist, a physiotherapist, a municipality case manager, and the production company PARTDESIGN. We thank everyone who contributed valuable insights and expertise to our process.

Katrine Damgaard

Sara Bjerring Søndergaard

Reading Guide

The thesis includes a product report, a process report, an appendix, and technical drawings. It is recommended to start by reading the product report to understand the product proposal before moving on to the process report, which details the process behind the product proposal. The appendix and technical drawings can be used as reference material while reading. The appendix will be referenced as (app. XX) when relevant raw data is mentioned.

Source references are made using the Harvard method and can be found in a reference list at the end of the process report. Following the reference list, there will be a list of illustrations referred to throughout the report as (ill. XX).

Requirements and needs throughout the report are marked with the following icon:

Requirement:

New requirement

Need:

New need

In the design brief a revised requirement or need will be marked as such:

~~Old requirement/need.~~ ▶ Revised requirement/need.

A new requirement or need found throughout the phase will be marked with a star:

★ New requirement/need.

Word Explanation

The following will be a word description of the meaning behind the words throughout the report:

Kitchen equipment: a wide array of tools and appliances used for cooking, baking, and food preparation such as a spatula, kitchen knives, wooden spoons, etc.

Bilateral leg amputee: a person with both legs amputated.

Healthy arm: the arm of the amputee that has not undergone an amputation.

Tilting: When pouring water out of a pot, the person tilts the pot towards the sink.

Shopping basket: a basket is a container that a person brings to a shop, and it can also refer to the baskets placed at the shop for borrowing while shopping.

Upper limp: an arm amputee.

Introduction

Amputation is a permanent, life-changing condition in which the individual is missing a body part. It can occur for various reasons, such as congenital factors, accidents, or illnesses (Lauritzen & Schlichting, 2024). A researcher noted a lack of research in Denmark on the number of amputations and their causes. The latest available data shows that in 2022, 1028 people over the age of 50 underwent significant amputations (rkkp, 2023).

The initial idea of this thesis was to understand the core problems amputees face in their daily lives. Undergoing an amputation is challenging, both mentally and physically. It can take time for individuals to mentally prepare for physical rehabilitation, often involving the use of a prosthetic. However, when talking to arm amputees, it became clear that many of them dream of having a prosthetic that can replace the missing limb, creating high expectations that may not be fulfilled, leading to the underutilization of the prosthetic.
This project focuses on arm amputees' need for independence, particularly in cooking, and the workarounds they use to achieve this. Through an iterative process, a product proposal addressing these issues was developed.

Initial Research

Right from the beginning, there was a strong interest in creating assistive devices specifically designed for a particular group of users. Based on previous projects and gained experience, designing something the team could test themselves in the early stages before the user tests it was desirable.

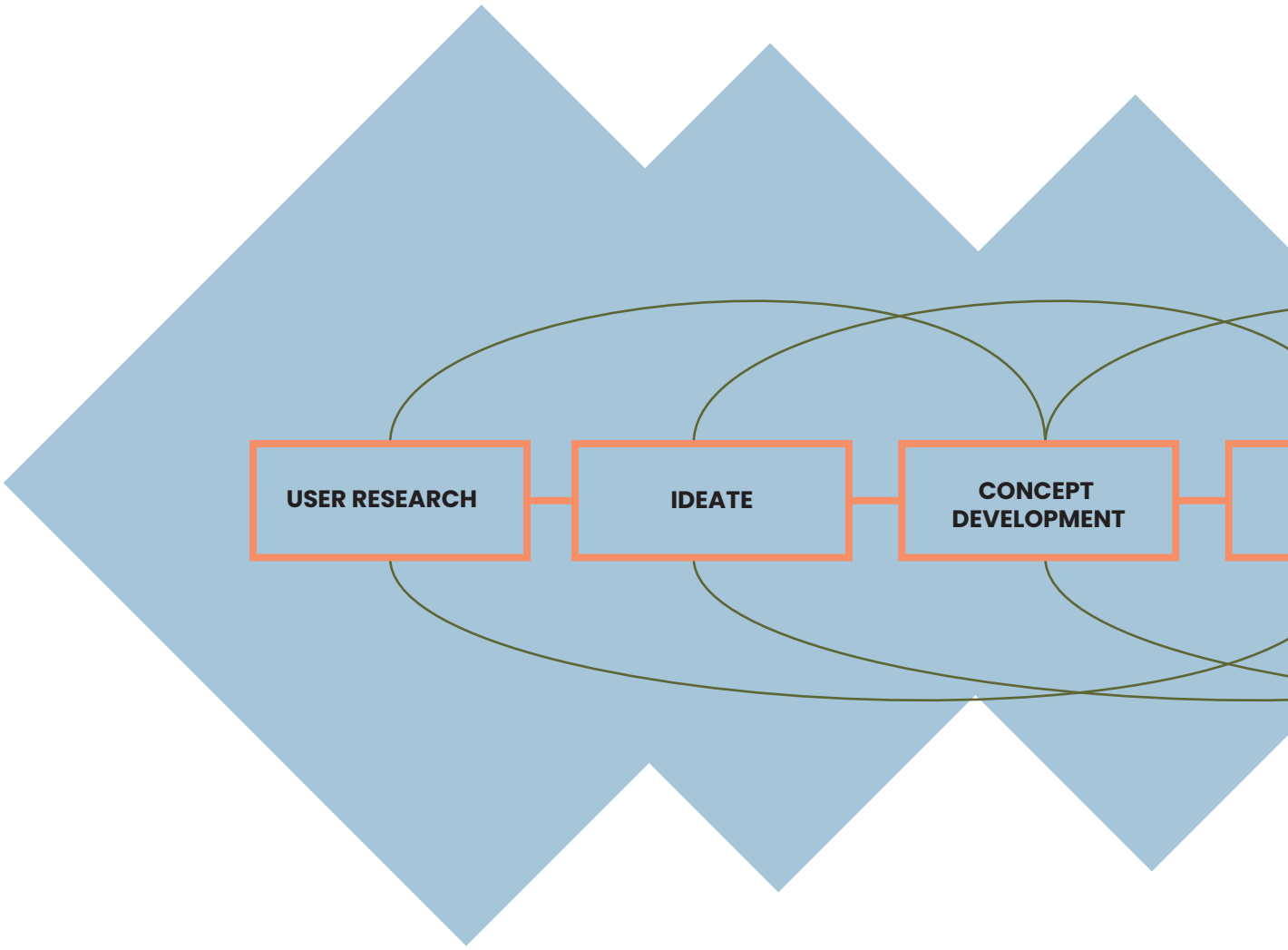
The amputee user group appeared attractive as it seemed possible to test prototypes ourselves to some extent, minimizing user inconvenience. The response received was heartfelt when reaching out to the amputee association in Denmark. The users expressed that they don't feel heard.

Initial questionnaires suggested that leg and arm amputees face significant difficulties and limitations in their daily lives, leading to a reduced quality of life. They deserve to have the same quality of life as they had before the amputation. The initial goal, therefore, is to design assistive devices that aim to restore their pre-amputation quality of life. (app. 1)

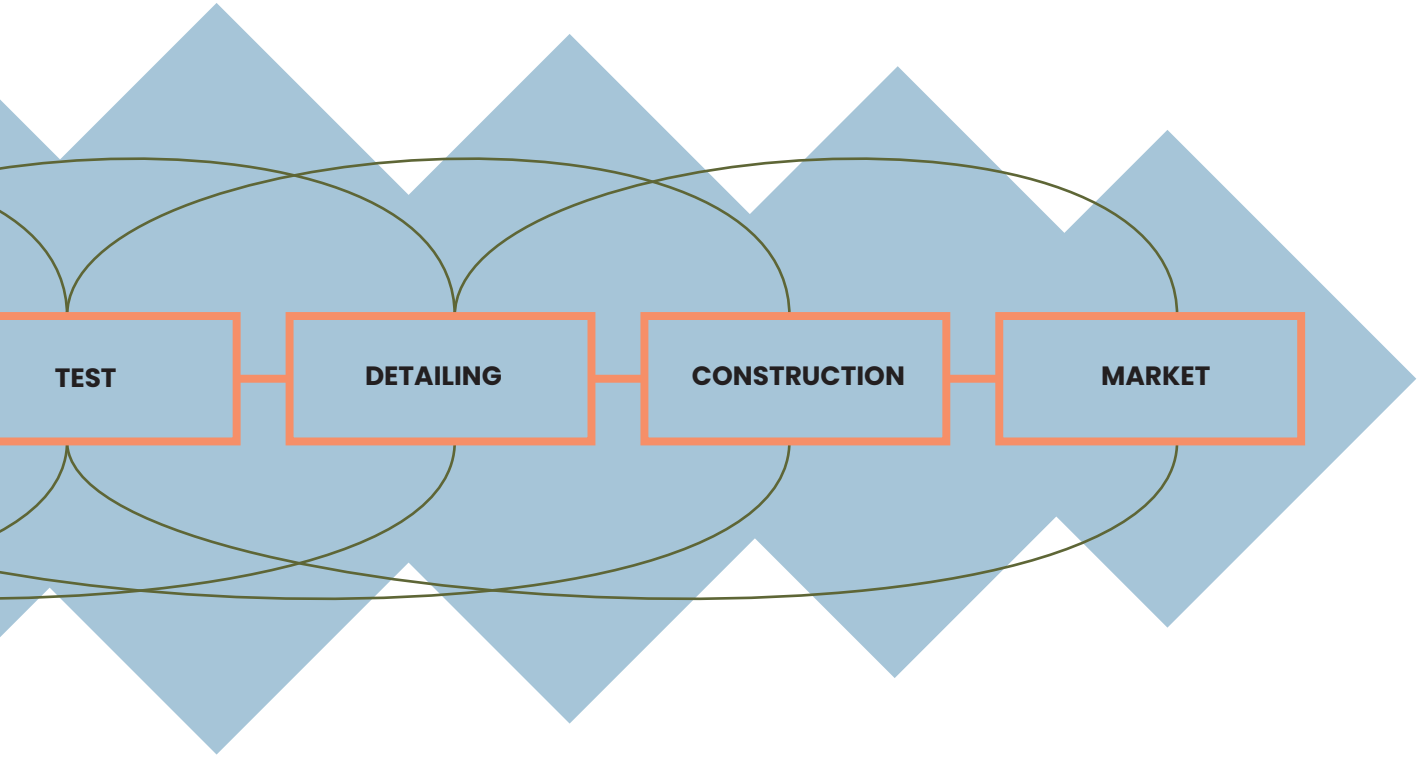
Table of Contents

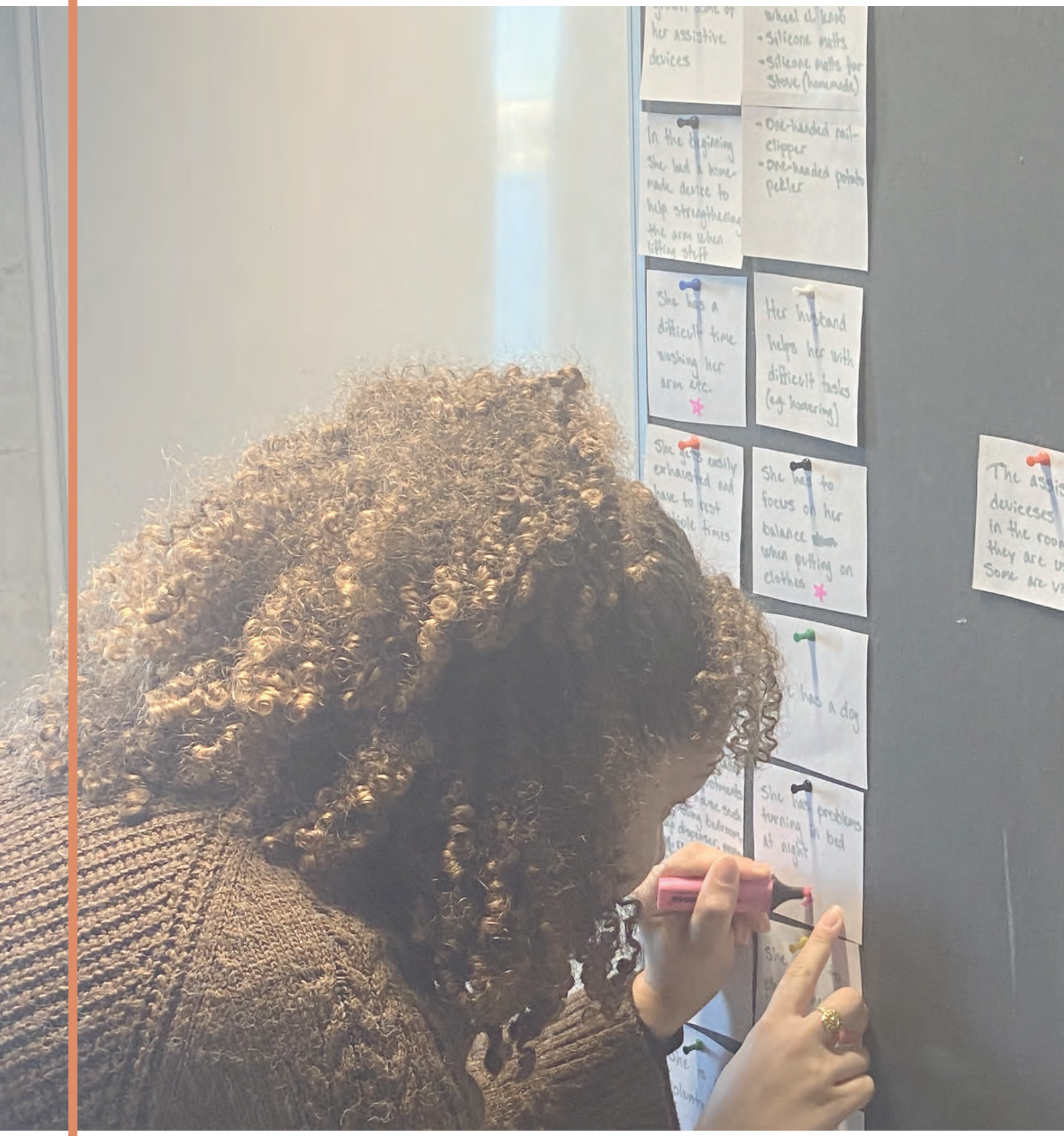
Process Timeline

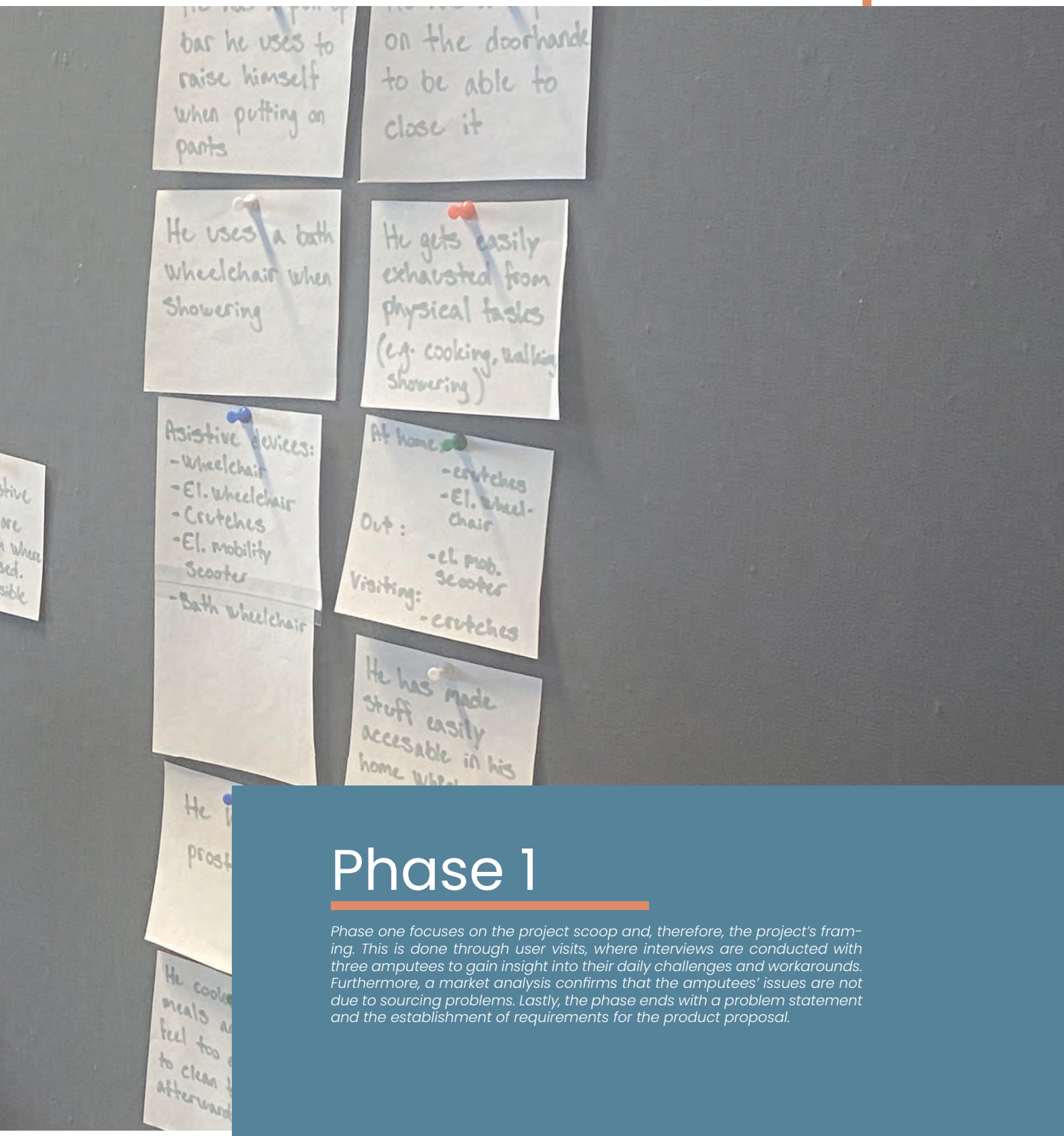
The process combines the double diamond (Dubberly, 2004) and design thinking (The Interaction Design Foundation, 2021) methodologies. Double diamonds involve a linear overall structure with phases of divergence and convergence to advance the process, while design thinking emphasizes an iterative approach. The product proposal has been thoroughly developed through these methods with the user as the focal point. The product proposal addresses a wicked problem (Churchman, 1967) identified at the outset and co-evolved (Crilly, N., 2021) through the process. In the process, there was initial divergence followed by convergence in every phase. Whenever divergence and convergence occurred, we got closer to the product proposal. (ill. 1)



Ill. 1 Process timeline.


TEST
DETAILING
CONSTRUCTION
MARKET


her assistive devices
-Silicone mitts
-Silicone cuffs for Stove (homemade)
-One-handed nail-clipper
-One-handed potato peeler
She has a difficult time washing her arm etc.
Her husband helps her with difficult tasks (eg. hoovering)
She has to focus on her balance when putting on clothes



Phase 1

Phase one focuses on the project scoop and, therefore, the project's framing. This is done through user visits, where interviews are conducted with three amputees to gain insight into their daily challenges and workarounds. Furthermore, a market analysis confirms that the amputees' issues are not due to sourcing problems. Lastly, the phase ends with a problem statement and the establishment of requirements for the product proposal.

User Visits

Three amputees with three different cases of amputation were visited to gain insight into their lives and the struggles they face every day, together with discovering if there are some similarities (ill. 2-4). The three users were interviewed in their homes through a Situated Interview (Bagger & Sperschneider, 2003).
Besides the Situated Interview, a timeline of their day was made as a tool to locate time-consuming daily activities and compare them to the time frame before the amputation. A mapping of the users' existing helping devices was made as well. This included demonstrating how the devices work and where they are placed in the home. (app. 2)

Ill. 2 Olai.

Olai

50 years old.

Leg amputee since 2022.

Works full-time as an operations manager at a water and heat supply.

He has a prosthetic but wishes for a better one, which he still argues with the municipality about.

He wishes to be able to walk further than he is today and be able to bike again.

He has pretty much given up cooking even though he is a trained chef.

His wife has taken over some of the daily chores.

He does not see a physiotherapist but visits the gym twice a week.

Assistive devices used today: crutches, a bath chair, a dressing chair (homemade), an electric scooter, a cooking chair (homemade), and rubber ramps.

Assistive devices used in the past: a wheelchair and a walking frame.

Ill. 3 Anette.

Anette

54 years old.

Arm amputee since 2014.

Early retirement pensioner (because of illness) but works as a volunteer at a sports club.

She does not have a prosthetic.

She struggles to wash and dry her arm and back when showering.

Initially, she struggled to cook, as lifting and carrying a baking tray and a pot filled with water is heavy when she can only use one arm, and it still takes a lot of effort today.

Her husband has taken over some of the daily chores.

She sees a physiotherapist twice a week.

Assistive devices used today: an electric steering wheel knob, silicone mats, silicone mats for stove (homemade), a one-handed nail clipper, a one-handed potato peeler, and a gripping device (homemade).

Assistive devices used in the past: a one-handed chopping board, a rolling table, and a sieve for potatoes.

Ill. 4 Peter.

Peter

75 years old.

Bilateral leg amputee since 2017.

Early retirement pensioner (because of illness not related to the amputation).

He has a prosthetic on each leg but uses a wheelchair and crutches as he is only able to walk 130 meters.

A home carer visits every other week and cleans the apartment.

He has all his things easily accessible on the tables around the home.

He struggles to get dressed as he finds it hard to lift himself from the wheelchair.

He sees a physiotherapist once a week.

Assistive devices used today: an electric scooter, an electric wheelchair, a bath wheelchair, crutches, a pull-up bar, a rope on the door to close it (homemade), a wheelchair-accessible minibus, and a wheelchair ramp.

What all three had in common was:

- They enjoy getting out of the house and doing activities.
- They want to feel more **independent**.
- They keep their assistive devices in the rooms where they are needed.
- They become **physically exhausted** easily and must rest throughout the day.
- They have **homemade assistive devices**.

Healthy with a Handicap

Though amputees experience limitations in their everyday lives, they do not want to be placed as ill people as they are not ill. Amputees can experience phantom pains from time to time, but besides the phantom pains, they see themselves as healthy people who have a disability.

"I don't use my wheelchair anymore. I feel ill when I use it."

- Olai

They still try to live the same life that they had before the amputation as much as possible. Having said that, they all struggled in the beginning after the amputation as a new daily life had to be shaped, but with time, they have learned to live with their amputation.

"And I also think that's why, for example, I've chosen to say no to a lot. It's because I don't think it's nice to have them displayed. Because when you come with those clumsy and colorful things, it just catches people's eyes, making you look more disabled than you are. Because now you come with a monster from another world or a color where people just think, wow, she's really going for it."

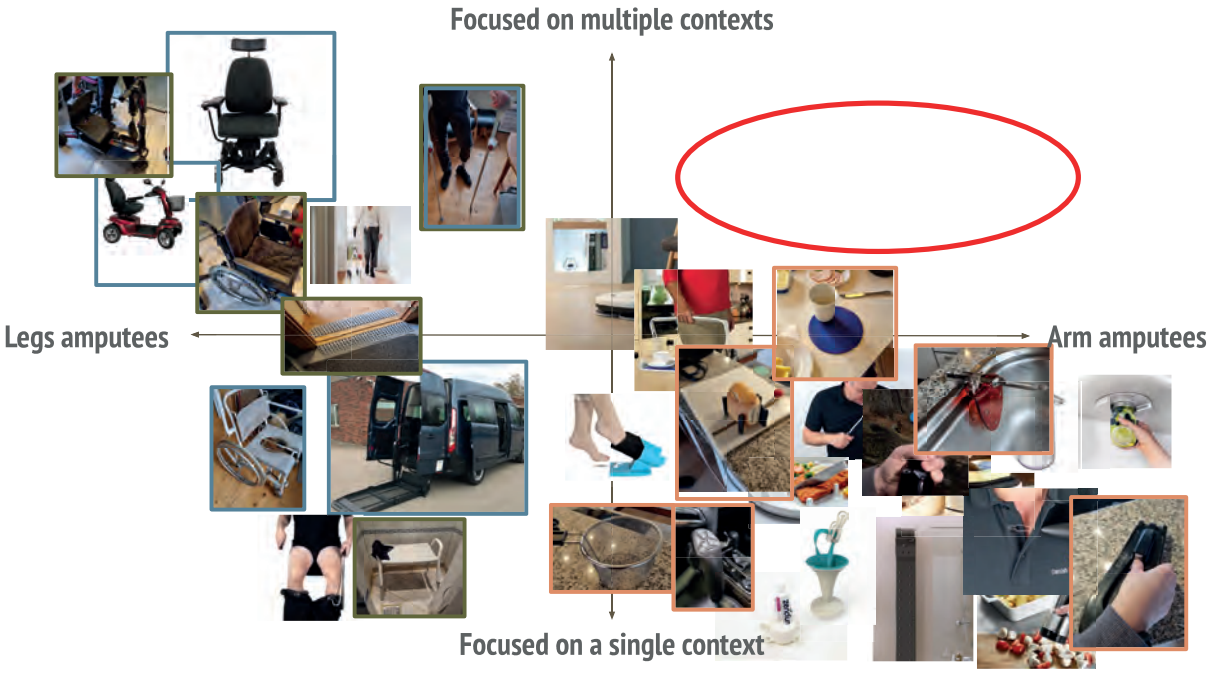
- Anette

Amputees do not see themselves as ill people. Therefore, they do not want many different devices, as they make them feel ill when using them. The users express a need for more discrete products with neutral colors.
The paradox of this project is to design an assistive device for amputees that does not make them feel or look ill while they use it.

Market Analysis

Knowing the assistive devices and the problems the amputees have, a market analysis was made through desktop research to get an overview of the existing assistive devices for arm and leg amputees.
The Danish market was first searched, and pictures, prices, links, and product names were recorded. Secondly, the international market was searched to ensure that choosing a problem direction wasn't just a sourcing problem (app. 3).

The products from the market analysis were divided into whether they were for arm or leg amputees and whether the devices were for one or multiple contexts. Doing so shows there are missing assistive devices for arm amputees that they can use for various contexts (see red ring at ill. 5). Furthermore, in illustration 5, the assistive devices from the three amputees (app. 2) are shown in the pictures with frames (orange: Anette, Blue: Peter, Green: Olai).



Ill. 5 Market analysis.

What is the Arm Amputee's Wheelchair?

A wheelchair enables a leg amputee to move around just as they would with their legs, eliminating the need for a prosthetic. However, an arm amputee faces challenges in situations that require the use of two hands. Unlike leg amputees who have wheelchairs, there is currently no similar device available for arm amputees.

There is a market gap for a "wheelchair" equivalent for arm amputees - an assistive device that can be used in various contexts. It would be beneficial to explore a product solution to address this need. While devices for leg amputees compensate for their inability to walk in different situations, those made for arm amputees mainly involve add-ons or replacements for existing tools. Market analysis and user feedback have revealed a gap in products designed for arm amputees that can be used in diverse contexts.

As a result, the decision was made to focus on this user group, as the issues faced by leg amputees primarily revolve around the need for improved prosthetics, which already exist, making it a sourcing problem.

Project Direction

After having chosen arm amputees as the user, the insights from the user visit were analyzed again, and two problems were selected for solution ideation: her not being able to wash her arm and dry herself afterward and her struggling to lift and carry objects after the amputation. Based on interest and the complexity of the problem, it was decided to work further on the issue surrounding lifting and carrying. (app. 2 & 4)

After the amputation, the user struggled with lifting and carrying heavier objects as she did not know and did not trust her strength.

Therefore, she relied on her husband to help her because there was no assistive device for this problem. This made her feel like she had lost some of her independence, making her feel a lower quality of life. The user would have needed the municipality's help or opt-out cooking if she did not have her husband.
Eventually, she got a homemade device to assist her when lifting things around the kitchen, giving her some of her independence back. She mainly used it until her strength increased and she trusted herself, but she sometimes still uses it when making heavy dishes in the oven.

"I could not lift a pot."

- Anette

The device consists of the top part of a crutch supporting the arm, while a water pump plier has been added as a grabbing mechanism. The mechanism is opened and closed by moving the handle back and forth. The user grabs the device around the handle of the crutch, leaving the hand in a vertical position (ill. 6).

Ill. 6 Crutch solution.

This workaround proves that there is a need for such a device.
This device will be called the "*crutch solution*" throughout the report.

Another place where strength is limiting her is when she is grocery shopping. Here, the user brings her basket and only puts in what she can carry. A possible product proposal could also function in this context.

"When I am grocery shopping, I have a basket, and when I feel like I can't lift anymore, I am done shopping."

- Anette

The following requirements and needs for the product proposal have been developed after choosing arm amputees as the user group and are based on the project direction:

Requirements:

- The user must be able to use the proposal with one hand.
- Using the proposal, the user must be able to lift and carry the cookware and baking dishes during cooking as they did pre-amputation.
- The proposal must be made of dishwasherproof materials.
- The user must be able to use the proposal with their existing cookware, baking dishes, and shopping basket.
- The proposal must be made of food-safe materials.
- The proposal must ease the load of a shopping basket while lifted and carried.
- The proposal must help the user maintain their strength.

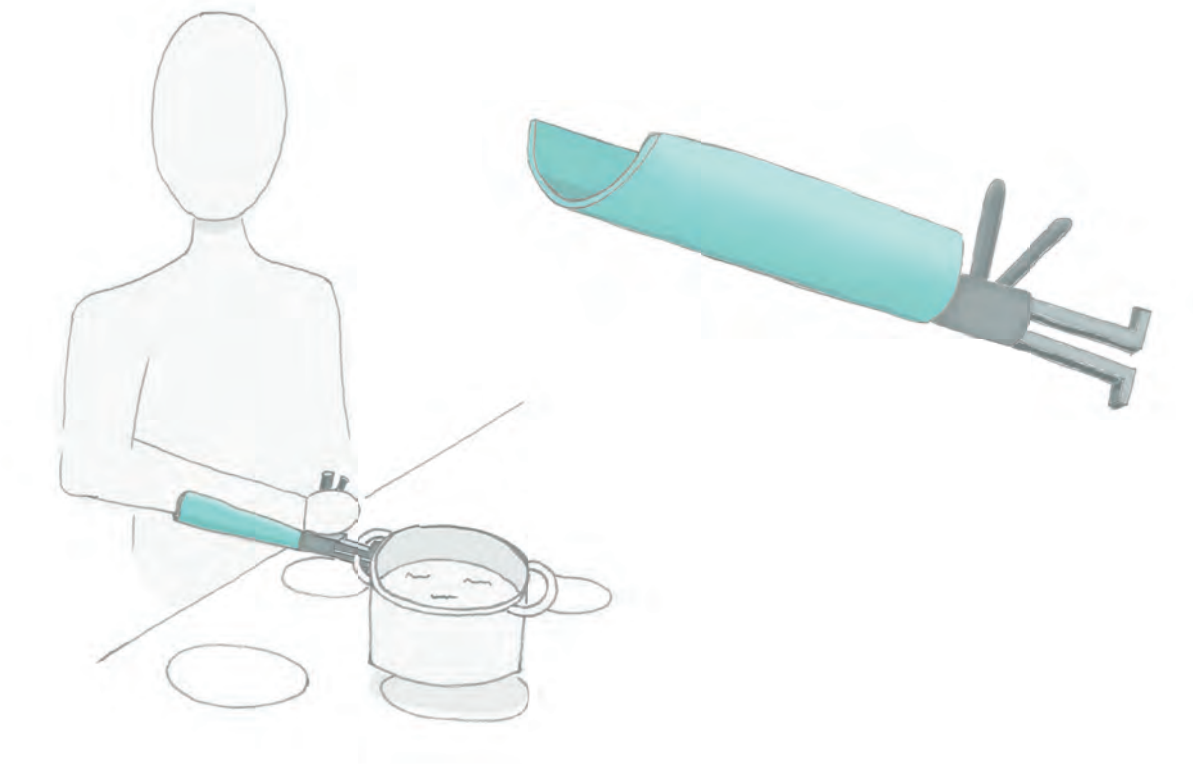
Needs:

- The proposal should make the user comfortable wearing it outside the home.
- The proposal should fit the same design language as kitchen equipment.
- The proposal should make the user comfortable wearing it outside the home.

Solution Direction

Based on the gathered information about the user and the chosen project direction, the solution space was opened through Brain Pool Writing (Tollestrup, 2004). This was done to generate as many ideas as possible that could then be clustered (Osborn, 1953) into five different directions that could subsequently be discussed and help set the framework for the project. (app. 5)

With the requirements in mind, a product proposal was chosen. The product proposal must be mounted onto the arm or body as it seems to be a more plausible solution in comparison to something built into the home. The proposal should allow the user to move freely as well as allow them to bring the product proposal with them outside of the house (ill. 7).



Ill. 7 Solution direction.

Requirements:

~~The user must be able to use the proposal with one hand.~~ ▶The proposal must facilitate independent application by the user, utilizing the same arm as the product is intended to be worn on.

Needs:

The proposal should be comfortable to wear on the arm.

The proposal should physically fit the user.

Design Brief 1

Through this first phase, a project direction was found based on a market analysis, user research, and interviews. Leg amputee's problems resulted from a sourcing problem; therefore, arm amputees were selected as users. A solution direction has also been set as the first Brain Pool Writing led to the first ideations of a possible product proposal.

Problem Statement

How can we design an assistive device that enables arm amputees to perform daily tasks that involve lifting and carrying, as before the amputation, while also helping them maintain strength in their arm and improving their quality of life?

Vision

Our product proposal must recreate the trust they had in lifting and carrying with two hands.

Requirements

Using the proposal, the user must be able to lift and carry the cookware and baking dishes during cooking as they did pre-amputation.

The proposal must be made of dishwasherproof materials.

The user must be able to use the proposal with their existing cookware, baking dishes, and shopping basket.

The proposal must be made of food-safe materials.

The proposal must ease the load of a shopping basket while lifted and carried.

The proposal must help the user maintain their strength.

The proposal must facilitate independent application by the user, utilizing the same arm as the product is intended to be worn on.

Needs

The proposal should make the user comfortable wearing it outside the home.

The proposal should fit the same design language as kitchen equipment.

The proposal should make the user comfortable wearing it outside the home.

The proposal should be comfortable to wear on the arm.

The proposal should physically fit the user.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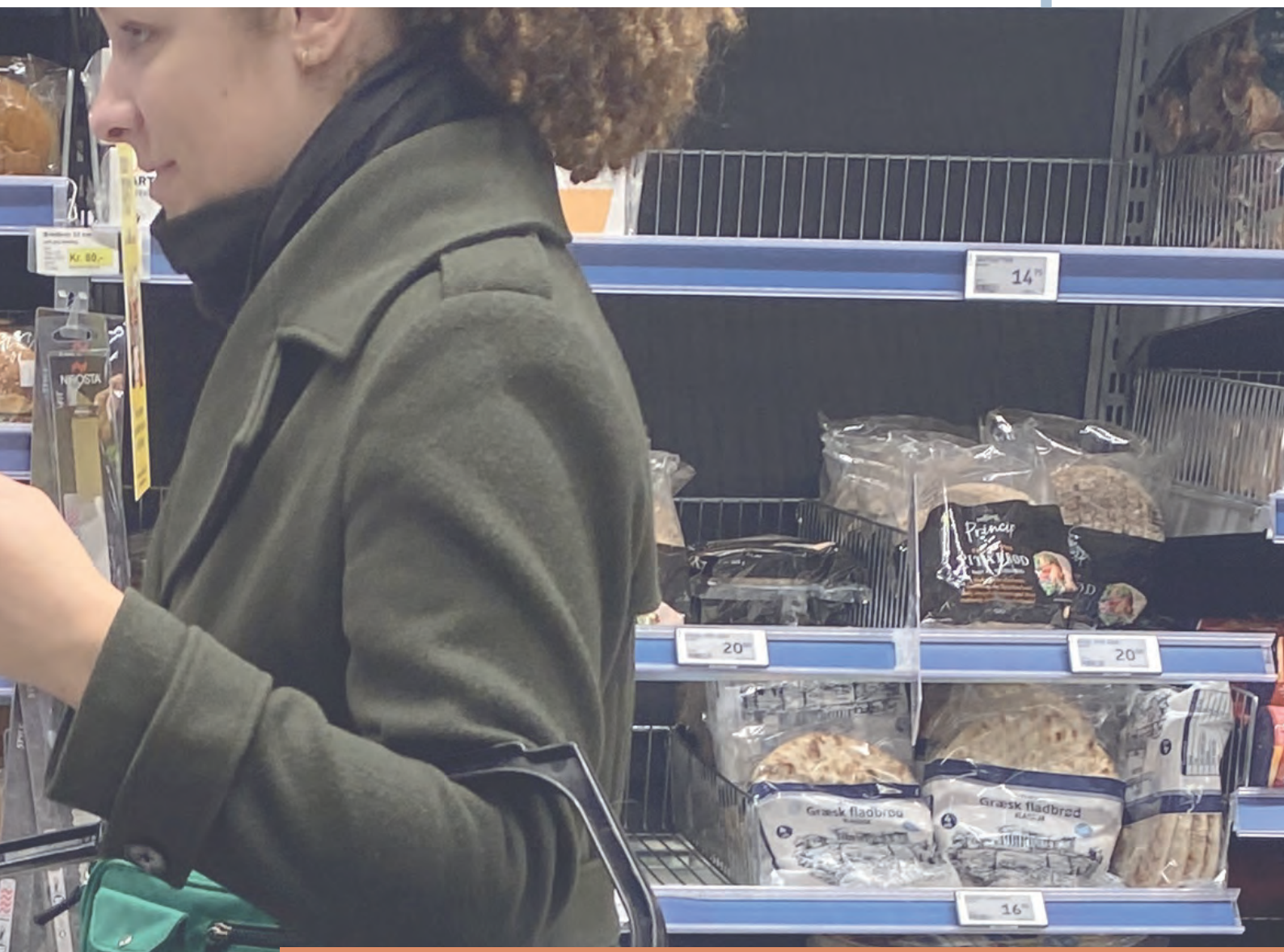


Phase 2

During phase two, the focus is to gain a deeper understanding of the identified problem, which helps to comprehend the solution space. This will be achieved through mapping subproblems, apprenticeship, conducting more interviews to confirm the discovery of the problem, and even seeking out the perspective of a case manager to gain additional knowledge about granting assistive devices. As a result of this phase, a more defined problem statement will be produced, which will consider the newfound understanding of the problem and any new requirements that have emerged for a potential product proposal.

Finding Subproblems

After choosing to focus on the difficulties arm amputees face when wanting to carry stuff, there was a need to define "carrying." The act of carrying consists of five focus points: grip, lift, carry, place, and let go.

Grip: the act of placing a hand around something and holding on with a firm grasp.

Lift: the act of bringing an object upward from the surface it was placed upon (in this case, with one hand).

Carry: the act of lifting an object from one place and holding it while taking it to another place.

Place: the act of putting the lifted object down on a surface.

Let go: the act of releasing the grip of the object.

These five focus points are all seen as part of the problem, as they are actions made to be able to carry something. Therefore, they need to be assessed further.

Though the main problem revolves around the difficulties of gripping, lifting, and carrying different objects, other subproblems were discovered as well through the interview (app. 6):

Assistive device: The product proposal should look like other assistive devices used in public when users use it grocery shopping.

Kitchen equipment: The product proposal should resemble other kitchen equipment used in the home kitchen.

Transport: The product proposal should be easy to transport so the user wants to bring it grocery shopping.

Take on and off many times: The user should easily take the product proposal on and off multiple times throughout the use.

Not a topic of speech: The product proposal should not be a topic of speech if someone sees it at home at the user or out in public when grocery shopping. It should be discreet or fit into the surroundings.

Easily cleanable: The product proposal should be easy to clean. The user mentioned she would like it to be dishwasherproof.

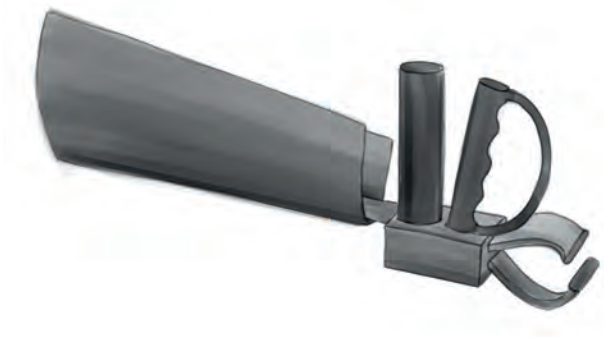
Placement: The product proposal should quickly be put away or have a designated placement when not used.

Design Language

After finding the subproblems, there was a need to investigate the design language of kitchen equipment and assistive devices used in public to solve these problems (app. 7).
Through ideation, each product category's design languages were combined with the five focus points (grip, lift, carry, place, and let go). After sketching, which principles recurred and what could be translated into a concept were examined. This resulted in three aesthetically different concepts:

Assistive devices used in public

These products do not have eye-catching colors compared to the assistive devices for the home (ill. 9). They primarily consist of grey, black, and skin-neutral colors. They are made from durable materials like hard plastic and different metals with rounded edges. Parts touching the skin or close to the body are padded or made from fabric, while handles are made from plastic. The products are very ergonomic and have a modular construction that allows worn-out parts to be replaced. (ill. 8)



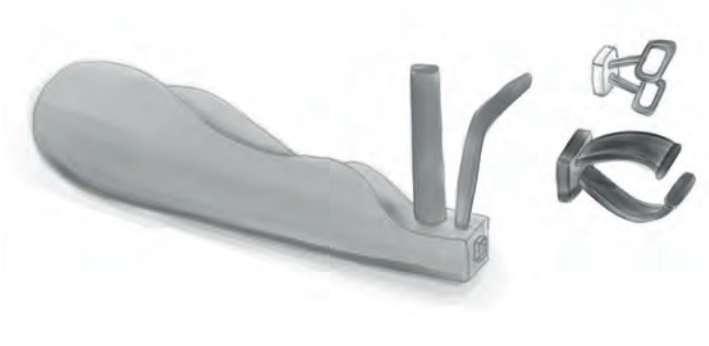
Ill. 8 Assistive device concept.

Ill. 9 Assistive devices used in public.

Kitchen Equipment

Kitchen equipment is available in many different colors and materials depending on the user's style (ill. 11). However, most equipment is in more neutral colors like black, grey, and white to appeal to a larger audience. Some of the equipment is made of wood, which is often kept in its natural color. The materials can consist of durable stainless steel, plastics, ceramic, etc. The products have handles that are marked through colors, materials, sizes, and shapes.

Spatulas and spoons have a big "head," long and slim rods, and bigger handles. This allows the user to avoid having their hands near the food or hot things. (ill. 10)



Ill. 10 Kitchen equipment concept.

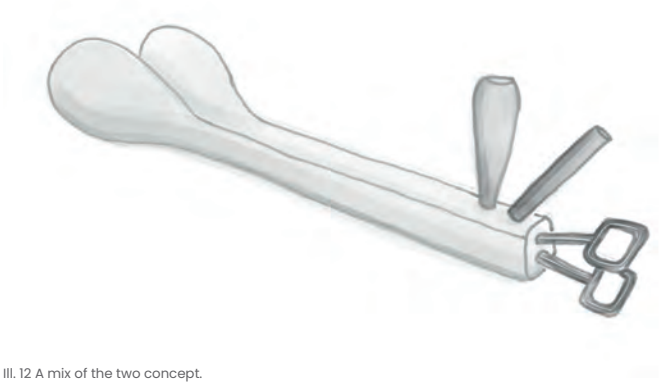
Ill. 11 Kitchen equipment.

A Mix of the Two

In both product categories, some recurring similarities were also found:

- Using neutral colors when the product is meant for different user groups.
- Durable materials as they are products often used daily.
- Comfortable handles and a clear indication of where to place hands when using the product.

Therefore, the last concept became a mix of the assistive device and kitchen equipment concepts, keeping the recurring similarities in mind. (ill. 12)



Ill. 12 A mix of the two concept.

Conclusion

Though the concepts aesthetically looked different, their function was the same. A better understanding of the exact problem regarding lifting and carrying for arm amputees was needed to make the concepts more functionally differentiated. This was done by acting out the two different scenarios.

Needs:

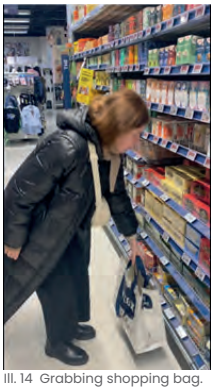
- The proposal should be made from durable materials.
- The proposal should be in neutral colors.
- There must be a clear indication of where to place the hand when using the product.

Apprenticeship

Apprenticeship (Sperschneider & Bagger, 2003) was used to gain insights into the difficulties newly-arm amputated individuals face when cooking and grocery shopping (app. 8). The insights that can be gained through Apprenticeship differ from those that can be obtained through interviews because interviewed users can experience difficulties remembering exactly what they used to do.
One team member acted out the scenarios using only one hand, while the other filmed and took pictures to study the scenarios further after the apprenticeship was over.

The scenarios acted out during grocery shopping included reaching items on the top and bottom shelves, picking up light items such as tea bags and heavy items such as potatoes, and comparing the differences between a shopping basket and a plastic shopping bag (ill. 13-15).


Ill. 13 Lifting shopping basket.


Ill. 14 Grabbing shopping bag.


Ill. 15 Putting it on the shoulder

Through the user visit, it was discovered that the arm amputee carries her shopping basket around the shop to be able to weigh the basket every time she picked up a new item to ensure she could lift it by the cashier into the car and at home.
Therefore, the shopping basket was carried around in the hand during the Apprenticeship.

Grocery Shopping Insights

When grocery shopping, the basket weighed 7.86 kg, which was quite heavy.

To lift the basket, the test person needed to lean to the side and use both the back and the shoulder to lift.

When putting a plastic shopping bag on the ground, it would close at the top, making it difficult to add more items.

No items in the shop were too heavy to lift with one arm.

Putting groceries into the basket while holding it on the arm was impossible.

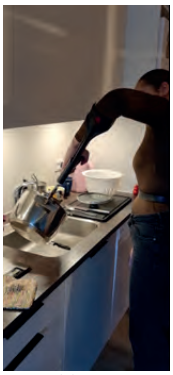
When cooking, a dish was prepared using both the stove and oven to ensure that all the scenarios were covered. The cooking was done with (ill. 16-18) and without the crutch solution (ill. 19-21) to get an understanding of both situations and why the user feels the need for the workaround.

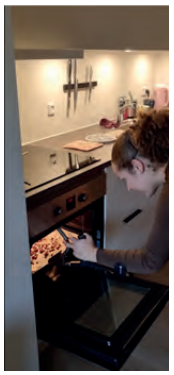

Ill. 16 Tilting.


Ill. 17 Lifting.


Ill. 18 Baking tray.


Ill. 19 Lifting w. crutch solution


Ill. 20 Tilting w. crutch solution.


Ill. 21 Baking tray w. crutch solution.

Cooking Without the Crutch Solution Insights

When attempting to lift a pot with one hand, it will rotate out of the hand (ill. 22).

At 3 kg, pouring out the water becomes difficult.

At 3 kg, the pot can be lifted, but only when a potholder is used to hold it against the pot.

At 5 kg, lifting becomes nearly impossible, let alone carrying it.

Cooking With the Crutch Solution Insights

When using the crutch solution, it was experienced that it makes it easier to lift heavy things.

While using the crutch solution, it creates some awkward positions.

On multiple occasions, the crutch solution's handle gets too far away, so it's hard or impossible to reach.

The arm also falls out of the mounting on the crutch solution.

The head of the crutch solution didn't fit the handles of the kitchen equipment, which made the test person uneasy about whether they would drop the item.

The crutch solution made it possible to lift and carry 5 kg, but it still seemed heavy.

There was no space in the kitchen to store the device, so it was placed on the kitchen table when not used.

The handle from the crutch solution was blocked by the edge of the oven when a baking tray was inserted into the oven. If the tray were placed lower, the hand would be burned by the oven.

The crutch solution was taken on and off multiple times during cooking, and it stopped this rotation, making it easier to carry.

Ill. 22 Rotating pot.

Conclusion

The insights from Apprenticeship showed that there are two different ways of lifting when comparing the scenarios. When grocery shopping, the lifts are primarily done with a straight arm, which is different when cooking, where the lifting is only done while the arm is bent. Furthermore, during the activity, the team experienced that there weren't any items in the shop that were too heavy to lift using only one arm.

Apprenticeship created an understanding of the difficulties when grocery shopping and cooking. Along with explaining why the user needs the crutch solution, it was also discovered that it has limitations. From Apprenticeship, the following requirements for a product proposal were made:

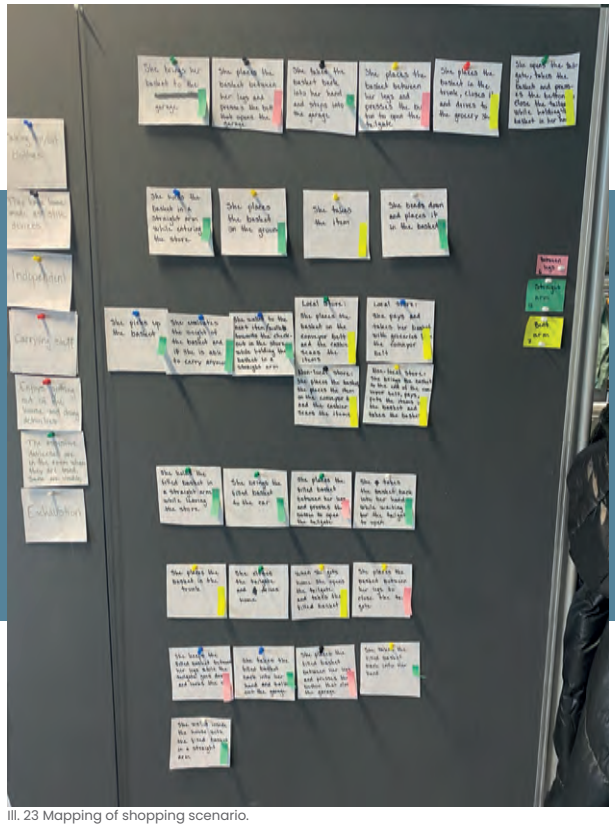
Requirements:

The proposal must allow control of the grip without straining the outer finger muscles.

The proposal must stop the cookware and baking dish from rotating out of the hand.

Grocery Shopping Solution

To explore various solutions for grocery shopping, the steps involved in the scenario were mapped on posters (ill. 23). Each step was analyzed to determine the arm's position and possible difficulties. This was done to break down the problem and make it easier to brainstorm solutions. The brainstorming resulted in multiple "strap-on" concepts, and these solutions were tested with mockups to test the feasibility of each proposed solution. These were first tested in the group room, and later, some were tested in the grocery shop context (ill. 24-27). (app. 9)

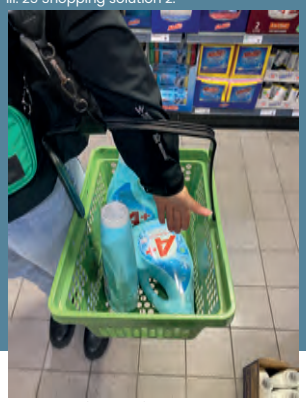


Ill. 23 Mapping of shopping scenario.

Ill. 24 Shopping solution 1.

Ill. 25 Shopping solution 2.

Ill. 26 Shopping solution 3.



Ill. 27 Shopping solution w. basket.

Conclusion

None of the solutions gave a satisfying result. The problem wasn't solved; instead, it moved to another place on the body, leaving the test persons unable to use their arm, which isn't better than the user's existing solution.
Testing some of the other ideas made during the brainstorming could be a possibility. Still, different solutions cannot be combined with the product proposal in mind/ with the kitchen scenario. The main reason for this is the way the user lifts and carries differently in the two scenarios.

The next step would be to reconsider if it would be an idea to focus only on one scenario to make a product fully functional for that scenario instead of a half solution for each by combining them.
We need to find out if we still want to work with this grocery shopping problem or if we should just focus on the kitchen scenario instead.

Interview with Arm Amputees

Ill. 28 Dennis.

Dennis, 7 years as an arm amputee

"*It has obviously been a **new body** that I have had to get to know after landing at Rigshospitalet.*„

Ill. 29 Anette.

Anette, 10 years as an arm amputee

"*My arm has to **hold twice as much** as yours, because I can never relax it.*„

Ill. 30 Annelise.

Annelise, born arm amputee

"*I couldn't dream of taking a roast pork out of the oven at the same time as the dish.*„

Ill. 31 Johnny.

Johnny, 42 years as an arm amputee

"*I train a crazy amount of **balance** … I need to keep my body still.*„

To understand whether the problem of lifting and carrying is common among arm amputees, it was essential to interview more individuals with similar experiences (ill. 28-31). Therefore, interviews were conducted with three different arm amputees.
The interviews were conducted differently, depending on the amputees' convenience. One amputee was visited at home, another was interviewed via an online video call, and the third was interviewed over the phone.

The interviewees were asked general and in-depth questions about the problems they faced while lifting and carrying objects. The questions and translated answers can be found in Appendix 2, 4, 10 and 11. Although the interview answers had some similarities, they also had some differences. The results of the interviews were new insights, confirmed insights, and debunked insights.

All the interviewees had experienced or could relate to the problem of lifting and carrying objects. To work around the problem in the kitchen scenario, they relied on others for help, which prevented them from facing the issue themselves. However, they all emphasized the importance of feeling independent.

Our interviews confirmed that Anette's problem in the kitchen was not unique to her. They had all, in some way, worked around the problem in the kitchen scenario. This was primarily done by getting help from others in the home or by making simple food where they didn't have to face the problem. But they all emphasized the importance of feeling independent.
However, in the grocery shopping scenario, Anette faced more difficulties than the other amputees because she didn't have a stump from her amputation.

When asked about their grocery shopping experience, two amputees used their stumps to carry their bags, and the third used his wheelchair. They did not see grocery shopping as a significant issue.

The interviews also confirmed that arm amputees commonly deal with issues such as imbalance, which is caused by the missing weight from the amputated arm. They do not grow out of this imbalance, even though it is present from birth. Additionally, the amputee who was born without the amputation had trouble lifting and carrying objects throughout her life.

The two amputees who lost their arms in accidents mentioned how overwhelming it is to wake up with a new body and how it can be mentally challenging to cope with such a situation.

It was furthermore discovered that the arm amputees didn't use their prosthetics because they were in the way and tended to make tasks more difficult. Research shows that more than 50% of upper limb amputees don't use their prosthetics because of the same reasons as the arm amputees mentioned (Salminger et al., 2020)

Arm amputees face challenges in lifting and carrying objects, which can impact their independence. While there are some workarounds, such as relying on help from others or using a wheelchair, these solutions may not always be practical or desirable. Additionally, arm amputees commonly deal with issues such as imbalance, which can be mentally challenging to cope with.

Getting on the Market

It is the amputees who will ultimately use assistive devices, but they do not directly purchase them. Instead, if an amputee feels they need an assistive device, they must contact their case manager from the municipality or visit the municipality website to request it.

Desktop research was conducted on the subject to better understand the process of getting an assistive device on the market. In addition, a semi-structured interview with case manager Pia Ozimek from Aalborg municipality (ill. 32) was conducted to better understand the criteria for assessing assistive devices (app. 12).

Ill. 32 Pia Ozimek
Case Manager, Aalborg municipality

1. How the Assistive Device Helps.

The municipalities are responsible for deciding whether the assistive device is necessary for the amputee's daily life. This means whether the device is approved can vary from one municipality to another. (Danske Regioner, n.d.)

When getting a request for an assistive device from a citizen, the case manager must understand the underlying problem to be solved and identify the individual's difficulties. They look at how the person manages everyday activities, what is significant, and what difference the device can make, enabling capabilities that were not possible before. They especially value the individual's ability to manage daily life effectively.

Even though prosthetic technology has advanced with electronic-powered solutions, this doesn't always cater to the user's needs. Pia Ozimek has found that prosthetics sometimes overlook the user's preferences. While a bionic hand may seem impressive, in reality, simpler options like a hook can be more effective due to its ease of use and accessibility.

> "*But one of the aspects that are **highly valued** is the **ability to manage daily life effectively**. This includes **essential tasks** such as **eating**, **getting dressed,** and **maintaining personal hygiene**.*"
>
> - Pia Ozimek, Case Manager

2. The Best and Most Cost-effective.

If the assistive device significantly improves the amputee's daily life at home, is necessary for their work, or helps alleviate the lasting effects of their reduced functional ability, the municipalities must support it according to the Service Act paragraph 113. (borger.dk, n.d.)

The case manager can choose which product on the market to buy. They must consider the product's quality, reliability, operating costs, durability, warranty, and other factors. Furthermore, they must find the most cost-effective assistive device. Therefore, when the case manager searches for an assistive device for a citizen, they look to find the device that best solves the problem for the lowest price when the criteria regarding durability and significance are fulfilled.

The amputee can borrow the device from the municipality or receive a subsidy to purchase it themselves. If the amputee wants a better device than the assigned one, they must pay the extra cost.
The price range for kitchen aids and similar assistive devices varies between 200 DKK and 2.000 DKK. Prosthetics, however, can range from 60.000 DKK for a cosmetic prosthetic and up to 1 million DKK for complex prosthetics.

> "*And it may be that we **don't start with a Mercedes**, but perhaps we s**tart with a Renault**. To thoroughly **investigate what benefits we get** from it.*"
>
> - Pia Ozimek, Case Manager

3. The Complexity of the Product.

The complexity of the product can affect how easy or hard it is to grant an assistive device. The more complex a product is, the more the case manager must advocate that it is necessary for the citizen and how each specific part of the product helps. Therefore, it is easier to grant a less complex product that solves one particular problem as it is more apparent how it benefits the citizen.

> "***Yes**, initially, **the process might be faster** because it's more apparent that this item is necessary... I think **it's more about the complexity of the product.**"*
>
> - Pia Ozimek, Case Manager

4. It Must Be a Medical Device.

They differentiate between medical devices and consumer goods. Consumer goods benefit everyone, while medical devices must be specifically designed for someone with reduced functional capacity. Assistive devices, like the product proposal, belong to medical device class I.

> "***Assistive devices** must be **specifically designed** and produced to address a **reduced functional capacity**, while **consumption grants** are items **beneficial to everyone.**"*
>
> - Pia Ozimek, Case Manager

5. Experienced Company.

When finding or buying new medical devices, they must buy from companies with dealers familiar with their products and understand the target group. The products must also be approved, and CE-marked and meet various requirements experienced companies are experts in. They often seek products from already-known suppliers as they know the desired service level and can easily source parts if anything needs to be repaired.

6. Finding New Products on the Market.

Every other year, Aalborg municipality sends some employees to a medical device fair, presenting them with new products. Here, the manufacturers approach people directly to show them their latest product. Others chose to advertise in magazines for older people or in the local newspaper.

Conclusion

The product proposal will be a medical device class I, which adds many specific requirements that the proposal must fulfill. These types of devices mostly cost 200 to 2.000 DKK.

Finding existing municipalities' suppliers would be ideal, making entering the market much more accessible.

The product must help the user fulfill a necessary need.

It should be reconsidered if necessary to solve the grocery shopping problem, as a less complex device with a specified use is easier to grant.

Requirements:

The proposal must fulfill the requirements for a medical device class I.

The collaboration company must be an existing supplier of the municipalities of Denmark.

Needs:

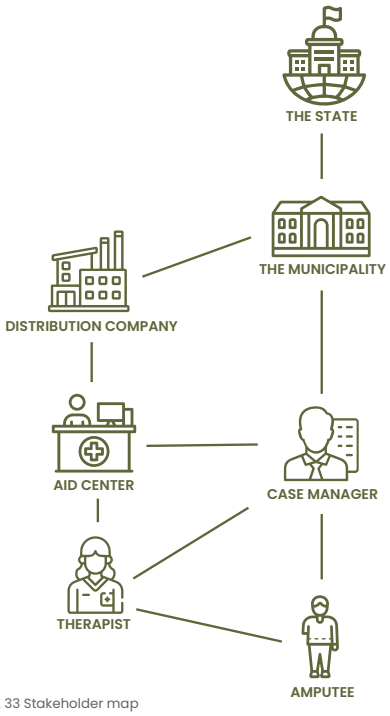
The proposal should be in the price range of 200 to 2000 DKK.

Stakeholder Map

In light of the new information, a simple Stakeholder Relationship Network map (Hendricks, n.d.) was created for the parties affected by or impacting our product proposal. This map visualizes the different stakeholders and helps understand how they are linked (ill. 33).

The municipalities gets most of their income from taxes, but it also gets money from the state. It is the government that determines how much money the municipalities receives. (FOA, n.d.) Therefore, the state is at the top of the stakeholder map.
The case manager works for the municipality and buys medical devices from the aid center, which has purchased the device from the manufacturing and distribution company. The herapist also works for the municipality and help the case manger with finding a suitable device and will install and help the amputee with their new device.

Stakeholders can have different opinions on the product proposal and requirements, which we must consider. As the majority of the stakeholders mostly have a financial interest in the product proposal, the focus will lie on the amputee and physiotherapist throughout the development process.



Ill. 33 Stakeholder map

Medical Device Regulations

As the product proposal will be classified as a medical device class I (Lægemiddelstyrelsen, 2022), it must meet specific requirements and regulations by the Danish Medicines Agency and the EU (ill. 34). Desktop research was conducted to ensure that any regulations influencing the development process were met (app. 13).

The regulations primarily consist of requirements regarding thorough testing and documentation. These tests include testing the device's quality, performance, and safety. In addition, a clinical evaluation must be conducted to show that the device is safe and that the risks associated with its use are acceptable compared to its performance. (Lægemiddelstyrelsen, 2022)

Ill. 34 Medical device classes.

CE Certification

CE marking (ill. 35) is proof that the device complies with EU legislation. Medical devices must be CE-certified and CE-marked when marketed, and because the product proposal is a class I, the manufacturer is responsible for the CE-marking process. To get the CE certification, the product proposal must undergo multiple documented tests on humans. (Lægemiddelstyrelsen, 2022)

The team cannot perform these tests. However, testing will be considered when evaluating the business aspect of the product proposal.

CE

Ill. 35 CE certification.

Requirement:

The proposal must be CE-certified.

Design Brief 2

During phase two, there have been delved deeper into both the shopping and kitchen scenarios, which helped understand the differences between the lifting in the scenarios. As a result, it was decided to focus solely on the kitchen scenario to ensure that product solutions are fully functional in that setting, rather than providing only half a solution for each scenario. Additionally, there were gained a deeper understanding of what it takes for an assistive device to be appealing to the municipality and reach them with a new assistive device.

Problem Statement

How to design an assistive device that enables arm amputees to lift and carry cookware or a baking dish, as prior to the amputation while also helping them maintain strength in their arm, feeling comfortable wearing and using it, and thereby improving their quality of life?

Vision

Our product proposal must recreate the trust they had in lifting and carrying with two hands.

Requirements

Using the proposal, the user must be able to lift and carry the cookware and baking dishes during cooking as they did pre-amputation.

The proposal must be made of dishwasherproof materials.

~~The user must be able to use the proposal with their existing cookware, baking dishes, and shopping basket.~~ ▶ The user must be able to use the proposal with their existing cookware and baking dishes.

The proposal must be made of food-safe materials.

~~The proposal must ease the load of a shopping basket while lifted and carried.~~

The proposal must help the user maintain their strength.

The proposal must facilitate independent application by the user, utilizing the same arm as the product is intended to be worn on.

- The proposal must allow control of the grip without straining the outer finger muscles.
- The proposal must stop the cookware and baking dish from rotating out of the hand.
- The collaboration company must be an existing supplier of the municipalities of Denmark.
- The proposal must fulfill the requirements for a medical device class I.
- The proposal must be CE-certified.

Needs

~~The proposal should make the user comfortable wearing it outside the home.~~

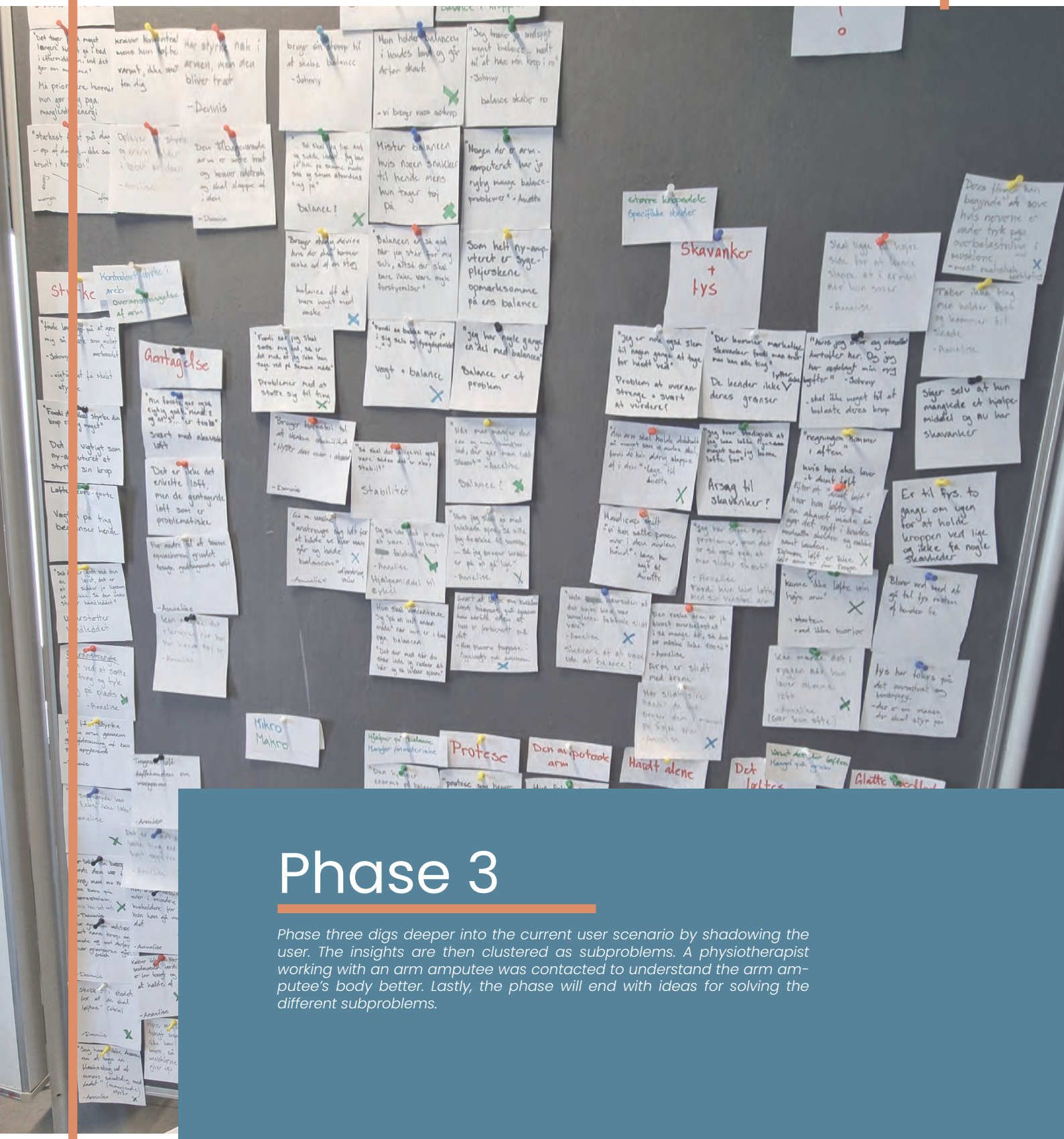
The proposal should fit the same design language as kitchen equipment.

The proposal should make the user comfortable wearing it outside the home.

The proposal should be comfortable to wear on the arm.

The proposal should physically fit the user.

- The proposal should be made from durable materials.
- The proposal should be in neutral colors.
- There must be a clear indication of where to place the hand when using the product.
- The proposal should be in the price range of 200 to 2000 DKK.



Phase 3

Phase three digs deeper into the current user scenario by shadowing the user. The insights are then clustered as subproblems. A physiotherapist working with an arm amputee was contacted to understand the arm amputee's body better. Lastly, the phase will end with ideas for solving the different subproblems.

Shadowing

Shadowing (Sperschneider & Bagger, 2003) was done while the user cooked a meal in her kitchen. This was done to gain insights about her workarounds and cooking difficulties that she didn't think about telling during the previously performed interview and to create measurable insights regarding the kitchen scenario. The dish made was one where she used both the stove, multiple kitchen equipment, and the oven to ensure that all touchable situations were shadowed (ill. 36).

The shadowing was done while filming her cooking, so this footage could be looked through afterward to look closer at the separate steps through the cooking. After the shadowing, some follow-up questions were asked as to why she did certain things, as well as some questions that had occurred between the last interview and the shadowing. (app. 14)

Insights from Shadowing

The cooking scenario took 1 hour and 12 min.

When carrying pots, pans, and baking dishes, the palm of the hand faces upwards.

Lift throughout the shadowing:

Pot: 9 times

Saucepan + pan: 13 times

Baking dish: 5 times

Time caring stuff throughout the shadowing in total:

Pot: 63 sec.

Saucepan + pan: 66 sec.

Baking dish: 26 sec.

The longest caring is 18 sec.

She rested her arm 43 times for a total of 16 minutes. Her breaks, during which the arm was rested, were an average of 22 seconds.

Insights from Follow-up Interview

She uses the silicone mate because her missing arm can create some spasms: *"Sometimes, my back just tweaks a bit. It gives these spasms. And then the brain, it's like it mirrors itself."* - Anette.

As the day progresses, her exhaustion can lead to troubles with imbalance.

She uses more energy to maintain her balance while carrying a pot or pan.

She insists on carrying stuff because she wants to be as independent as she was pre-amputation. *"Why did you carry it when your husband was home? Well, because it was me who wanted to be helpful."* - Anette

Through time, she has learned to balance the objects she is carrying.

Carrying liquid things makes her unsure of her balance.

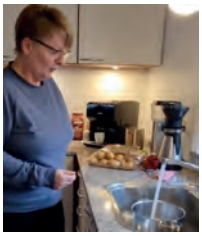
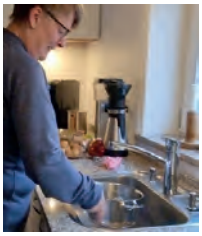
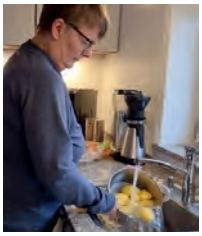
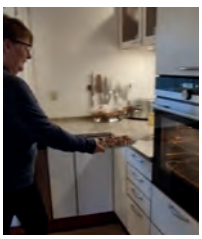
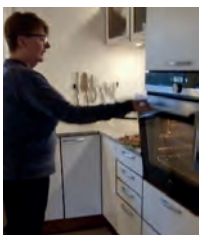
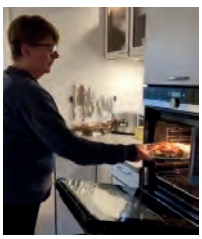
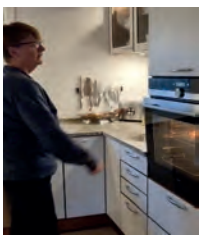
She feels it in her arm and lower back in the evening when she lifts incorrectly during the day.

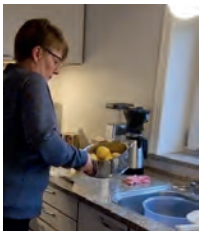
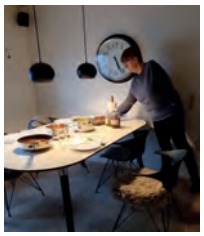
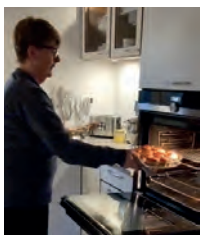
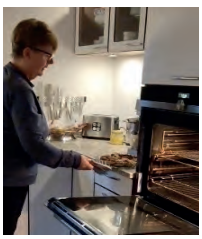
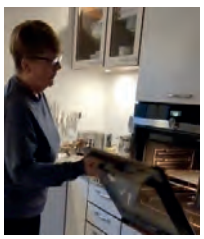
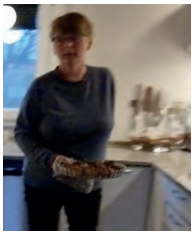
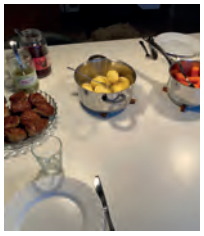
When putting on socks, she loses concentration if someone speaks to her while putting on her socks; she looks at them while they talk.

Core Tasks

Based on the insights acquired during Shadowing, the following three core tasks were defined: lifting a filled pot, emptying a pot for water, and taking a filled baking dish out of the oven.
Any proposed product must undergo testing in these core tasks to confirm that it effectively meets the necessary requirements.

In addition to the core tasks, the product proposal should act as her potholder. It should be just as easy and fast (2 sec.) to grab and use as a potholder or oven mitt, and should replace these in her existing routine. Therefore, a metaphor was added for the product proposal: ***"It should be like an oven mitt."***

Time	Kitchen scenario			Key insights
00:00 - 00:13	She finds her pot in the drawer underneath the stove. She carries the pot over to the sink.			She uses the edge of the pot when carrying the pot instead of the handle.
00:13 - 00:26	She fills the pot with water. She lifts the pot with water to place it on the kitchen counter next to the sink.			She is using the edge of the pot to carry it.
00:26 - 07:01	She peels the potatoes and puts them in the pot. She lifted the pot while washing the potatoes and poured new water onto them.			She uses the pot's handle and places her hand so some of her fingers are inside the pot.
07:01 - 07:07	She carries the pot with water and potatoes. She is placing the pot on the stove.			She places the pot on a silicone mat and turns the pot so the handle is pointing toward her.
07:07 - 41:51	While the food cooks, she cleans the kitchen and prepares the ingredients. She sets the table in between stirring the pots and pan.			She utilizes the time to do other things instead of resting her arm.
41:51 - 41:59	She brings the food to the oven and places it beside the oven. She opens the oven.			
41:59 - 46:15	She places the baking dish inside the oven. She closes the oven and returns to the stove to stir the pots.			She uses the edge of the pot when carrying the pot instead of the handle.
46:15 - 46:21	She removes the lid from the pot and finds her potholder in the drawer next to the stove.			Her potholder is stored in the drawer next to the stove. While cooking she takes a lit on and off the pot multiple times.

46:21 - 46:30	She grips the pot while holding the pot-holder in her hand. She carries the pot to the sink and pours some water.			She uses her potholder to carry the pot.
46:30 - 49:27	She carries the pot back to the stove and places it on it. She stirs the food in the pan and pots and waits for it to be cooked. She grips the pot with the potholder and carries it to the sink.			She places the potholder on the countertop next to the stove.
49:27 - 49:32	She pours the rest of the water out of the pot and the potatoes into a colander. She drops the pot while pouring the water and potatoes out of it.			She loses her grip on the pot.
49:32 - 68:35	She drains the potatoes through a colander, returns them to their pot, and places it back on the stove. After another round of stirring, she drains the carrots in the same manner, then resumes her stirring on the stove.			
68:35 - 69:58	She walks back and forth multiple times to carry the pot, the pan, the saucepan, and the coaster to the table one at a time.			
69:58 - 70:35	She grabs the potholder. She places the potholder next to the oven, opens the oven, takes the potholder, and lifts the baking dish.			The potholder is placed on the kitchen counter.
	She places the baking dish next to the oven and puts the potholder next to the dish. She closes the oven.			She uses the edge of the pot when carrying the pot instead of the handle.
	She wraps the potholder around the edge of the baking dish. She carries the baking dish to the table and places it, and the meal is ready to be eaten.			It takes her 2 seconds to grab the potholder and be ready to grab the edge of the dish.

Ill. 36 Shadowing.

Requirements:

The proposal must be able to fit into a kitchen drawer.

The proposal must allow the user to take it on and off in 2 sec.

The proposal must allow the use of a pot lid.

The proposal must enable the user to pour out water from a pot.

The proposal must enable the user to lift a filled pot.

The proposal must enable the user to take a filled baking dish out of the oven.

The proposal must allow the user to place it by the stove, oven, and sink.

Need:

The proposal should fit into the user's existing routine when cooking.

Micro & Macro Situations

From the interviews of the arm amputees and the shadowing, every insight, problem, and consequence resulting from a problem was written on a piece of paper and put onto a pinboard. This was done to dig deeper into the problem and determine which consequences resulted from the same problem. The problems and consequences were then clustered (ill. 37) as subproblems under headlines describing the theme of the subproblems to organize the gathered information (app. 15).

The subproblems were then further clustered into micro and macro situations. Micro situations can involve small muscles, such as the fingers or a specific small place on the body. Macro situations can involve muscles in the arm or problems with balance.
As a result of this, micro and macro situations were found for each of the insights.

When analyzing the micro and macro situations, many of the problems and consequences originated from the same four problems:

They have difficulty balancing their wrist when holding an object.

They lack controlled strength in their grip.

They use extra energy to balance their upper body and counteract the imbalance in their back.

They tend to overuse their arm because they can't rest it properly.

The clustering led to some questions regarding the body in general and how losing a body part can affect it, which needed to be answered before another ideation.

Ill. 37 Micro & macro situations.

Requirements:

The proposal must ensure the stabilization of the pot and baking dish while lifted and carried.

The proposal must ensure a continuous firm grip around the pot and baking dish.

Interview with Therapists

Contact was made with a physiotherapist and an occupational therapist to gain insights into how the body reacts when an arm is missing. This information will contribute to the project by establishing requirements for a product to support arm amputees when gripping, lifting, and carrying objects. A situated interview (Sperschneider & Bagger, 2003) was conducted with the occupational therapist (ill. 39), and a video call was made with the physiotherapist (ill. 38) (app. 16). The insights were divided into three categories: insights into the newly amputated arm, insights into the body of an arm amputee, and insights regarding the product proposal.

Ill. 38 Rebecca Ohnstad Broch, Physiotherapist

Ill. 39 Helle Puggård, Occupationaltherapist

Newly Arm Amputated

> *"The biggest challenges would be that in the beginning, there's so much to deal with. It would be such chaos."*
>
> - Helle Puggård, Occupational therapist.

Losing the Dominant Hand

When an amputee undergoes amputation, they may lose their dominant hand and have to learn to use their non-dominant hand. This can prolong the physical rehabilitation and further add frustrations, which can affect the psychological aspect.

> *"Fine motor skills can be difficult if it's your non-dominant hand. So, just that alone would require a lot of energy."*
>
> - Helle Puggård, Occupational therapist.

The Psychological Aspect

As newly amputated, arm amputees can have a hard time psychologically, which can delay the physical rehabilitation.

> *"I have a lot of people who lose a finger or several fingers or half a hand, who have a psychological reaction. And, of course, if you lose half or a whole arm, the psychological reaction must not be smaller. So there's the whole psychological aspect initially, which probably gets in the way of actually starting the more physical rehabilitation."*
>
> - Helle Puggård, Occupational therapist.

Phantom Pains

For individuals who have recently undergone an amputation, phantom pains can be a significant challenge. Some may find that managing this pain is something they must contend with for the rest of their lives.

The Body of an Arm Amputee

Muscles used

When lifting an object, the primary muscles used are the biceps. However, additional muscles come into play when carrying the object, including the core muscles, chest, biceps, shoulders, back, hands, and forearms. The muscles used to keep an object static are the shoulders, chest, and back.

Overuse of the Remaining Arm

Arm amputees rely on their healthy arm and use it twice as much as before. However, this can lead to overuse, causing irritation of the nervous tissue, which can result in pain, reduced arm strength, and sensory disturbances in the fingers. The overuse primarily affects the muscles and tendons, and in the worst-case scenario, amputees may experience pain so severe that they won't be able to use the arm at all.

> *"So the worst-case scenario would be if one experiences an overuse reaction. If you keep maintaining it, then it just develops into a bigger problem, leading to more pain and less strength, and so on."*
>
> - Helle Puggård, Occupational therapist.

When an arm is overused, the only way to heal it is by resting it. However, this can be challenging as the patient does not have another arm to use while resting the overused one. Currently, there are no products or solutions available to help with this problem. The only option for treatment is manual therapy, such as acupuncture, in addition to resting the arm.

> *"If you're constantly lifting something just with your hand, then your hand becomes overloaded. But when you have larger muscles, it's better to use them."*
>
> - Rebecca Ohnstad Broch, Physiotherapist.

Balance in the Body

An arm weighs about 5% of the body weight, and losing it results in the amputee having trouble with their balance. Therefore, the amputees use energy to keep their balance.

> *"...our center of gravity in the body will shift a bit because you don't have that weight there."*
>
> - Rebecca Ohnstad Broch, Physiotherapist.

> *"If I have to take a pot in my right arm, then I still have 5 kilos over in my left to provide a counterweight, that is, for balance. So if I don't have them, well, then the pot will have a larger impact on my body than if I could just put my arm out for balance."*
>
> - Helle Puggård, Occupational therapist.

Furthermore, the occupational therapist emphasized that having a prosthetic can help recreate balance in the body. Continuously taking the prosthetic on and off can confuse the body and create an even more significant imbalance.

> *"If one spends a large part of their time using a prosthesis, and then takes it off, they experience imbalance because they are used to having that weight."*
>
> - Helle Puggård, Occupational therapist.

Insights Regarding the Product Proposal

Moving the Strain

When holding objects, it's recommended to shift the pressure into the palm of the hand instead of gripping it with the fingers. This will help to avoid staining the fingers, and it's essential for amputees who may experience sensory issues in their fingers.

Distribute the Strain onto Multiple Joints

When lifting and carrying objects, the weight is concentrated on the wrist. To help arm amputees, it is preferable to distribute the weight across multiple joints.

> *"Those joint protection principles when lifting, which we try to teach them, involve using larger joints rather than smaller joints or multiple joints at once."*
>
> - Helle Puggård, Occupational therapist.

Position the Hand in Neutral Position

While lifting and carrying objects, the wrist is more likely to be injured if it is not kept in a neutral position. Therefore, it would be preferable to keep the hand in a neutral position while caring (ill. 40).

Ill. 40 Neutral hand position.

Get the Weight Close to the Body

When lifting an object close to the body, it doesn't feel as heavy as if it is carried in a straight arm away from the body.

> *"So, if I have to hold something out here, it becomes twice as heavy as if I were to hold it close to my body... It would be less strain on the body for sure."*
>
> - Rebecca Ohnstad Broch, Physiotherapist.

Conclusion

After consulting with two therapists, it became clear that helping arm amputees carry objects is not enough. It's also important to ensure they do it safely, minimizing the risk of injury. Overusing the arm can lead to critical injuries, making it difficult for the amputees to use their arm. Furthermore, balance is a lifelong struggle for amputees, and carrying objects can worsen the imbalance.
As a new arm amputee, there are many challenges to overcome, not just physical ones. Psychological reactions to the situation can hinder physical rehabilitation.

Although the product proposal doesn't directly address the psychological aspect, it can make the physical rehabilitation process more manageable and help prevent injuries. By concentrating on the focus points (grip, lift, carry, place, and let go) in the kitchen, the product can help amputees focus on their psychological reactions and make it more tangible for them to continue cooking while going through the rehabilitation process.

Requirements:

~~The proposal must allow control of the grip without straining the outer finger muscles.~~
▶ The proposal must enable the user to lift and carry with the palm of the hand.

The proposal must divide the pot and baking dish load over multiple joints while lifted and carried.

The proposal must ensure the user's hand is placed in a neutral position.

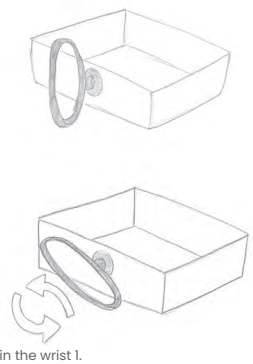
Ideation on Subproblems

With the new knowledge about the body, the team started to ideate based on the found subproblems regarding strength and balance, as it seemed they were the core problems resulting in the other subproblems. The methodology Brain Pool Writing was again used to ideate on the micro and macro situations of each of the two subproblems: balance in the wrist, balance in the body, controlled strength in grip, and overuse of the arm. (app. 15)

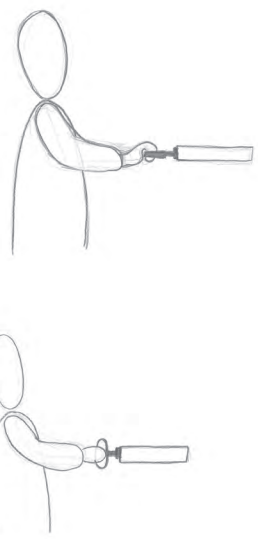
Based on the Brain Pool, a principle was created for each subproblem.

Balance in the Wrist

A rotating handle would help create balance in the wrist. The handle's rotation ensures that the object always stays right side up, no matter how much the user shakes or turns their hand/wrist. This helps create balance, so the user doesn't have to worry about spilling from the object (ill. 41-42).



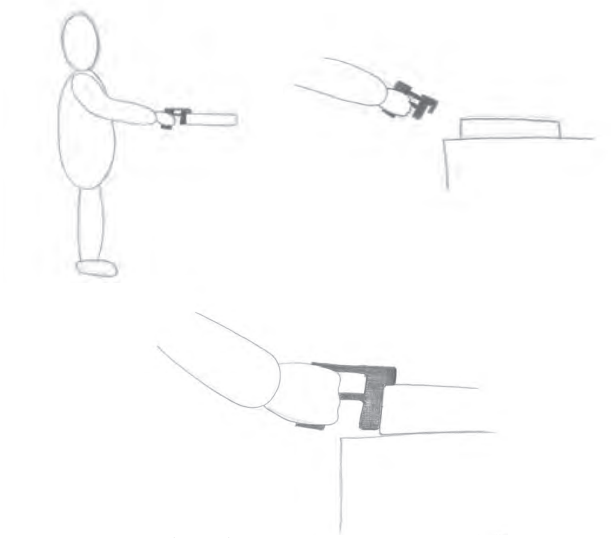
Ill. 41 Balance in the wrist 1.



Ill. 42 Balance in the wrist 2.

Controlled Strength in the Grip

A handheld "gripper" principle would help recreate the user's control and strength in the grip they miss now. The handle allows the user to get a better grip on an object that does not have handles. Depending on the tightness of the squeeze, the user is in control of the tightness of the grip (ill. 43).



Ill. 43 Controlled strength in the grip.

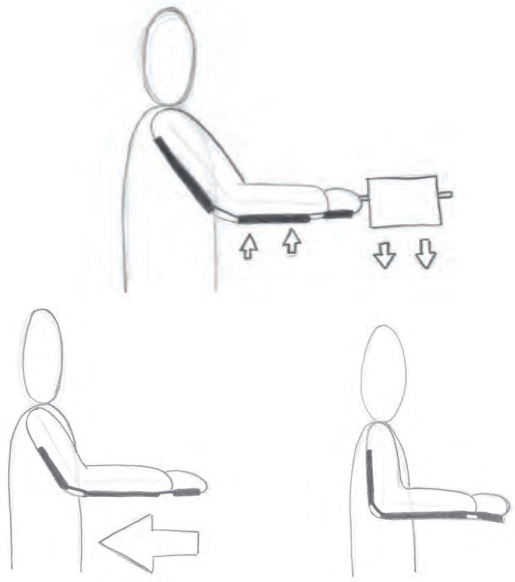
Ill. 44 Balance in the body.

Balance in the Body

To balance the body, a shirt with unilateral weight was created. On the side of the amputated arm, a weight compensating for the missing weight would be placed, which would help create balance in the body and thereby make it easier to lift and carry objects (ill. 44).

Overuse of the Arm

Lastly, a principle to prevent overusing the arm was created. The principle would support the whole arm and distribute the weight of the carried object. It would also be possible to "lock the arm" onto the body at a 90-degree angle, distributing some weight to the body while forcing the user to lift objects closer to the body (ill. 45).



Ill. 45 Overuse of the arm.

Conclusion

The principles were combined into one concept, except for the principle of balance in the body (ill. 46).

During the interview with the occupational therapist, she mentioned how adding and removing weight from the amputated side of the body can mess with the balance even more. Therefore, the solution for this subproblem could have the opposite effect and worsen the problem. Furthermore, a prosthetic could solve the problem just as well.

Through the ideation, it also became clear that there was a need to specify the lifts made in the kitchen further. It was therefore decided to focus on lifts below shoulder height as lifts above shoulder height are very different ergonomically. In addition, when looking at heavier lifts during cooking, these are primarily below shoulder height. (app. 15)

Ill. 46 The principles combined.

Design Brief 3

This phase started with Shadowing of the user resulting in three core tasks that the product proposal must make the user able to achieve: lifting a filled pot, emptying a pot for water, and taking a filled baking dish out of the oven. Furthermore, it led to some micro and macro situations that were ideated on, resulting in a product proposal that combines multiple principles into one. Two interviews were conducted with a physiotherapist and an occupational therapist to obtain insights into the arm amputee's body and how the product proposal can help the problem.

Metaphor

"It should be like an oven mitt."

Problem Statement

How to design an assistive device that provides arm amputees with a secure grip, minimizes overuse, maintains balance while handling cookware or a baking dish, and helps maintain arm strength? Additionally, how can the device be integrated into the kitchen environment and routine, ultimately enhancing the quality of life for the users?

Vision

Our product proposal must recreate the trust they had in lifting and carrying with two hands.

Requirements

~~Using the proposal, the user must be able to lift and carry the cookware and baking dishes during cooking as they did pre-amputation.~~ ▶ Using the proposal, the user must be able to lift and carry the pot and bake dishes while cooking as they did pre-amputation.

The proposal must be made of dishwasherproof materials.

The proposal must be made of food-safe materials.

The proposal must help the user maintain their strength.

The proposal must facilitate independent application by the user, utilizing the same arm as the product is intended to be worn on.

~~The proposal must allow control of the grip without straining the outer finger muscles.~~ ▶ The proposal must enable the user to lift and carry with the palm of the hand.

~~The proposal must stop the cookware and baking dish from rotating out of the hand.~~ ▶ The proposal must stop the pot and baking dish from rotating out of the hand.

The collaboration company must be an existing supplier of the municipalities of Denmark.

The proposal must fulfill the requirements for a medical device class I.

The proposal must be CE-certified.

★ The proposal must be able to fit into a kitchen drawer.

★ The proposal must allow the user to take it on and off in 2 sec.

★ The proposal must allow the use of a pot lid.

★ The proposal must enable the user to pour out water from a pot.

★ The proposal must enable the user to lift a filled pot.

★ The proposal must enable the user to take a filled baking dish out of the oven.

★ The proposal must divide the pot and baking dish load over multiple joints while lifted and carried.

★ The proposal must ensure the user's hand is placed in a neutral position.

★ The proposal must allow the user to place it by the stove, oven, and sink.

★ The proposal must ensure the stabilization of the pot and baking dish while lifted and carried.

★ The proposal must ensure a continuous firm grip around the pot and baking dish.

Needs

The proposal should fit the same design language as kitchen equipment.

The proposal should be comfortable to wear on the arm.

The proposal should physically fit the user.

The proposal should be made from durable materials.

The proposal should be in neutral colors.

There must be a clear indication of where to place the hand when using the product.

The proposal should be in the price range of 200 to 2000 DKK.

★ The proposal should fit into the user's existing routine when cooking.

Phase 4

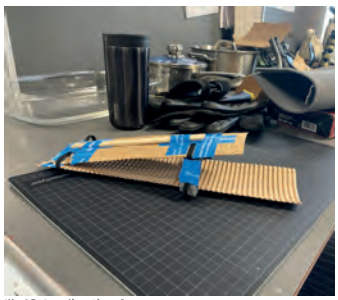
Phase four of the product development process involves researching and testing principles from other products that could be used in the product proposal. During this phase, the measurements for the pots and baking dishes will be determined. Furthermore, a decision was made to make an attachment for the pot and the baking dishes.

Testing Existing Principles

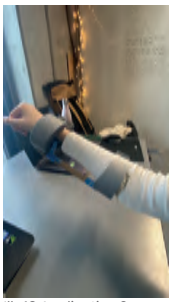
Existing products were examined and tested for principles that could be translated into the product proposal (app. 17). This process began with desktop research on the following principles: products that help raise the user's arms, grip, stabilize balance in the wrist, independent application on the arm, and carry objects from a distance (ill. 47). The research was conducted on assistive devices and other categories where the relevant principles could be found.

Ill. 47 Existing principles.

After the desktop research, mockups of the principles believed to be qualified to solve the problem regarding the independent application of the product proposal on the arm were made (ill. 48-49).



Ill. 48 Application 1.



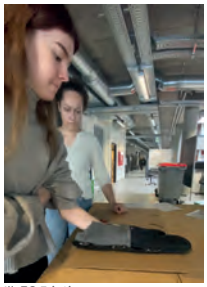
Ill. 49 Application 2.

This test concluded that friction was the fastest and easiest way of taking the mockup on and off. Rubber was added to an oven mitt, making it possible to quickly take it on and off using the table's surface (ill. 53). Therefore, it was decided to continue with this solution and take the product proposal on and off. Furthermore, the oven mitt was easier to get on if the opening was held open, making it easier for the hand to access the mitt (ill. 52).

Ill. 50 Missing support 1.

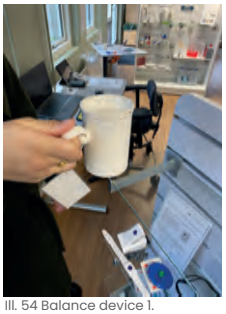
Ill. 51 Missing support 2.

Ill. 52 Opening.

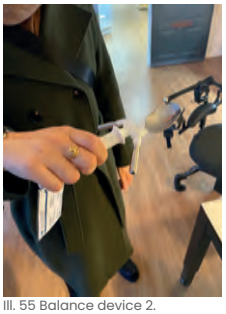


Ill. 53 Friction.

In addition, two of the stabilizing products found during the research could be tested at the Center for Velfærdsteknologi (Center for Welfare Technology), where assistive devices are stored (ill. 54-55). It was believed that these products could help stabilize the wrist, but upon testing, the team realized that the devices were uncontrollable and, therefore, would worsen the problem. Consequently, the team went in a different direction.



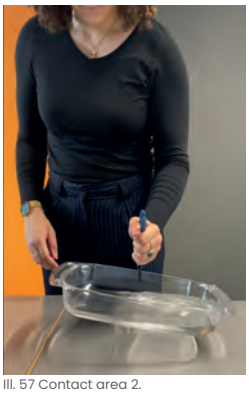
Ill. 54 Balance device 1.



Ill. 55 Balance device 2.

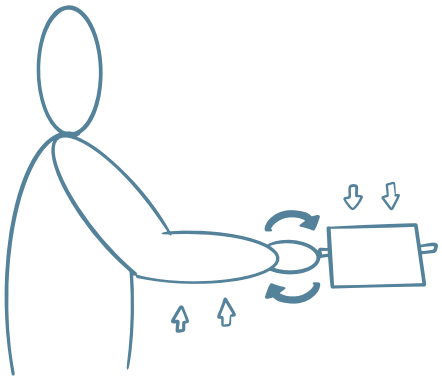
By adding different contact area sizes to a baking dish, it was investigated how the size and placement of the contact area could influence the stabilization of an object. This test determined that stabilizing the baking dish required a contact area that covered at least 25% of the center along the dish's longest side (ill. 56, 57 & 59).

Ill. 56 Contact area 1.

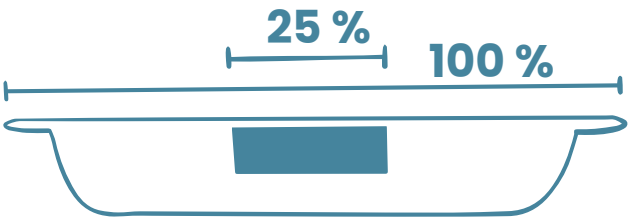


Ill. 57 Contact area 2.

Lastly, it was tested through mockups how the product proposal could support the arm and help distribute the weight when lifting a pot. Support in the form of a ruler was added to an oven mitt, but the "support" didn't help because no moment was created (ill. 50-51). However, The crutch solution creates a moment around the handle and supports the arm (ill. 58). Therefore, through the tests, it was discovered that a handle is needed to create the moment that divides the weight and supports along the arm.



Ill. 58 Creating a moment.



Ill. 59 Size of contact area.

Requirements:

The proposal must cover 25% of the length of the pot and baking dish.

The proposal must fit one of the longest sides at the midpoint of the pot and baking dish.

The proposal must create a moment between the pot or baking dish and the arm.

Measurements

The requirements needed to be more specific, with a more specific concept direction and testing of different principles for the product proposal. Making the requirements more specified will help make the decision-making and prototype-building process easier. The more specified requirements were made by measuring the different aspects influencing the product proposal. This was done through desktop research and acting out (app. 18 and 19).

The Context

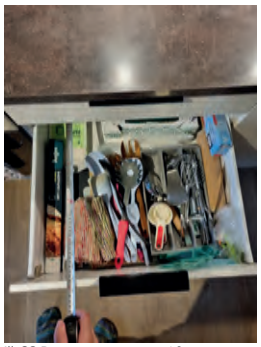
During the Shadowing, the team discovered that the user kept her potholder in a kitchen drawer. Therefore, it was investigated where individuals keep their potholders and oven mitts.

63% of the respondents had oven mitts and potholders in a kitchen drawer, 25% hanging on a wall, and 12% in a cabinet.

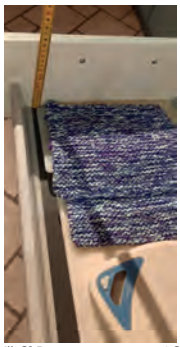
The respondents were also asked to measure the space around their potholders and oven mitts (ill. 60-63). From the data received, it was clear that the kitchen drawers would be the most critical space to make the product proposal fit into, as some strict measurements had to be met. One of these measurements was the height of the drawer, which only allowed the product proposal to be 160 mm in height.

Requirement:

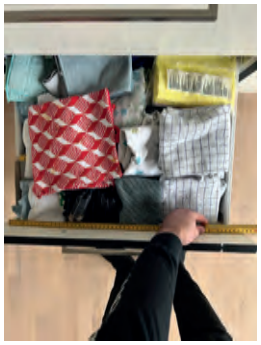
The proposal must have a maximum height of 160 mm.



Ill. 60 Draw measurement 1.



Ill. 61 Draw measurement 2.



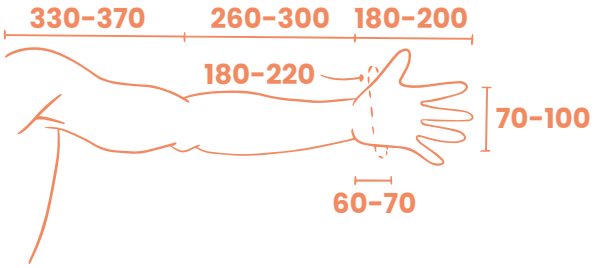
Ill. 62 Draw measurement 3.

Ill. 63 Draw measurement 4.

The received data also showed that oven mitts and potholders were not the only kitchen equipment placed at their given location. A kitchen weight, cooking spoons, etc., could be found with the potholder, dishcloths, and tea towels. Therefore, this must also be considered when developing the product proposal.

The User

As the arm attachment of the product proposal will be placed around the user's arm, it made sense to also look at arm measurements. Through a report (Gordon et al., 1989), different measures were found for various parts of the arm for both women and men. Spans were created for each part of the arm by taking the smallest and largest measurements that could be translated into the product proposal (ill. 64).

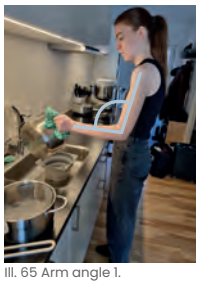


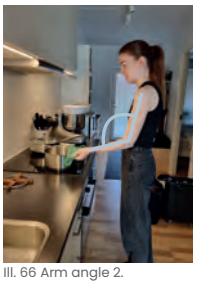
Ill. 64 Arm measurement.

Angles

The method of Apprenticeship (Sperschneider & Bagger, 2003) was used to understand the different positions of the arm better when cooking. During this, one of the team members simulated different cooking scenarios with one arm, such as taking a baking tray out of the oven, lifting a pot, and pouring water out of a pot. The data was analyzed afterward, and it could be seen that the arm is between 100 and 150 degrees (in an angle between the upper and lower arm) during cooking (ill. 65-67).

It was discovered that the pot is tilted 90 degrees when pouring water into the sink. Therefore, the product proposal must allow this movement in addition to the other angles.


Ill. 65 Arm angle 1.


Ill. 66 Arm angle 2.


Ill. 67 Arm angle 3.

Requirements:

- The proposal must allow the arm to go from a 100-150-degree angle between the upper and lower arm while using it.
- The proposal must allow the user to tilt a pot 90 degrees.
- The proposal must enable the lifting and carrying of objects with lengths ranging from 200 to 500 mm.
- The proposal must fit the average handbreadth of 70-100 mm.
- The proposal must fit the average hand circumference of 180-220 mm.
- The proposal must fit the average hand length of 60-70 mm from wrist to grip.
- The proposal must fit the average lower arm length of 260-300 mm from elbow to wrist.

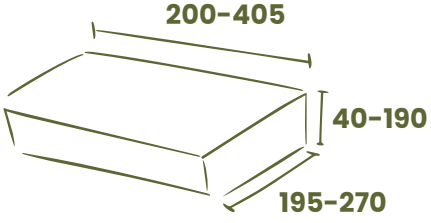
Interface on the Objects

Based on the interviews and shadowing, the user must be able to lift and carry pots and baking dishes with the product proposal. Therefore, it must be ensured that it can attach to the different pots and baking dishes. These were investigated in terms of measurements and materials. In addition, the temperature that the product proposal must withstand will also be investigated. These measurements will help determine if it is possible to make a universal attachment that can attach to all the different pots and baking dishes.

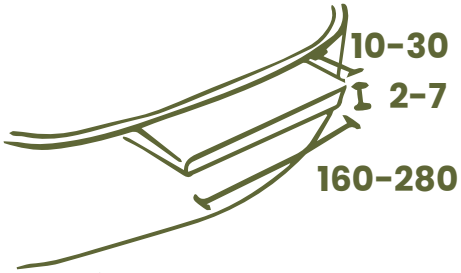
Measurements

The investigation was done through desktop research and field research in a cookware store to find the last measurements. (app. 18 & 20)
Different measurements were found on these objects, resulting in length, height, and depth spans.

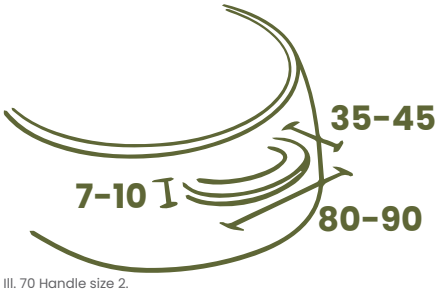
Furthermore, the body and handles of pots and baking dishes were measured. This concluded that the handle sizes and shapes of the various pots and baking dishes differ. However, the measurements of the edges of the baking dish and pots are alike throughout (ill. 68-70).



Ill. 68 Object size.



Ill. 69 Handle size 1.



Ill. 70 Handle size 2.

Weight

To find the maximum weight of these objects, research was conducted on the average family size, the most popular dinner dishes in Denmark in 2023, and how much potato the average person eats, as potatoes were among the most popular dishes. It is also assumed that potatoes are one of the heavier dishes served.

Based on these facts, the team conducted a test by filling a 3-liter pot with water and 1000g of potatoes, enough to feed a family of four (Alletiders Kogebog, n.d.). The pot with contents weighed 3300g.

Temperature

The product proposal involves attaching onto objects in the oven and on the stove. A stove can reach a maximum temperature of 220 degrees Celsius (Samvirke, 2022), and an oven can reach a maximum temperature of 300 degrees Celsius (Ovn Test, 2023).

Requirements:

- At a minimum, the proposal must allow lifting and carrying objects at 3300 grams.
- The proposal must withstand a temperature of 300 degrees Celsius.
- The proposal must enable the lifting and carrying of objects with lengths ranging from 200 to 450 mm.
- The proposal must enable the lifting and carrying of objects with heights ranging from 40 to 190 mm.
- The proposal must enable the lifting and carrying of objects with depths from 195 to 270 mm.

Grabbing onto the Object's Handles or Edge

When gripping the different objects, the product proposal can either grab onto the handle or on the edge of the objects. Pros and cons for each direction have been listed:

Interface on the Handles

Pros:

- The device will not be touching food/water.
- The proposal will utilize the handles and how the user interacts with the object.
- While using the proposal, the pot can have a lid on it.

Cons:

- There will be a need for more than three different grippers to grab onto the various handles.

Interface on the Edge

Pros:

- This solution would need fewer grippers or only three grippers.

Cons:

- The proposal will be touching food/water.
- The handles on the pots and pans will be in the way.
- It is not possible to use a lid while gripping onto the object.

After considering the pros and cons of comparing the interface on the edge to the interface on the handles, it has been decided to continue working with the proposal attached to the handles. The next step was to investigate the solution space for how the device could attach to the different handles. The following directions were investigated by testing mockups (app. 21).

Requirements:

- The proposal must fit a handle with a widths of 80 to 280 mm.
- The proposal must fit a handle with a thickness of 2 to 10 mm.
- The proposal must fit a handle with a depths of 10 to 45 mm.

Different Head Attachments

The solutions regarding changing the head of the proposal (whether it is only the head itself or the whole head with the handle) will make the routine longer than before. Instead of just being able to grab the product proposal and do what they wanted to do, the user needs to lay the product proposal down on the kitchen counter, change the head, and then move on with what they initially wanted to do. This can create frustrating situations when the user needs to do something fast. For example, if the potatoes boil over, they must grab them fast.
Changing the gripper is like having a potholder for each pot, and you can only take the red pot with the red potholder (ill. 71-73).

Ill. 71 Different head attachments 1.

Ill. 72 Different head attachments 2.

Ill. 73 Different head attachments 3.

Creating the Same Interface

With this solution, it's essential to be aware that others (not arm amputated) still need to be able to use the object. With an attachment installed onto the different pots and pans, you can use the same potholder on all your cookware (ill. 74-76).

Based on the findings of this test, the direction in which an attachment is installed on the cookware will be the direction continued. This will allow the user to use the same device to grab different objects, simplifying the user's routine instead of changing heads depending on the object. In addition, how this attachment could be installed was researched. However, it was concluded that this needed testing to determine the best solution (app. 22).

Ill. 74 Same interface 1.

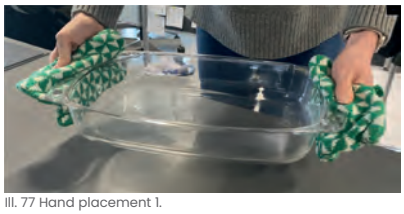
Ill. 75 Same interface 2.

Ill. 76 Same interface 3.

Requirement:

A universal attachment must be installed on the pot and baking dishes.

The next area that was looked into was ensuring the attachment on the object didn't interfere with others using the pot. To ensure this, it was investigated where the hands are placed when using the pot and baking dish (ill. 77-79). Non-arm amputees also need to be able to grab the cookware and baking dish with the attachment installed. Therefore, the product proposal must allow this. (app. 22)



Ill. 77 Hand placement 1.

Ill. 78 Hand placement 2.

Ill. 79 Hand placement 3.

Requirement:

The proposal must allow the non-arm amputees to interact with the pot and baking dish as before the attachment installation.

Design Brief 4

During phase four testing, existing principles and measurements were investigated to create measurable requirements for a better understanding of the product proposal. It was found that interaction with the objects should be through the handles. Because of the different shapes of the handles, it was decided that there should be an attachment on the object to create a universal interface.

Metaphor

"It should be like an oven mitt."

Problem Statement

How to design an assistive device that provides arm amputees with a secure grip, minimizes overuse, maintains balance while handling cookware or a baking dish, and helps maintain arm strength? Additionally, how can the device be integrated into the kitchen environment and routine, ultimately enhancing the quality of life for the users?

Vision

Our product proposal must recreate the trust they had in lifting and carrying with two hands.

Product proposal

Requirements:

~~Using the proposal, the user must be able to lift and carry the pot and baking dishes during cooking as they did pre-amputation.~~

The proposal must be made of dishwasherproof materials.

The proposal must be made of food-safe materials.

The proposal must help the user maintain their strength.

The proposal must facilitate independent application by the user, utilizing the same arm as the product is intended to be worn on.

~~The proposal must be able to fit into a kitchen drawer.~~ ▶The proposal must have a maximum height of 160 mm.

The proposal must allow the user to take it on and off in 2 sec.

~~The proposal must enable the user to pour out water from a pot.~~ ▶The proposal must allow the user to tilt a pot 90 degrees.

The proposal must enable the user to lift a filled pot.

The proposal must enable the user to take a filled baking dish out of the oven.

The proposal must divide the pot and baking dish load over multiple joints while lifted and carried.

The proposal must allow the user to place it by the stove, oven, and sink.

The proposal must ensure a continuous firm grip around the pot and baking dish.

The proposal must stop the pot and baking dish from rotating out of the hand.

The collaboration company must be an existing supplier of the municipalities of Denmark.

The proposal must fulfill the requirements for a medical device class I.

The proposal must be CE-certified.

★ The proposal must create a moment between the pot or baking dish and the arm.

★ The proposal must allow the arm to go from a 100-150-degree angle between the upper and lower arm while using it.

★ At a minimum, the proposal must allow lifting and carrying objects at 3300 grams.

★ The proposal must withstand a temperature of 300 degrees Celsius.

★ The proposal must enable the lifting and carrying of objects with lengths ranging from 200 to 500 mm.

Needs:

The proposal should fit the same design language as kitchen equipment.

The proposal should be in neutral colors.

The proposal should be in the price range of 200 to 2000 DKK.

The proposal should be made from durable materials.

~~The proposal should fit into the user's existing routine when cooking.~~

The Arm Attachment

Requirements:

The proposal must fit the average lower arm lengths of 260-300 mm from elbow to wrist.

Needs:

The proposal should be comfortable to wear on the arm.

The Proposal's Handle

Requirements:

The proposal must ensure the user's hand is placed in a neutral position.

The proposal must enable the user to lift and carry with the palm of the hand.

~~The proposal should physically fit the user.~~ ▶

- The proposal must fit the average handbreadth of 70-100 mm.
- The proposal must fit the average hand circumference of 180-220 mm.
- The proposal must fit the average hand lengths of 60-70 mm from wrist to grip.

Needs:

There should be a clear indication of where to place the hand when using the product.

The Pot and Baking Dish Attachment

Requirements:

The proposal must allow the use of a pot lid.

~~The proposal must ensure the stabilization of the pot and baking dish while lifted and carried.~~ ▶ The proposal must cover 25% of the length of the pot and baking dish.

- A universal attachment must be installed on the pot and baking dishes.
- The proposal must fit one of the longest sides at the midpoint of the pot and baking dish.
- The proposal must allow the non-arm amputees to interact with the pot and baking dish as before the attachment installation.
- The proposal must fit a handle with a widths of 80 to 280 mm.
- The proposal must fit a handle with a thickness of 7 to 10 mm.
- The proposal must fit a handle with a depths of 10 to 45 mm.

Phase 5

In phase five, the team will test whether a mechanical solution is necessary. Three prototypes will be constructed and tested with the user to gather feedback. In addition, the proposal's visual expression will be considered further.

Is Mechanical the Solution?

The ideas up until now consisted of mechanical solutions for grabbing the object. When looking closer into how a mechanical prototype could be constructed, the team found that this would make the prototype and, therefore, the product proposal more complex. Thus, the team questioned if the proposal had to be mechanical, as there was a wish to keep it more uncomplicated. This became the focus when making the prototypes.

First Prototype

A functional prototype was created to identify any issues early in development. This involves working in the workshop and seeking assistance from the workshop worker. It is expected that some parts of the solution may not work as intended. Still, engaging with the prototype can generate new ideas to resolve issues rather than simply doing desktop research. (app. 23)

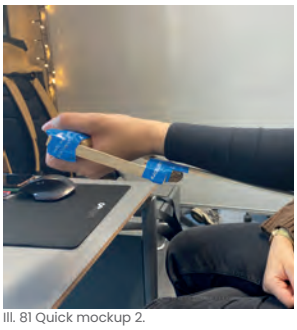
Before making a prototype, the crutch solution was tested again to understand how this construction could be imitated in a prototype. However, when doing so, the team realized that unnecessary strength was used to hold the device as gravity pulled it down while it was also heavy to carry. The device was weighed to 768 g.
As a result, it was questioned if this could be avoided by having a "horizontal" handle instead of the "vertical" handle on the crutch solution. Through testing, it was concluded that a horizontal handle, allowing the handle to rest in the palm of the hand, was more comfortable as fingers wouldn't strain in an attempt to hold the device. Consequently, the team decided to make the handle horizontal and add the requirement that the product proposal be lighter than the crutch solution.

Requirement:

The proposal must weigh less than 768 g.

A quick mockup was created to understand how the construction would look if the handle were placed horizontally instead of vertically (ill. 80-81). This helped to determine that the handle should be positioned higher than the rod on which the arm is placed. This is necessary to ensure the user's hand is neutral while using the product.

Ill. 80 Quick mockup 1.

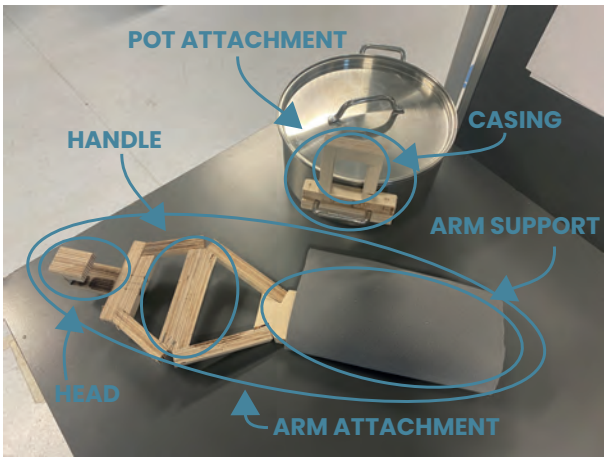


Ill. 81 Quick mockup 2.

The prototype was constructed in wood with fabric around the arm (ill. 82-84). Rubber was mounted on the bottom of the prototype to ensure friction, as tested on the oven mitt.
The initial prototype was constructed out of wood to better understand the construction of the prototype before making it out of a more complex material, like metal. This was done to ensure that if any issues were found in the construction, it could be easily disassembled and reassembled again. However, this also resulted in some dimensions being larger than necessary for the actual product proposal. This could lead to misleading results when testing out the product's functions, particularly concerning the size of the hook and the pot attachment. Therefore, it is essential to consider these factors.

Ill. 82 Making prototype 1.

Ill. 83 Making prototype 2.



Ill. 84 Part names.

Insights while making the prototype:

When handling the prototype, it's essential to account for the extra space required for the fingers to wrap around the handle. Initially, the fingers are straight, occupying more space before closing around the handle. This leads to the hook being positioned farther away from the hand, leaving a space of 43 mm.

Creating a one-size-fits-all solution that works for every user is not feasible. If the proposal is made bigger to fit a larger arm, it becomes loose on someone with a smaller arm. Thus, the solution around the arm and the handle size must be customizable. (Currently, the size of the handle is 116 mm.)

The prototype tilts because its weight is unevenly distributed towards the handle and hook.

The arm is more relaxed because the handle is placed 20 mm higher than the rod.

The distance between the handle and the end of the arm rod should be reduced to about 7 mm.

Testing the Prototype

During prototype testing, an empty pot was used to confirm that it could handle the weight. The pot was then filled with water, lifted, and tilted without falling off the hook (ill. 85-86). However, some adjustments must still be made to fulfill the core tasks.

Ill. 85 Testing prototype 1.

Ill. 86 Testing prototype 2.

Inserting the Hook

Ill. 87 Testing prototype 3.

Ill. 88 Testing prototype 4.

Ill. 89 Testing prototype 5.

Ill. 90 Testing prototype 6.

Insights

Lifting the Pot from the Surface

When lifted, the pot rotates slightly away from the body, likely due to the movement between the hook and the pot as experienced during Apprenticeship (see "Apprenticeship").

Tilting the Pot

When the pot was tilted, it caused the hook and pot to move, making it feel unsafe (ill. 86).

The pot rotates when it gets tilted to the side to pour water.

When tilting the pot, it doesn't provide much support for the arm, but the test person still uses their larger muscles.

Other Insights

The interaction area is too far away from the pot.

It supports the underarm as expected.

The weight is moved into the hand.

The fabric is wider at the opening and tapers towards the end, resulting in a better lifting fit.

The angle of the handle prevents the wrist from straining.

The textile on the handle creates a "comfortable" grip.

Inserting the hook (ill. 87-90) is a little challenging initially. It could be made more manageable (and quicker).

The prototype weighs 500 grams.

The Shape of the Handle

During the test, it was found that the handle would be more comfortable if it mimicked the natural shape of the hand. It was noticed that crutches have thicker handles in the middle, allowing the hand to relax more effectively (ill. 91-93).


Ill. 91 Handle shape 1.


Ill. 92 Handle shape 2.


Ill. 93 Handle shape 3.

Vertical vs. Horizontal Handle

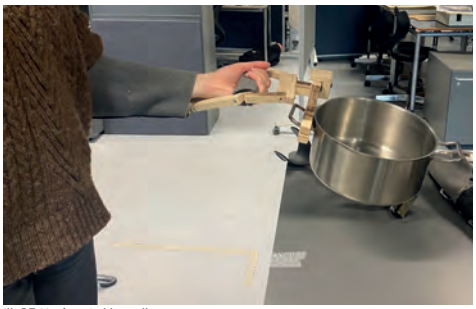
The crutch solution was compared to the prototype to ensure that turning the handle horizontally was the right decision (ill. 94-95).

After reviewing the test results, it has been decided to proceed with the horizontal handle solution. Using the horizontal handle was more comfortable, as it rested in the palm and allowed the test person to let go of the pot without dropping it.
Three individuals tested the prototype: a muscular male, a shorter female, and a tall female. This quick experiment revealed a significant variation in how well the prototype fit each person. (app. 23)

The next step is to create a second version of the prototype, addressing the issues from the first version:

- The interaction area should be closer to the pot.
- The prototype should support the arm when tilting the pot.
- Ensure that the pot doesn't "rotate" when tilted.
- Make it quicker/easier to insert the hook.
- Ensure that the pot doesn't rotate when it is lifted.


Ill. 94 Vertical handle.


Ill. 95 Horizontal handle.

Static Gripper Principles

With the decision to move away from making a mechanical solution and with the hook solution not working, there was a need to research "static" ways of grabbing and lifting objects. This was done through desktop research where existing principles from static grippers were found (app. 24).

Tool Hook

The tool hook principle consists of two hooks mounted to a wall in which a tool is slit into. The tool has a rod going between the two hooks with a horizontal part resting in the two hooks. This stops the tool from sliding further down (ill. 96-97).

This could be a possible solution for the product proposal, as the tool is locked in the sense that it can only come out the same way it came in. However, this solution is only seen when hanging objects. It has not been possible to find an existing solution like this for lifting objects, and therefore, this is the closest resemblance.


Ill. 96 Tool hook 1.


Ill. 97 Tool hook 2.

Pallet Lifter

A pallet lifter is a well-known static way of lifting an object. It consists of two long prongs slid into the two holes of a pallet, allowing the user to lift the heavy pallet (ill. 98).
Pallet lifters are known for lifting objects upright, but the product proposal also needs to be able to tilt without the object falling off. However, it was possible to find more advanced pallet lifters that could tilt the lifted object, though they can only tilt 40 degrees (ill. 99).


Ill. 98 Pallet lifter 1.


Ill. 99 Pallet lifter 2.

The pallet lifter principle could also be a principle for the product proposal. Like the tool hook, the object is locked as the prongs must slide out the same way they came in. However, the holes have been made wider to make it easier for the user to insert the prongs, resulting in the object being able to slide when tilted. If the solution were translated to the product proposal, the holes had to be smaller, resulting in possible complications when inserting the prongs.

Conclusion

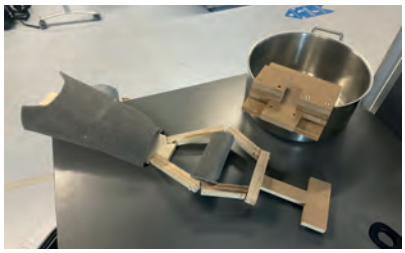
Though the pallet lifter is a well-known lifting principle, there was a need to test out the "tool hook" principle. The principle seemed compatible with the product proposal as the user would have a T-shape that would slide into a casing, making the user feel when the T-shape is placed correctly. Furthermore, it seems easier to slide the T-shape back into the casing than to hit the two prongs into the holes. Something to consider from the pallet lifter is that the prongs go underneath the object it is lifting, making the object rest on the prongs.

Second Prototype

The second prototype will incorporate the successful aspects of the first prototype, including the arm support, the fabric with rubber, and handle while testing a new static grip principle, the tool hook principle.
The process started with Brain Pool Writing on the areas that required improvement. Then, a rough prototype sketch was created (ill. 100), which was later constructed in the workshop. As a result, the hook was replaced with a T-shaped component (ill. 102) and a new casing (ill. 101) to test if this could resolve the issues. (app. 25 & 26)


Ill. 100 Prototype sketch.


Ill. 101 New casing.


Ill. 102 Second prototype.

Testing the T-shape

Putting the T-shape into the casing resulted in a "backward" movement. The test person placed the T-shape on the surface behind the casing and slid it back towards themselves until it hit the back wall inside the casing, telling the test person that it was placed correctly (ill. 103-106).
During testing, it was found that the time it took to attach the pot remained the same in both versions. However, it was easier to coordinate the placement of the T-shape into the casing in the second prototype than in the first one. Also, the pot did not rotate away from the body when lifted.

The test person naturally raised their arm away from their body when tilting the pot to pour water (ill. 107), which was initially suspected to be caused by the prototype. However, the same was confirmed without the prototype (ill. 108). After analyzing the situation, it was concluded that this was a natural and insignificant motion.


Ill. 103 Testing the T-shape 1.


Ill. 104 Testing the T-shape 2.


Ill. 107 Tilting w. T-shape.


Ill. 105 Testing the T-shape 3.


Ill. 106 Testing the T-shape 4.


Ill. 108 Tilting without T-shape.

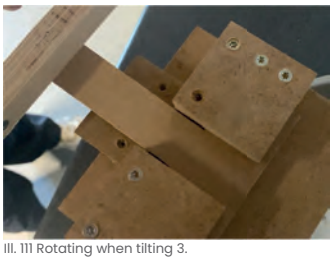
Stop the Pot from “rotating” when Tilted

The pot rotated again while pouring water into the sink, just like in the first prototype (ill. 109-110). Analyzing the issue led to a solution - placing a piece of wood on each side of the casing prevented it from rotating, and chamfering the two pieces of wood facilitated easier insertion of the T-shape into the casing. This solution effectively minimized the pot rotating. However, the pot can still rotate slightly to allow for some tolerance in inserting the T-shape into the casing, as observed in the picture (ill. 111-112). Nonetheless, the new solution significantly enhances safety.

The decision has been made to continue with the T-shape design, as the issue with the rotating pot has been successfully resolved. However, the proportions of the prototype could be improved. It is assumed that this will be resolved by fabricating a metal prototype.


Ill. 109 Rotating when tilting 1.


Ill. 110 Rotating when tilting 2.


Ill. 111 Rotating when tilting 3.


Ill. 112 Rotating when tilting 4.

Support the Arm when Tilting the Pot

A new prototype was created that was identical to the current one. However, a piece of wood was added to the side of the latest prototype to support the underarm when tilting (ill. 113-115). This modification allows for a comparison between the two prototypes and determines if the addition of the wooden piece makes a noticeable difference in performance.

The added piece worked as hoped by creating support when tilting the pot (ill. 116-117). However, the prototype had become much heavier on the arm because of the thick piece of wood added. It is assumed that the proportion of the support will be solved when making the prototype in metal.


Ill. 113 Support when tilting 1.


Ill. 114 Support when tilting 2.


Ill. 115 Support when tilting 3.


Ill. 116 Testing support when tilting 1.


Ill. 117 Testing support when tilting 2.

Shortening Tilting Support

As the arm did not touch the whole board, some material that supported the arm when tilted was removed to make the prototype lighter without degrading the tilting experience (ill. 118-119).


Ill. 118 Shortening support 1.


Ill. 119 Shortening support 2.

Changing the Handle Height

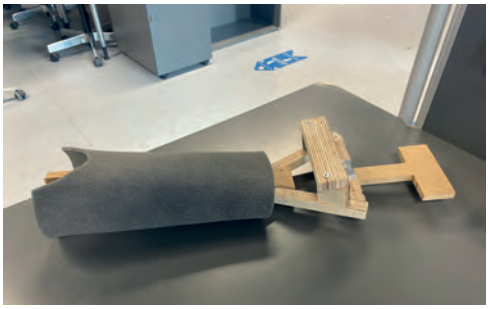
When the test person lifted a pot, their wrist tended not to touch the support. Therefore, the handle was raised, resulting in the hand moving into a neutral position while lifting. However, the team realized that this didn’t influence the experience of the support. Having the wrist against the support doesn’t help, as it naturally raises itself when the muscles are tensed (ill. 120).


Ill. 120 Changing the handle height.

Second Test of the Prototype

Adjusting the handle's position made it possible to remove some parts, allowing the T-shape to be closer to the hand and body. This adjustment made lifting the pot a more pleasant experience and made it seem lighter than when it was further away, just as the physiotherapist had advised. Additionally, the T-shape became more accessible to handle and place in the pot attachment (ill. 121-126).

It would be great if the hand could be positioned closer to the pot. This would make it easier to lift and move the pot around.


Ill. 121 Second test 1.


Ill. 122 Second test 2.


Ill. 123 Second test 3.


Ill. 124 Second test 4.


Ill. 125 Second test 5.


Ill. 126 Second test 6.

New Placement of the T-shape

The T-shape was placed underneath the hand to get the pot closer to the hand (ill. 127-130). This improved the control over the lifted pot and made it feel like the weight was more evenly distributed in the palm rather than in front of the hand, making the object seem less heavy. However, maneuvering the T-shape into the casing proved difficult, as it was not intuitive where it should be positioned relative to the handle (ill. 131-133).


Ill. 127 New placement 1.


Ill. 128 New placement 2.


Ill. 129 New placement 3.


Ill. 130 New placement 4.

To imitate the movement of grabbing a pot, the pot attachment was rotated by 180 degrees, creating a reversed version of the original concept. This modification led to a more intuitive movement, allowing a forward hand motion to grasp the pot, unlike the previous backward slide. Although the pot tilting remained unchanged, there is now a risk of the pot dropping if the arm is turned downwards. Previously, the pot could only slide out of the casing if the arm were held at a 45-degree angle or lower between the upper and lower arm.


Ill. 131 Test new placement 1.


Ill. 132 Test new placement 2.


Ill. 133 Test new placement 3.

A prototype must be created using a more durable material to test both methods of inserting the T-shape into the casing and determine if friction improves safety.

Test of the Attachment

Requirements need to be made before the pot attachment can be made. The requirements were made based on the knowledge gained about the user.

There was a wish to make the pot attachment easy to install. By "easy," it meant that the installation could be done with only one hand and without multiple tools. Additionally, removing the attachment from the pot and baking dish should allow the user to change their pots and baking dishes. Lastly, it must be securely placed without any movement.

Requirement:

The user must be able to install the pot and baking dish attachment.

The user must be able to install the pot and baking dish attachment using one tool.

The pot and baking dish attachment must be detachable.

The pot and baking dish attachment must be securely placed without any movement.

Detachable Solution

Two different principles were tested through a test on how to make a detachable solution for the pot attachment (app. 27). Following the test, it was determined that the screw solution is the best option for the proposed product as it provides a level of security that is difficult to find in other products. Additionally, this solution can be used on handles of different thicknesses, unlike the other principle, which cannot accommodate this requirement.

However, the attachment could still slide a little on the handle. Silicone foam was added to the screw solution to see if it would provide a better solution. However, the foam wasn't firm enough and bulged out due to the pressure it was under. This lack of firmness also led to the attachment rocking. Despite these issues, the foam could tightly form around the handle, providing slip-resistant properties to the solution. Furthermore, the silicone hinders the attachment from scratching the pot (ill. 134-135).

Ill. 134 Detachable solution 1.

Ill. 135 Detachable solution 2.

It was debated whether the users needed to install the attachment themselves as the municipalities would deliver the product proposal and ensure it fits the user. It was decided that the municipalities would install the attachment on the pot, making it a one-time task.

Baking Dish Attachment

A prototype of the attachment for a baking dish was made and tested, questioning whether installation was necessary on both sides (ill. 137) or if one side (ill. 136) was sufficient (app. 27). Upon testing, it was found that the lifting experience remained the same as before, but the baking dish began to slide around when held in place at only one point.
The positioning of the attachment on the baking dish causes it to be placed relatively far away from the hand (290 mm), making it uncomfortable to lift and carry. Therefore, solutions must be found to bring the hand closer to the baking dish and the pot.

Ill. 136 Baking dish attachment 1.

Ill. 137 Baking dish attachment 2.

Requirement:

The pot attachment must not scratch the pot.

~~The user must be able to install the pot and baking dish attachment.~~

~~The user must be able to install the pot and baking dish attachment using one tool.~~

Oven Mitts' Visual Expression

As the product proposal metaphor has been that "it should be like an oven mitt," and it currently imitates the function and use of an oven mitt, desktop research was conducted on the visual expression of oven mitts, potholders, and grill gloves (ill. 138). This was done to understand better the visual expression of this type of kitchen equipment and ensure the product proposal would fit into the kitchen context (app. 28).

Insights

The longest oven mitt is 530 mm.

The longest grill glove is 400 mm.

Oven mitts are available in many colors and are made of silicone and fabric.

Potholders are mostly round or square.

Grill gloves have individual fingers, while only the thumb is separated from the rest of the fingers in oven mitts.

Oven mitts have a rounded shape that follows the shape of the fingers.

Grill gloves have a "rougher" and more eye-catching look than the more passive oven mitts.

Ill. 138 Oven mitt expression.

Conclusion

Oven mitts, potholders, and grill gloves are versatile in their visual expression. Grill gloves are assumed to be more eye-catching as they are used in an outdoor environment where they can quickly disappear. Furthermore, grill gloves have individual fingers, while oven mitts do not, which is presumed to be because equipment like tongs are used with the grill gloves. This is unnecessary in the kitchen as oven mitts are used to grab baking dishes and cookware.
Fabric or silicone (or a combination of both) is often used in this product type. In addition, long oven mitts are not uncommon, as one was 530 mm long. Therefore, it is assumed that it is acceptable that the product proposal has approximately the same length.

Third Prototype

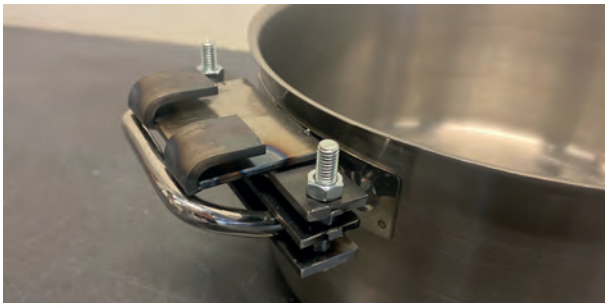
A third version of the prototype was created in metal. This was done to see how much it was possible to downscale the different parts, as it was assumed that the pot attachment and the T-shape could be downscaled a reasonable amount.
Furthermore, there was also a desire to test the friction in this new material to ensure that the principle with the T-shape still works. It was assumed that the metal would have less friction than the wood.
Later, a scenario would be created where the test person had to carry a pot of boiling water to test the prototype (app. 29 & 30).

Downscaling

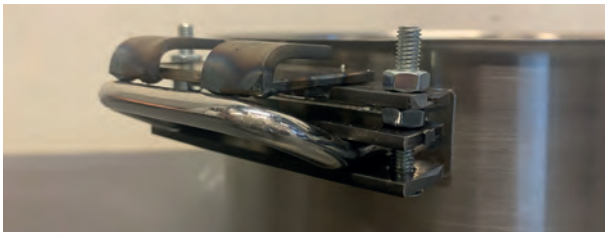
As metal is a much stronger material, it was possible to downscale the prototype significantly compared to the last (ill. 139-142). However, the pot attachment and the T-shape still had to be big enough to fit the different handles measured previously in the process (see "Interface on The Objects").
Furthermore, the user must also trust the product proposal and believe it can carry the weight of a filled pot, which could become an issue if it is downscaled too much.

Ill. 139 Third prototype 1.

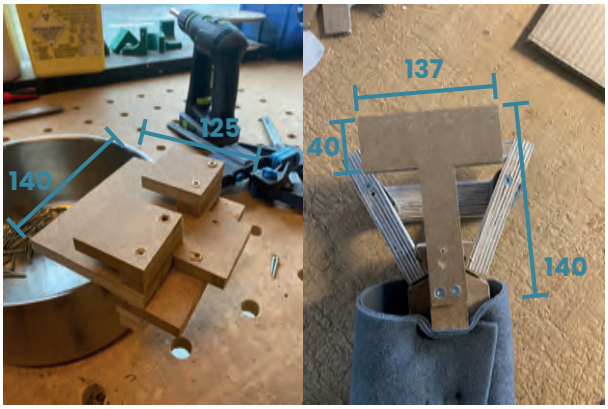
Ill. 140 Third prototype 2.



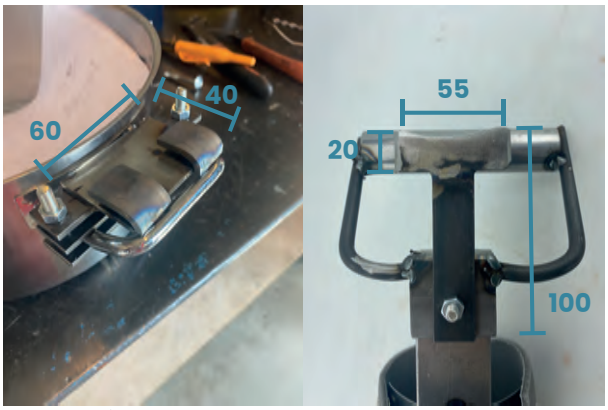
Ill. 141 Third prototype 3.



Ill. 142 Third prototype 4.



Ill. 143 Downscaling 1.



Ill. 144 Downscaling 2.

It was possible to downscale the T-shape by 45%, while the pot attachment was downscaled by 56% compared to the wooden prototype. The T-shape now had a width of 55 mm, while the pot attachment had a width of 137 mm (ill. 143-144).

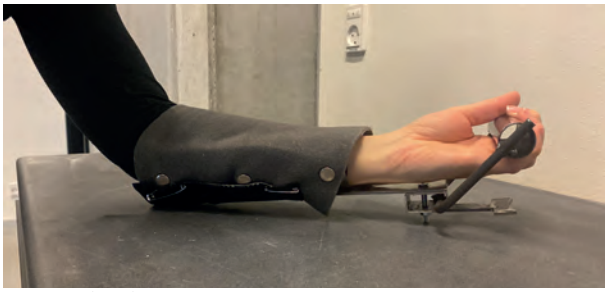
Scenario Testing

Through the method of Apprenticeship (Sperschneider & Bagger, 2003), a worst-case scenario was laid out where the test person had to walk 4 meters from the sink to the stove using the prototype to lift and carry a pot with boiling water. During the testing, the T-shape was placed into the casing in a backward motion (see "Testing the T-shape")

It was easy for the test person to put on the prototype and get it off again, as the rubber underneath helped create a higher friction than it did on the wooden prototype. However, the bolt used to mount the handle to the arm support peeped out underneath, lifting the whole arm attachment and reducing the contact area between the rubber and the countertop (ill. 145-146).

Insight

The entire rubber surface must have contact with the surface on which it rests.



Ill. 145 Scenario testing 1.

Ill. 146 Scenario testing 2.

When testing the friction of the prototype, the friction was the same as the wooden prototype. This meant that sliding the T-shape in and out of the casing was still easy.
With the downsizing of the T-shape and pot attachment, the T-shape became harder to see as the hand now blocked the view. However, after a couple of tries, the test person could place the T-shape into the casing without looking.

Insight

The test person can learn how to place the T-shape after a couple of tries and even do it without looking afterward.

The test person had to fill the pot with water. The test person placed the pot in the sink and was meant to remove the arm attachment, but the test person could not remove the arm attachment at this angle, so it had to stay on the pot. This resulted in the arm attachment resting on the countertop, leaving the pot lopsided in the sink (ill. 147).
A solution to this problem was to place the pot on the countertop in the corner of the sink and turn the kitchen faucet over the pot (ill. 148).

Insight

The arm attachment leaves the pot lopsided in the sink if it is left attached into the casing.


Ill. 147 Scenario testing 3.


Ill. 148 Scenario testing 4.

The test person fully trusted the prototype while moving the pot with boiling water from the sink to the stove. It was easy to walk without the pot rotating out of the hand, and the prototype supported the arm, making it easier to carry (ill. 149).

Lastly, the test person was able to pour the boiling water into the sink using the prototype. The pot did not move or make any uncomfortable movement (ill. 150).


Ill. 149 Scenario testing 5.


Ill. 150 Scenario testing 6.

Test with Boiling Water

Another test with the new prototype was whether the hand would get burned during cooking. To test this, a 5-liter pot was filled with water and placed on a stove until the water started boiling. While holding the prototype, the test person had their hand over the pot to see how long they could keep it in the steam. To test a worst-case scenario, the hand was held further over the pot's body than the proposal would normally demand (ill. 151).


Ill. 151 Boiling water test 1.


Ill. 152 Boiling water test 2.

The test person could only place their hand in the steam for 4-8 seconds before it got too hot. However, when placing the hand at the edge of the pot's body where it is normally placed using the product proposal, the test person wasn't bothered by the heat, as the hand wasn't directly over the steam (ill. 152). Therefore, it was concluded that a shield for the hand was unnecessary.

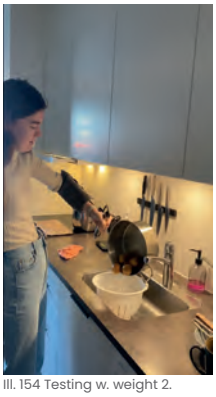
Test with Weight

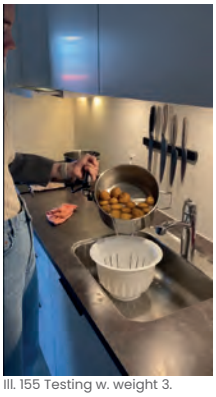
To test the prototype further, a scenario surrounding two of the core tasks was laid out: *lifting a filled pot* and *emptying a pot for water*. In doing so, the pot was filled with potatoes and water, and it ended up weighing 3500g.

The test persons could not lift the pot with just one hand, but using the prototype made it possible. Both test persons could lift the pot successfully from the stove to the sink, completing the first core task (ill. 153-155).

The test persons then had to pour the pot's content into a colander in the sink. Again, both test persons could complete the core task without the prototype giving in or making uncomfortable movements.


Ill. 153 Testing w. weight 1.


Ill. 154 Testing w. weight 2.


Ill. 155 Testing w. weight 3.

Test with an Oven

Lastly, the core task regarding *taking a baking dish out of the oven* was tested.
The test person had to attach the baking dish in the oven. In doing so, the test person's hand went inside the oven to attach the dish with the risk of the hand touching the top of the oven, resulting in them getting burned (ill. 156-158). To avoid this, the baking dish must be placed at the bottom of the oven.

Measurements were taken to determine the length of the T-shape to determine how far the hands normally go into the oven when placing a baking dish. When comparing this to the product proposal, the T-shape must be 80 mm longer to not bring the hand further into the oven (ill. 159-160)


Ill. 156 Oven test 1.


Ill. 157 Oven test 2.


Ill. 158 Oven test 3.


Ill. 159 Oven test 4.


Ill. 160 Oven test 5.

Conclusion

Overall, the tests concluded that the prototype works, as it is possible to lift the pot with its contents, which was not possible before. Thus, two of the three core tasks have been completed.
However, the pot is left lopsided in the sink because of the product proposal. A solution must be found for this problem as it is not optimal.

When developing the product proposal and prototypes, the focus was on the core tasks regarding the pot, which were more complex than first anticipated. The oven scenario should have been tested much earlier in the process, and now extending the T-shape seems like the only solution for the scenario. However, as previous prototypes have shown, it will degrade the experience with the pot. Consequently, the oven scenario was opted out as a core task.

Requirement:

~~The pot and baking dish attachment must be detachable.~~ ▶ The pot attachment must be detachable.

~~The pot and baking dish attachment must be securely placed without any movement.~~ ▶ The pot attachment must be securely placed without any movement.

User Feedback

A user visit was planned with the primary intention of getting feedback on the prototype in case of the function and if the user could see herself using it (ill. 161-164). The desired outcome from the visit was feedback on the arm and pot attachments. In addition to trying the prototype, the user was asked some follow-up questions that had come up since the last user visit (app. 31).

Putting on the Prototype

The user has found putting on the prototype effective and considers it a great solution. She appreciates the rubber bottom, which makes sliding on the prototype easy.
She suggests that it could be improved by making a place on the handle for the thumb to rest. Additionally, the user noticed that the weight of the third prototype was heavier than that of the crutch solution and preferred that the handle be placed vertically instead of horizontally.

Placement in the Kitchen

She prefers the product proposal placed on the kitchen counter next to her stove, as this will make it easier for her to use instead of putting it in the drawer even though there is enough space.

Pot Attachment

She trusts that the T-shape is strong enough to hold the pot and believes it's acceptable with the pot attachment as long as it remains accessible to others to lift it.

Mounting the Pot Attachment

When asked what she thinks about the municipality installing the pot attachment to her pot, she mentioned that she would prefer this because she would be sure it was correctly mounted. Additionally, she believed the municipalities would provide their own pots and attach the attachment to those rather than do it on citizens' pots.

Ill. 161 User test 1.

Ill. 162 User test 2.

Ill. 163 User test 3.

Ill. 164 User test 4.

Feedback

When inserting the T-shape into the casing, the user was asked for her thoughts on the missing feedback. She stated that she didn't see the need for feedback because she could feel when the T-shape hit the back wall of the casing. Adding sound feedback would make her worried about potentially not hearing it, and adding feelable feedback would make her concerned about the T-shape being more challenging to insert and remove from the casing due to minor bumps affecting the smoothness and friction.

Chapter about Muscles

The user preferred the handle to be placed vertically instead of horizontally. This raised concerns about whether the wrong decision was made in opting for the horizontal placement. To ensure the right choice was made, the physiotherapist consulted earlier in the process and was contacted again for further input (app. 31).

The physiotherapist explained that the user may find the proposed product more difficult because she is accustomed to the crutch solution and has trained the relevant muscles for that rather than for the new solution. She also compared the two solutions to two different exercises.

> *"The movement Anette has in her crutch solution can be compared to a hammer curl when training, where the forearm muscles become slightly more activated. And when the muscles of the forearm are activated, namely the brachioradialis and then it's also the biceps brachii, the biceps and brachialis are also activated so that it may be a bit of synergy. While the solution you have made perhaps disconnects the muscles of the forearm a little more, and then it's more just about the biceps."*
>
> - Rebecca Ohnstad Broch, Physiotherapist.

Bicep Curl vs. Hammer Curl

When comparing bicep curls to hammer curls, it's important to note that while bicep curls only target the biceps, hammer curls work both the biceps and triceps (ill. 165). This makes hammer curls a more challenging exercise to perform. (Simpkins, 2024)
Based on these insights, the team has decided to continue with the bicep curl solution. Furthermore, new users will not be familiar with the crutch solution.

Bicep Curl *Hammer Curl*

Ill. 165 Bicep curl vs. Hammer curl.

Requirement:

The proposal's handle must be horizontal.

Design Brief 5

Through phase 5 the prototyping started. The first prototype was made of wood and following multiple tests, and first thoughts of the visual expression, the final prototype was made of metal. This prototype underwent further testing leading to the elimination of the cores task regarding the oven scenario. The phase ended with a user visit to get feedback on the product proposal and research on the muscles to determine the horizontal handle as the most suitable solution.

Metaphor

"It should be like an oven mitt."

Problem Statement

How to design an assistive device that provides arm amputees with a secure grip, minimizes overuse, maintains balance while handling pots, and helps maintain arm strength? Additionally, how can the device be integrated into the kitchen environment and routine, ultimately enhancing the quality of life for the users?

Vision

Our product proposal must recreate the trust they had in lifting and carrying with two hands.

Product proposal

Requirements:

The proposal must be made of dishwasherproof materials.

The proposal must be made of food-safe materials.

The proposal must help the user maintain their strength.

The proposal must facilitate independent application by the user, utilizing the same arm as the product is intended to be worn on.

The proposal must allow the user to take it on and off in 2 sec.

The proposal must allow the user to tilt a pot 90 degrees.

The proposal must enable the user to lift a filled pot.

~~The proposal must enable the user to take a filled baking dish out of the oven.~~

The proposal must divide the pot and over multiple joints while lifted and carried.

~~The proposal must allow the user to place it by the stove, oven, and sink.~~ ▶ The proposal must allow the user to place it by the stove and sink.

~~The proposal must ensure a continuous firm grip around the pot and baking dish.~~ ▶ The proposal must ensure a continuous firm grip around the pot.

~~The proposal must stop the pot and baking dish from rotating out of the hand.~~ ▶ The proposal must stop the pot from rotating out of the hand.

The collaboration company must be an existing supplier of the municipalities of Denmark.

The proposal must fulfill the requirements for a medical device class I.

The proposal must be CE-certified.

~~The proposal must create a moment between the pot or baking dish and the arm.~~ ▶ The proposal must create a moment between the pot and the arm.

The proposal must have a maximum height of 160 mm.

The proposal must allow the arm to go from a 100-150-degree angle between the upper and lower arm while using it.

At a minimum, the proposal must allow lifting and carrying objects at 3300 grams.

~~The proposal must withstand a temperature of 300 degrees Celsius.~~

~~The proposal must enable the lifting and carrying of objects with lengths ranging from 200 to 500 mm.~~ ▶ The proposal must enable lifting and carrying of pots with a diameter ranging from 200 to 280 mm.

★ The proposal must weigh less than 768 g.

Needs:

The proposal should fit the same design language as kitchen equipment.

The proposal should be in neutral colors.

The proposal should be in the price range of 200 to 2000 DKK.

The proposal should be made from durable materials.

The Arm Attachment

Requirements:

The proposal must fit the average lower arm lengths of 260-300 mm from elbow to wrist.

Needs:

The proposal should be comfortable to wear on the arm.

The Proposal's Handle

Requirements:

The proposal must ensure the user's hand is placed in a neutral position.

The proposal must enable the user to lift and carry with the palm of the hand.

The proposal must fit the average handbreadth of 70-100 mm.

The proposal must fit the average hand circumference of 180-220 mm.

The proposal must fit the average hand lengths of 60-70 mm from wrist to grip.

★ The proposal's handle must be horizontal.

Needs:

There should be a clear indication of where to place the hand when using the product.

The Pot Attachment

Requirements:

The proposal must allow the use of a pot lid.

~~The proposal must cover 25% of the length of the pot and baking dish.~~ ▶ The proposal must cover 25% of the length of the pot.

~~A universal attachment must be installed on the pot and baking dishes.~~ ▶ A universal attachment must be installed on the pot.

~~The proposal must fit one of the longest sides at the midpoint of the pot and baking dish.~~ ▶The proposal must fit one of the longest sides at the midpoint of the pot.

~~The proposal must allow the non-arm amputees to interact with the pot and baking dish as before the attachment installation.~~ ▶ The proposal must allow the non-arm amputees to interact with the pot as before the attachment installation.

The proposal must fit a handle with a widths of 80 to 90 mm.

The proposal must fit a handle with a thickness of 7 to 10 mm.

The proposal must fit a handle with a depths of 35 to 45 mm.

★ The pot attachment must be detachable

★ The pot attachment must be securely placed without any movement.

★ The pot attachment must not scratch the pot.

Phase 6

Phase six will begin by detailing the product proposal and addressing the challenge of accommodating users with varying body sizes. However, due to difficulties encountered during the detailing process and questions arising about the placement of interfaces, this phase will conclude with a pivot. Despite this pivot necessitating the reassessment of specific details, considerations will be brought along throughout the process.

Detailing

Through this section, the pot and arm attachment will be further detailed, as the attachments must fit into the kitchen context. Throughout the detailing, the following requirements will be considered:

The proposal should fit the same design language as kitchen equipment.

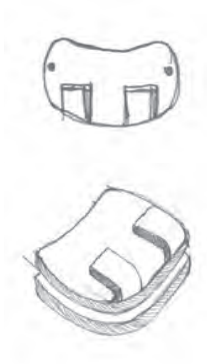
There should be a clear indication of where to place the hand when using the product.

Pot Attachment

The visual aspect of the pot attachment was discussed after a session of Brain Pool Writing, during which the pot attachment was sketched to understand the design better. It was agreed that the design should have a curved shape to blend well with the pot and the kitchen environment (ill. 166-167).

The session was followed up by desktop research on various principles for concealing the bolts, aiming to integrate them seamlessly into the product. One of the principles found was a vice, and a test was performed inspired by this principle. However, some issues arose, and consequently, the principle was deemed unsuitable for the product proposal.
The desired principle from the vice was hiding the bolt inside the two parts, adding a more "clean" look to the vice. Other solutions allowing the same cleanliness and durability were researched, and ultimately, it was decided to use a partly threaded bolt for the product proposal (ill. 168). (app. 32)

Ill. 166 Detailing pot attachment 1.

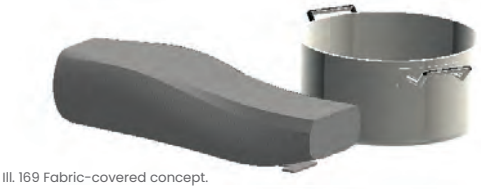


Ill. 167 Detailing pot attachment 2.

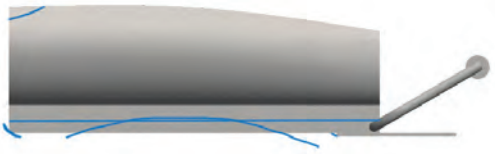
Ill. 168 Bolt.

Arm Attachment

The first visual test was to sculpt it as a 3D model to better understand the overall expression if the arm attachment resembled an oven mitt (app. 33).
A pot was placed next to the product proposal to determine if the fabric-covered concept (ill. 169) was viable. The comparison revealed that the product proposal without fabric covering the handle (ill. 170) was more suitable for the pot's expression. Furthermore, it was decided to round the arm attachment to look more suited to being worn on the body (ill. 171-172).



Ill. 169 Fabric-covered concept.



Ill. 171 Rounded arm attachment 1.

Ill. 170 Semi-covered concept.

Ill. 172 Rounded arm attachment 2.

Handle

Examining other kitchen equipment (ill. 174) inspired an indication of where the hand should be placed on the product (app. 33). The shape of the handle implies it is designed to fit a hand, while a different material or color can serve the same purpose.
Furthermore, research was conducted on how D-shaped on D-shaped handles and the continuity between the handle and the rods leading to the handle (ill. 173). The inspiration from the D-shaped handle was added to the product proposal (ill. 175).

Ill. 173 D-shape handle.

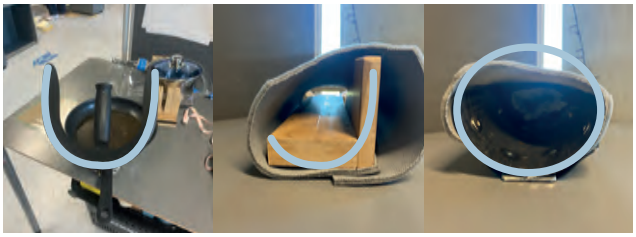
Ill. 174 Kitchen equipment handles.

Ill. 175 D-shaped handle concept.

Feedback from a user visit also highlighted the benefit of having a designated place for the thumb to rest. Consequently, a rounded edge on the end of the handle will be added to accommodate the thumb. The arm attachment's handle will be designed with a shape that indicates its purpose, with an area to place the thumb. Additionally, the material used where the hand is placed on the handle will be modified to differentiate it from the rest of the handle.

The Arm Support

The arm support was initially shaped like a "U" in the second prototype, similar to a crutch, but it was changed to an "O" shape in the following prototype (ill. 176). Both shapes were tested to determine which was more effective, and the "U" shape was the most secure. Therefore, the "U" shape was chosen as the final design for the arm support. (app. 34)



Ill. 176 Arm support shape.

Conclusion

The pot attachment was designed to fit the pot and the kitchen environment while being accessible and usable for amputees and non-amputees.

The overall design aesthetic emphasizes rounded shapes.

The arm attachment's design process culminated in:

- A rounded handle without fabric covering it
- A "U" shaped arm support
- Feedforward on hand placement.

Sizes

The goal is to determine how the arm part of the product proposal can fit multiple arm sizes. The two directions are that the product proposal is adjustable, and the other direction is that there are predefined sizes (x-small, small, medium, large, x-large). This is a need because arm size differs, and it is therefore not manageable to make a product that fits all (app. 35). For instance, a crutch may have a standard size, but it may not fit all users. The person in the pictures is size L, and the crutch does not fit him properly when he bends his arm (ill. 177-179). Hence, different sizes ensure a comfortable fit for all users.

Ill. 177 Large arm size 1.

Ill. 178 Large arm size 2.

Ill. 179 Large arm size 3.

To choose the right direction, a list of pros and cons for each available option was made (app. 35). This included price, durability, and other relevant considerations. However, it's important to note that no option will have only advantages. Therefore, all pros and cons were carefully evaluated to determine the best solution.

	Adjustable product direction	Predefined sizes product direction
Pros	Only "one-size" casting mold but multiple components. (lower cost) The size will fit the user perfectly.	Minimization of insecurities surrounding the product's durability (increase life span) The user can not adjust the product after an occupational therapist has found the correct size. No tricky corners and, therefore, easier to clean. Only a few lengths and widths of fabric are needed. Lower (loose) tolerances (lower cost)
Cons	Concerns about the durability of the adjustable mechanisms. (decrease life span) The user can adjust the product themselves after an occupational therapist has found the correct size. We need multiple lengths of fabric that fit every step of the length and width. (higher cost) Difficult corners to clean. Higher (tight) tolerances as the adjustable parts must fit perfectly. (higher cost) More parts are to be assembled. (higher cost)	Multiple casting molds. (higher cost) The sizes may not fit the users perfectly.

Conclusion

The predefined solution is believed to be more cost-effective and efficient than the adjustable solution. Furthermore, the adjustable solution created concerns about durability and complexity, which made it less feasible. Therefore, the predefined size will be chosen for the product proposal.

The predefined sizes are selected by looking at app. 18, where the sizes for both women and men are noted. Five sizes, from XS to XL, will be made using the range from the smallest women's to the largest men's.

Requirement:

The proposal must be available in sizes XS, S, M, L, and XL.

Pivot

While detailing the product proposal, it was challenging to resemble an oven mitt and an object that could fit with the attachment on the pot visually. It was therefore questioned if it could resemble an oven mitt more, as this had been the metaphor throughout the product development. While wearing an oven mitt, it is possible to do other things, but this is not possible with the current solution, as the user has their hand around the handle while wearing the arm attachment. The handle is necessary to create a moment, but it was questioned if it had to be mounted to the arm attachment. It was therefore tested (app. 36).

Ill. 180 Possible to do other things 1.

The Arm Attachment

After removing the handle from the arm attachment, the first thing tested was whether the test person could do other things while wearing the arm attachment.
The placement of the T-shape bumped into everything the test person was trying to interact with. This is not ideal, as it is in the way, and there is a risk of damaging the items (ill. 180-181).

Ill. 181 Possible to do other things 2.

When moving around, the T-shape hung loosely under the hand, making it difficult to place it into the casing (ill. 182-183). An elastic fabric could solve this issue.
In addition, it created an awkward hand position to avoid the hand lying on the T-shape. It was tested if the handle could be moved to change the placement of the T-shape, but consequently, it was concluded that the arm attachment still must be removed when not in use.


Ill. 182 Awkward hand position 1.

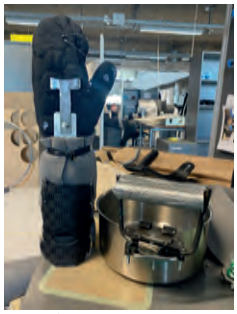

Ill. 183 Awkward hand position 2.

Requirement:

The fabric on the arm attachment must be elastic.

Arm Attachment with a Mitt

A mitt was attached to the arm attachment to make the hand position less awkward (ill. 184). Furthermore, it adds the properties of an oven mitt and protects the hand when, for example, taking things out of the oven. Once more, it was tested if it was possible to do other things while still wearing the arm attachment, and from the test person being able to fill the pot with water, it was assumed that the user would be able to do what is normally possible with an oven mitt on (ill. 185). They still need to take off the arm attachment when doing other things.


Ill. 184 Mitt concept 1.


Ill. 185 Mitt concept 2.

Requirement:

The arm attachment should end in a mitt.

The Handle

The shape of the handle needed to be changed if the user must be able to use it without the arm attachment as the pot rotates out of hand with the round shape it had at this point (ill. 187).
The wooden prototypes made earlier in the process had a square handle, stopping the prototype and pot from rotating. Thus, an oval handle was made, inspired by the square handle, but made rounder to make it more comfortable (ill. 186 & 189). The handle had a circumference of 140 mm, fitting a size M, and stopped the pot from rotating out of the hand. Furthermore, the shape of the handle made it easier to place the T-shape into the casing, as the test person could follow the shape of the handle to set the T-shape at the right height (ill. 188).


Ill. 186 Handle shape 1.


Ill. 187 Handle shape 2.


Ill. 188 Handle shape 3.


Ill. 189 Handle shape 4.

Requirements:

The handle on the pot must be perpendicular to the casing.

The handle on the pot must have an oval shape where the longest diameter is horizontal.

The handle's breadth must fit the glove's breadth.

The Pot Attachment

It didn't make sense to use the same method of placing the T-shape in the casing by sliding it "backward" towards the user while also grabbing the handle. This creates an awkward movement and is hard to do. Therefore, the pot attachment was rotated 180 degrees as tested on earlier prototypes (see "Second Prototype"), which means the T-shape is placed "forward" in the same motion as the user grabs the handle (ill. 190-191).


Ill. 190 Sliding "backward".


Ill. 191 Sliding "forward".

Guiding was added to make placing the T-shape into the casing easier. Angled pieces were added on both sides of the casing and underneath, allowing the T-shape to slide into the casing (ill. 192-193). This allowed the test person to slide the T-shape into the casing without looking.
Padding was added to the rods leading to the handle to ensure that the breadth of the handle was the same as the breadth of the glove (ill. 194). This helped the test person correctly place their hand, allowing the test person to place the T-shape into the casing 8 out of 10 times.


Ill. 192 Guiding 1.


Ill. 193 Guiding 2.


Ill. 194 Guiding 3.

Requirement:

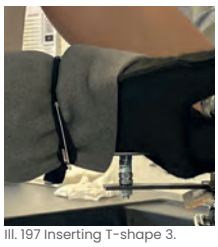
There must be guiding on both sides of the casing and from the bottom of the pot attachment.

The T-Shape

To further control the T-shape, a string was added around it, holding it close to the hand (ill. 195-196). However, the height of the T-shape also affected the success rate, as adjusting the height influenced the ease of placing the T-shape correctly. Having the T-shape at the correct height allowed the test person to make a more natural movement, resulting in them placing the T-shape correctly when grabbing the handle (ill. 197-198).


Ill. 195 Inserting T-shape 1.


Ill. 196 Inserting T-shape 2.


Ill. 197 Inserting T-shape 3.


Ill. 198 Inserting T-shape 4.

Conclusion

To decide whether this new solution, where the handle is mounted on the pot, was better than the current solution, the pros and cons of each solution were written on a whiteboard and compared to one another.

	Current solution	**New solution**
Pros	No handle takes up space and hinders interaction with stuff in the pot. The user must hit one area (slide T-shape into the casing). Doesn't require a left and right handed solution.	The handle is always placed on the pot. Secures a better grip on the pot even though the user is not using the arm attachment. There is a handle included for the other family members. Separates the two expressions (the expression of the handle and arm attachment). The arm attachment is lower and more accessible to store in a drawer. Indicate how your hand should be turned when putting on the arm attachment. Opening the tap and oven with the arm attachment on is possible.
Cons	The two expressions are not separate (the expression of the handle and arm attachment). The handle takes up space in the drawer. Requires a separate handle for other family members. The arm attachment must be removed to open the tap and oven.	The handle is taking up space on the pot and hinders interactions with the stuff in the pot. The user must hit two areas (slide the T-shape into the casing and grab the handle). Requires a left and right handed solution.
Neutral	The head must be a T-shape. New gripping movement.	It doesn't need to be a T-shape. Known gripping movement.

In addition to the pros of the new solution, it will solve the issue of the pot in the sink. With the current solution, the arm attachment must stay on the pot when placed in the sink, as the user will not have a firm grip on the pot otherwise. The arm attachment was too large to fit in the sink, so it had to rest on the countertop, leaving the pot lopsided. Because the new solution has the handle permanently mounted, the user has a firm grip without the arm attachment, which solves the lopsided pot issue.

Additionally, it was discovered that the significance of the T-shape's form had become irrelevant. The shape made sense with the current solution, but the T-shape could be square on the new solution where the pot attachment has been turned 180 degrees. It is assumed that this will keep the user experience the same and that the contact area will remain the same. This will be decided later on through a Finite Element Analysis (FEA).

Based on the advantages of the new solution, it was decided to continue with the new solution, mounting the handle on the pot attachment (ill. 199).

Ill. 199 New solution.

Requirement:

The handle must be placed on the pot attachment.

Proof on Concept

With the change in the product proposal, the concept needed to be proved by letting the user test out the new prototype. Therefore, a final user visit was made during which the user, through Simulated Use (Sperschneider & Bagger, 2003), used the prototype in her kitchen (app. 37).

Insights

She liked the two options of only using the handle or the handle and arm attachment.

She worries that she cannot take the fabric on and off with just one hand.

She doesn't mind that she needs to "learn" to use it as she had to learn everything again after the amputation. She doesn't see learning to use the product proposal as a big hurdle.

The product proposal was more straightforward for her to tilt than her crutch solution.

She would like the mitt made from silicone rather than fabric, as she believes it would be easier to clean.

She pointed out that she needs to remove the arm attachment to use the touch buttons on her stove.

"Because the handle is on the pot, you don't use as much strength... You don't lift in your fingers anymore; you lift with the palm of your hand."

- Anette

"It is actually kind of funny how heavy it (the pot) felt without the added handle and how much difference it makes to have some support up your arm."

- Anette

Overall, the user was content with the new product proposal and thought it was improved from the previous one. She could feel the arm attachment help and mentioned that she wouldn't lift the pot only in the pot attachment if she had 2 liters of water and 1 kg of potatoes in it. She wouldn't dare walk around with the pot without the arm attachment to divide the load.

During the Simulated Use, the user had to use her silicone mat under the pot to free the arm attachment from the pot attachment. This is assumed to result from the uneven welding on the prototype, which also troubled the team during testing. A professional production would solve this issue.

Solution Scenario

In addition to the proof of concept, a solution scenario has been developed as the team expects it to look. Visualizing the scenario will help better understand how the product proposal would influence the user's existing routine (ill. 200).

She finds her arm attachment in the drawer next to the stove.

She finds her pot in the drawer underneath the stove.

She carries the pot over to the sink.

She fills the pot with water either in the sink or...

next to the sink.

She grabs the pot while using the arm attachment.

She carries the pot over to the stove.

The potatoes gets cooked.

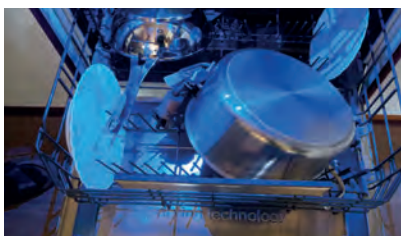
She grabs the pot while using the arm attachment.

She carries the pot over to the sink.

She tilts the pot to pour out water and drains the potatoes.

She slide off the arm attachment.

She puts the arm attachment in the dishwaser.



She puts the pot with the pot attachment in the dishwaser.

The arm and pot attachment on the counter top.

Ill. 200 Solution scenario.

Conclusion

The user's remarks primarily consist of minor concerns, and the user is content with the product proposal's help to reduce the main problem regarding lifting and carrying. As a result, it is assumed that the concept can succeed.
When comparing the solution scenario to the one made during shadowing (see "Shadowing"), the change that sticks out is the user taking on and off the arm attachment. However, during shadowing, it was noticed that she needed to get the potholder and place it correctly in her hand every time she wanted to lift the pot. It is assumed that getting the arm attachment and putting it on will be the same, and minimal time will be added to the routine.

Design Brief 6

During the detailing process, difficulty was encountered in determining the design of the arm attachment to seamlessly blend in with the kitchen environment. As a result, adjustments were made by creating a pivot where the handle is placed on the pot attachment. This modification led to rounding the pot attachment to fit the pot and provide a comfortable area for the user to place their hand. The arm attachment is intended to visually be an oven mitt while also being able to be attached to the pot attachment. The new product proposal underwent user testing, and the feedback received was promising.

Metaphor

"It should be like an oven mitt."

Problem Statement

How to design an assistive device that provides arm amputees with a secure grip, minimizes overuse, maintains balance while handling pots, and helps maintain arm strength? Additionally, how can the device be integrated into the kitchen environment and routine, ultimately enhancing the quality of life for the users?

Vision

Our product proposal must recreate the trust they had in lifting and carrying with two hands.

Product proposal

Requirements:

- The proposal must be made of dishwasherproof materials.
- The proposal must be made of food-safe materials.
- The proposal must help the user maintain their strength.
- The proposal must facilitate independent application by the user, utilizing the same arm as the product is intended to be worn on.
- The proposal must allow the user to take it on and off in 2 sec.
- The proposal must enable the user to lift a filled pot.
- The proposal must divide the pot load over multiple joints while lifted and carried.
- The proposal must allow the user to place it by the stove and sink.
- The proposal must ensure a continuous firm grip around the pot.
- The proposal must stop the pot from rotating out of the hand.
- The collaboration company must be an existing supplier of the municipalities of Denmark.
- The proposal must fulfill the requirements for a medical device class I.
- The proposal must be CE-certified.
- The proposal must create a moment between the pot and the arm.
- The proposal must have a maximum height of 160 mm.
- The proposal must allow the arm to go from a 100-150-degree angle between the upper and lower arm while using it.
- The proposal must allow the user to tilt a pot 90 degrees.
- At a minimum, the proposal must allow lifting and carrying objects at 3300 grams.
- The proposal must enable lifting and carrying of pots with a diameter ranging from 200 to 280 mm.
- The proposal must weigh less than 768 g.
- ★ The proposal must be available in sizes XS, S, M, L, and XL.

Needs:

- The proposal should fit the same design language as kitchen equipment.
- The proposal should be in neutral colors.
- The proposal should be in the price range of 200 to 2000 DKK.
- The proposal should be made from durable materials.

The Arm Attachment

Requirements:

~~The proposal must fit the average lower arm lengths of 260-300 mm from elbow to wrist.~~

★ The fabric on the arm attachment must be elastic.

Needs:

The proposal should be comfortable to wear on the arm.

★ The arm attachment should end in a mitt.

The Pot Attachment's Handle

Requirements:

~~The proposal must ensure the user's hand is placed in a neutral position.~~ ▶ The proposal must ensure the user's hand is placed in a neutral position when using the arm attachment with the pot attachment.

The proposal must enable the user to lift and carry with the palm of the hand.

~~The proposal must fit the average handbreadth of 70-100 mm.~~

~~The proposal must fit the average hand circumference of 180-220 mm.~~

~~The proposal must fit the average hand lengths of 60-70 mm from wrist to grip.~~

The proposal's handle must be horizontal.

★ The handle's breadth must fit the glove's breadth

★ The handle on the pot must have an oval shape where the longest diameter is horizontal.

★ There must be guiding on both sides of the casing and from the bottom of the pot attachment.

★ The handle on the pot must be perpendicular to the casing.

Needs:

There should be a clear indication of where to place the hand when using the product.

The Pot Attachment

Requirements:

The proposal must allow the use of a pot lid.

The proposal must cover 25% of the length of the pot.

A universal attachment must be installed on the pot.

The proposal must fit one of the longest sides at the midpoint of the pot.

The proposal must allow the non-arm amputees to interact with the pot as before the attachment installation.

The pot attachment must be detachable

The pot attachment must be securely placed without any movement.

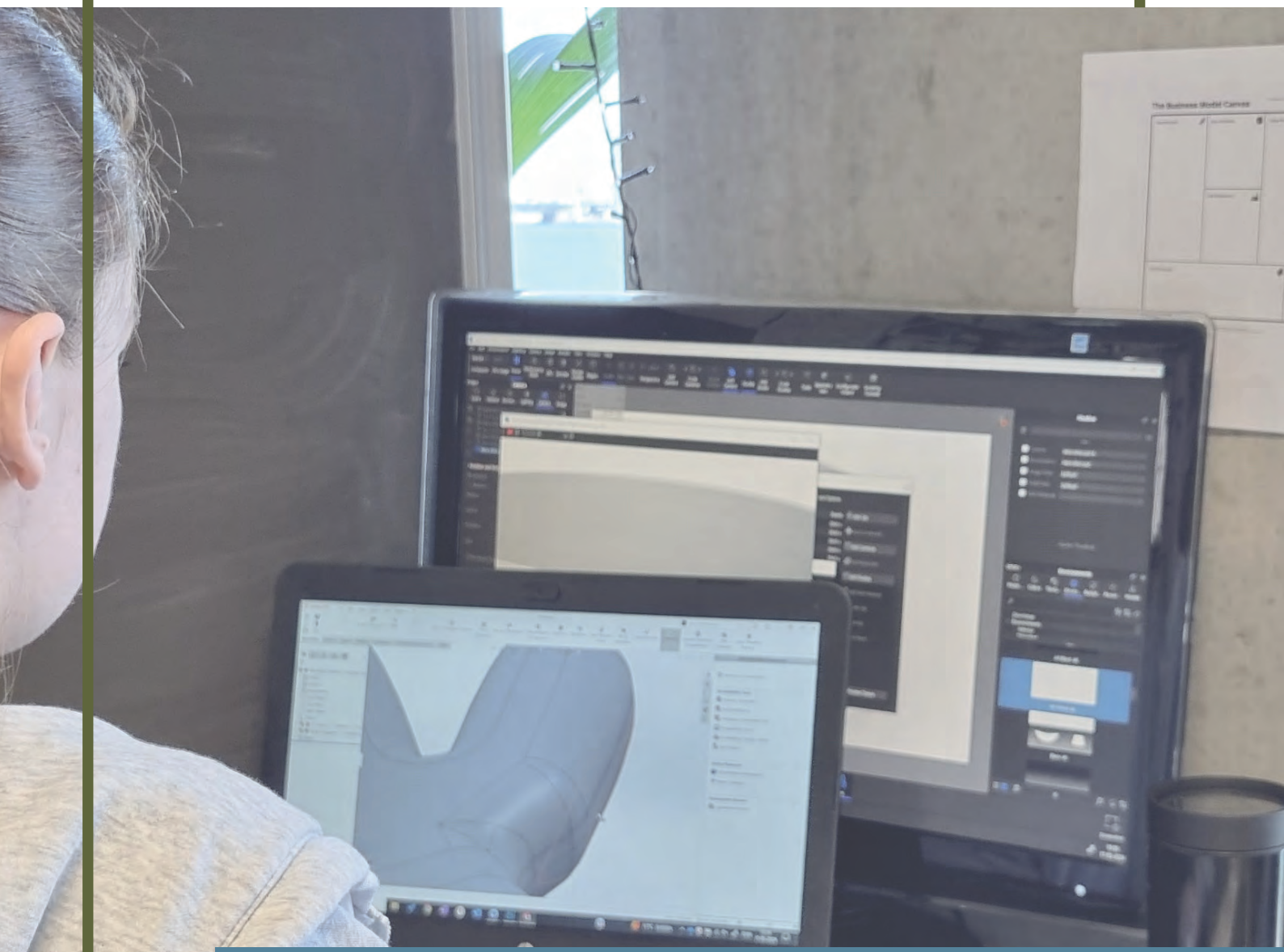
The pot attachment must not scratch the pot.

The proposal must fit a handle with a widths of 80 to 90 mm.

The proposal must fit a handle with a thickness of 7 to 10 mm.

The proposal must fit a handle with a depths of 35 to 45 mm.

★ The handle must be placed on the pot attachment.



Phase 7

Phase seven marks the final design phase, which focuses on fixing loose ends and finalizing the product proposal. The process begins by reviewing the construction and materials used in the product, followed by a final evaluation of the product's visual design. Next, the technical aspect of the product is addressed in the production method chapter. Lastly, the business aspect of the product proposal is discussed, and the environmental considerations are addressed.

Product Expression

The final decisions regarding the product expression needed to be made to determine materials, construction, and production methods. As the expression of the arm attachment had already been made (see "Visual Expression like Oven Mitt"), this section focuses on the visual expression of the pot attachment. This was done through a shape study of the handles on pots and a 3D-model shape study (app. 38).

Shape Study

The handles of different pots were analyzed to ensure that the pot attachment fit different pots. The analyzed pots were found during an earlier field research where different pots were measured (app. 20).

Insights

The handles can be more angular but have rounded edges and corners.

Some pots have a thin rod leading to a thicker handle, while others have shaped the thin rod into a handle. This suggests that some brands focus more on comfortability, while others value aesthetics more.

The shape of the handles adds elegance to the pot.

The pot and handle are not necessarily the same material. It differs depending on whether this is based on aesthetic, functional, or both reasons.

Furthermore, the handle had the following requirements:

The proposal must ensure the user's hand is placed in a neutral position when using the arm attachment with the pot attachment.

The proposal must enable the user to lift and carry with the palm of the hand.

The proposal's handle must be horizontal.

The handle's breadth must fit the glove's breadth

The handle on the pot must have an oval shape where the longest diameter is horizontal.

There must be guiding on both sides of the casing and from the bottom of the pot attachment.

The handle on the pot must be perpendicular to the casing.

These insights and requirements will be considered when making the shape study of the handle.

Shape Study

A rounded attachment was compared to a more angular one to see the significance this had on the attachment's expression (ill. 201-202). The rounded attachment made the whole thing appear lighter and more inviting than the angular one. Therefore, it was decided to continue with the rounded attachment, which matches the rest of the kitchen equipment.

The thick handle was the main struggle throughout the design of the pot attachment. The size of the handle had been determined in tests earlier on and was, therefore, not a parameter that could be changed. The handle looked heavy, so the aim was to make it appear more lightweight through the rods leading to it.

Ill. 201 Shape study 1.

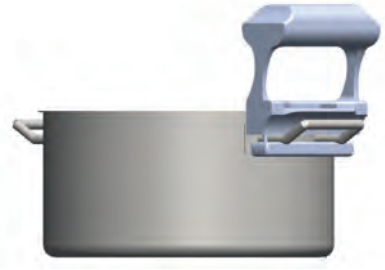
Ill. 202 Shape study 2.

Firstly, two thin and round rods were added, which minimized the material and left an open hole in the middle (ill. 203-204). This was done to make the handle lighter, but the thin rods had the opposite effect, making the handle appear even thicker and heavier. Furthermore, the thin rods between the voluminous bottom and top divided the attachment into parts instead of making it look like a whole.

A thin rod was added, which helped with the coherence of the attachment. However, the handle still looked heavy. In addition, a deepening was made for placing the thumb, which also helped reduce some of the handle's bulkiness (ill. 205).

Ill. 203 Shape study 3.

Ill. 204 Shape study 4.



Ill. 205 Shape study 5.

To further emphasize the coherence, the rods were made thicker and more curved, allowing the different "parts" of the attachment to melt together as one. The attachment now had more inviting curves and a dynamic look that distinguished it from looking like a medical device (ill. 206-207).

Ill. 206 Shape study 6.

Ill. 207 Shape study 7.

Materials

The following section shows the different considerations regarding materials for the product proposal. Various materials and their properties have been researched through field research, interviews, and desktop research.

The materials have been chosen based on their durability, weight, and price.
In addition, some requirements have been made for the product proposal's materials. The following requirements and needs will be considered when deciding on materials:

Requirements:

- The proposal should fit the same design language as kitchen equipment.
- The proposal should be in neutral colors.
- The proposal must be made of dishwasherproof materials.
- The proposal must be made of food-safe materials.
- The proposal must weigh less than 768 g.
- The pot attachment must not scratch the pot.

Needs:

- The proposal should be comfortable to wear on the arm.
- The arm attachment should end in a mitt.
- The proposal should be made from durable materials.

Fabric

The fabric on the arm attachment has, until now, consisted of two different fabrics, as there were various requirements for the part around the arm and the mitt around the hand. A requirement for the fabric around the arm was that it must be elastic to hold the arm support against the arm. This has since been questioned, as the support automatically will press against the arm when placing the T-shape and lifting the pot. Furthermore, oven mitts are usually made from something other than elastic but quilted fabric, making it difficult to make a natural transition between the two materials. Consequently, it was decided that only quilted fabric would be used.

Requirement:

~~The fabric on the arm attachment must be elastic.~~

The fabric on the arm attachment must be heat-resistant.

An oven mitt consists of two layers of thick cotton and batting, which is also 100% cotton. The batting is sandwiched between the two lining layers of cotton fabric and quilted together to make the batting stay in place (ill. 208). Cotton is used, as polyester doesn't have the same heat resistance, and polyester lining melts when exposed to heat. (Maker, 2021)

The price per mitt is estimated to be 11 DKK (app. 39).


Ill. 208 Quilted fabric.

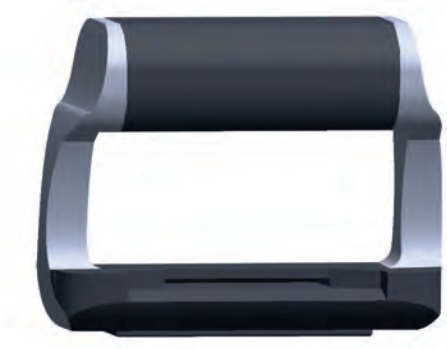
Plastic

PARTDESIGN, a plastic molding company with over 40 years of experience in integrated product development and manufacturing, was consulted for their expert knowledge on production and material criteria. They specialize in developing, verifying, sourcing, and manufacturing solutions with experience in injection molding. (Partdesign n.d.)
The feedback and insights from the consultation will be inserted throughout this phase (app 40).

Nylon

Before the visit, there was a wish that the rods leading to the handle on the pot attachment had the expression of steel, as it would fit the context better and give it an elegant expression that assistive devices typically don't have (ill. 209). Using actual steel for the rods would make the attachment much heavier and further complicate the production.
The metallization of plastic was suggested as a possible proposal. This is a galvanic process in which the metal binds itself to butadiene in ABS. This is done by adding the chemical nickel, which binds to the ABS, and then adding other metals.

Two different materials were considered for the product proposal, based on the wish to metalize the plastic: PC-ABS and PA66 (nylon 66).
The plastic used for the product proposal must be durable and have a high softening point, as the pot attachment will be attached near high temperatures. PC-ABS has a softening point of around 100 degrees Celsius (app. 40), while PA66's softening point, on average, is 233 degrees Celsius (MatWeb, n.d.). Consequently, PA66 is chosen for the arm support inside the arm attachment and the pot attachment. Furthermore, it is also used in kitchen equipment and crutches (Pietergdp, 2014) and can withstand disinfecting (Induflex, 2021).


Ill. 209 Nylon.

Following the material choice, the metallization of the plastic was opted out. Furthermore, it wasn't possible to find any tests regarding putting metalized plastic in the dishwasher, which is a requirement. The metallization would also unnecessarily increase the production cost as more molds are needed, among others.

The price per unit (arm support and pot attachment) will be 36 DKK (app. 40).

Silicone

A soft and slip-resistant material is needed for the handle, the pot attachment, and the mitt to create high friction, allowing the user to put it on (ill. 210). Both silicone and TPE were discussed as possible materials.

TPE is already used in medical-grade devices and food compliance industries. However, TPE can only withstand being heated up to 150 degrees Celsius, while silicone can withstand up to 250 degrees. (Hoffman, 2022)
Consequently, silicone is chosen because the handle must withstand high temperatures. Silicone is also already used in products that directly interact with food in the kitchen context, such as silicone baking sheets and cake forms.

The price per unit will be 2 DKK (app. 40).


Ill. 210 Silicone.

Construction & Production

The chapters on construction and production methods will be combined as they overlap. Production methods influence construction choices and vice versa. The FEA will also be included in this chapter to determine the best construction options.
The following requirements are applicable to the production and construction:

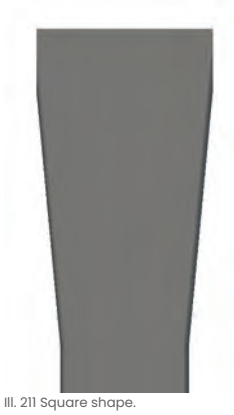
At a minimum, the proposal must allow lifting and carrying objects at 3300 grams.

The proposal must weigh less than 768 g.

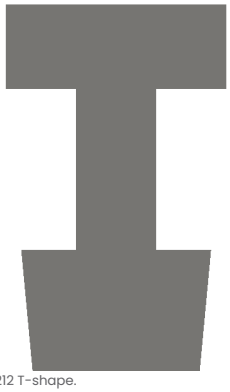
FEA Square vs. T-Shape

Regarding the construction, an FEA was made on the arm support with a T-shape and a square shape. This was done to determine which shape to continue to work with. (app. 41)

An FEA of the displacement was made to ensure that a square shape (ill. 211) could replace the T-shape (ill. 212) without having any downfalls. When comparing the two, it could be seen that the displacement of the T-shape is more than 66 times bigger than that of the square shape (ill. 213 & 215). Also, when looking at the stress of the two shapes (ill. 214 & 216), it is clear that the stress is more critical on the T-shape as it is more concentrated on the area where the T-shape is mounted to the rest of the arm support. Therefore, it has been chosen to continue to work with the square shape as it adds more material to the critical area.



Ill. 211 Square shape.



Ill. 212 T-shape.

Ill. 213 FEA T-shape 1.

Ill. 214 FEA T-shape 2.

Ill. 215 FEA Square shape 1.

Ill. 216 FEA Square shape 2.

Safety Factor

Existing products were investigated to determine the safety factor. The first area researched was guidelines for safety factors for medical devices. This does not exist as they look at current products' safety factors and the following conditions: What is the product's intended use? Who should use the product? And where is the product to be used? It has not been possible to find a reference product where the safety factor could be found.

So, to determine the safety factor, the conditions mentioned were examined. Because the material is ductile, there are no environmental conditions to consider. Furthermore, it is assumed that the added load of 4 kg (rounded up from 3,3 kg) is not considered severe. Therefore, the minimum safety factor is set at 2, allowing a doubling of the load (8 kg). (app. 41)

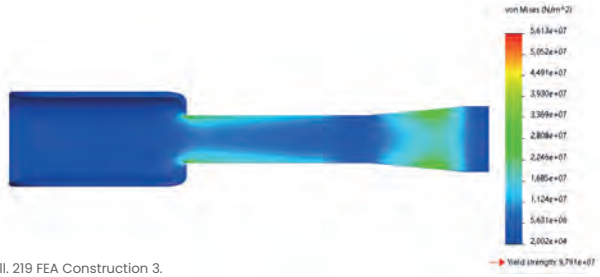
FEA Construction

Another FEA ensured the construction could withstand the load using the safety factor. The material of the arm support is Nylon 66 (see "Materials"), and the added load when using the safety factor was 8 kg. (app. 41)

The displacement with Nylon 66 is 3,46 mm (ill. 217), which is acceptable as it is believed that this will not affect the use. The maximum stress is not near the yield strength (ill. 218), and the material will not permanently deform. However, it is desired to have as small a displacement as possible so the geometry will still be enhanced.
The first area that will be improved is the end of the arm support. Material is added to the area where the load is placed (the area of green color ill. 219).

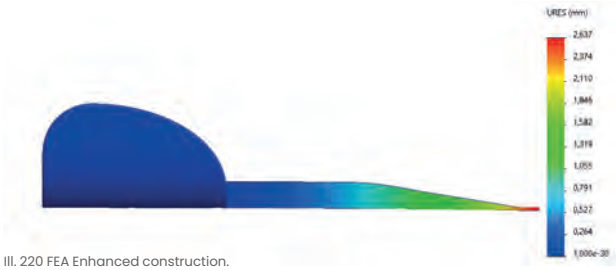
Ill. 217 FEA Construction 1.

Ill. 218 FEA Construction 2.



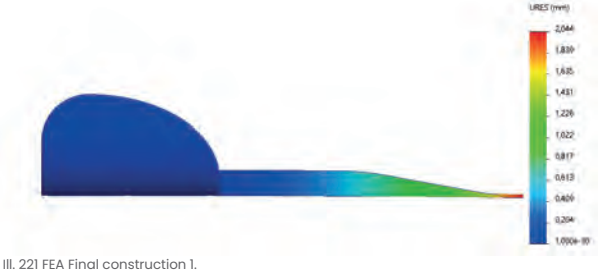
Ill. 219 FEA Construction 3.

After enhancing the geometry (ill. 220), the displacement decreased to 2,5 mm. Other areas of the geometry were enhanced but only helped reduce the deflection by less than 1 mm. Therefore, these enhancements were removed as it would result in changes in the different parts of the product, which seems unnecessary for its small effect on the displacement. (app. 41)

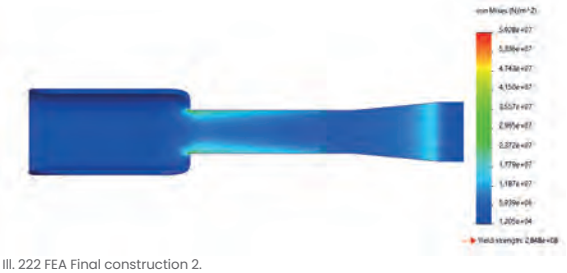


Ill. 220 FEA Enhanced construction.

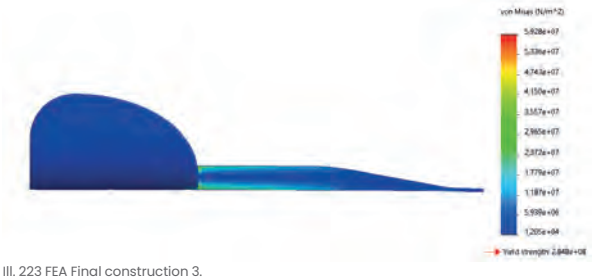
The material was reinforced with 60% glass to ensure that the displacement decreased, as this is the highest reinforcement available for nylon. The change in the material made a big difference. The displacement was now at 2 mm, which is tolerable because this displacement will not make the pot slide off the arm support, and the maximum stress is still not near the yield strength. Therefore, the final geometry of the arm support will be the one in illustration 221-223. Furthermore, the final weight of the arm attachment was calculated to be 563 g. This is 205 g less than the crutch solution. (app. 41)



Ill. 221 FEA Final construction 1.



Ill. 222 FEA Final construction 2.



Ill. 223 FEA Final construction 3.

Production Methods

Different production methods will be used to produce the different parts of the product proposal. The following chapter clarifies the production methods and the conditions regarding the chosen method.

Pot & Arm Attachment

Injection Molding
The pot attachment and arm support will be produced using injection molding (ill. 224). This process was chosen after consultation with PARTDESIGN because it is one of the leading processes for manufacturing plastic products.

There is a high tooling cost when using injection molding, but the price depends on the complexity. Opposite the tolling cost, the unit cost is low. (Thompson, R., 2007)

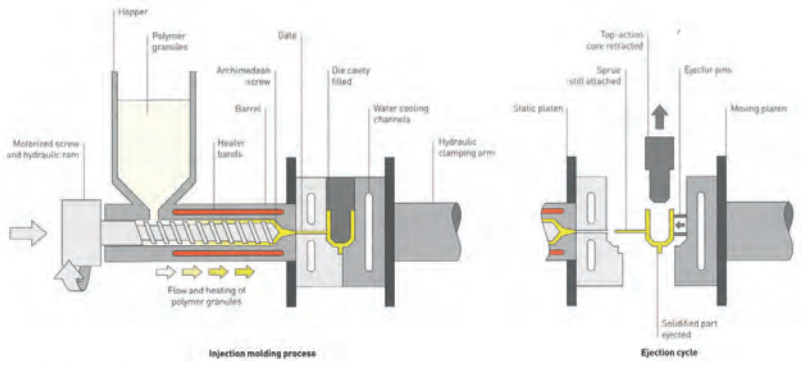
When using injection molding, are there some production criteria, such as making draft angles and not having too sharp edges on the product, to be sure that stress will not build up and break the casted object (Thompson, R., 2007). Overall, there is a need for a 2-degree angle on the product proposal, but in the casing of the pot attachment, PARTDESING believes that a draft angle of 0.25 degrees is enough for it to get out.

The injection cycle time is generally between 30 and 60 seconds, whereas the arm support will be closer to 60 seconds (app. 40). Larger parts have a longer cycle time as it takes longer for the polymer to resolidify, which has to be done while they stay in the mold. (Thompson, R., 2007)

Cooling time is also one reason why it is essential to make an element with a low material thickness. Ribs are added to decrease the wall thickness and aid the flow of the material during molding. (Thompson, R., 2007)

The plastic will have a matt finish, as this visually makes the product less eye-catching than a gloss finish and is less expensive. (Thompson, R., 2007)

The arm support requires one mold, which is also necessary for the pot attachment bottom. The pot attachment top will require two molds because it needs to be cast in two halves to ensure that it is hollow. The arm support will require a four-part mold, whereas the others will be simple split molds made of two halves.
The silicone will be attached to the two pot attachment parts by over-molding the plastic with the silicone. (Thompson, R., 2007)



Ill. 224 Injection molding.

Fabric

Stitch Bonding: Quilted Fabric with Batting
The fabric used is quilted cotton fabric with cotton batting made through stitch bonding (ill. 225). When quilting the material, the three layers, in this case, two layers of cotton textile with a layer of batting in the middle, are brought together and stitched in a quilting machine. (Thompson, R. & Thompson, M., 2014)

A diamond pattern has been chosen because a costume pattern will increase the cost. The needles work in a straight line to create this pattern while the fabric moves from side to side. (Thompson, R. & Thompson, M., 2014)

CNC Cutting
After the three layers of fabric have been stitched together, the next step is to cut the fabric, and this will be done through CNC cutting. It is a high-speed computer-guided process where the machine is able to cut the fabric without a die or paper market. A CAM file is inserted into the computer, and the knife cutting will follow the x- and y-axis. CNC knife cutting is low-cost, but the routing of the cutting is low- to moderate-cost. (Thompson, R. & Thompson, M., 2014)
This method is chosen instead of laser cutting because the laser can leave scorch marks on the surface and edges of the fabric, which will not meet the requirements of the product's visual appearance. Die cutting has yet to be chosen because the die is a high cost that would be preferable not to have. (Thompson, R. & Thompson, M., 2014)


Ill. 225 Stitch bonding.

Machine Stitching
Machine stitching will be used to sew the fabric pieces together because it is low to moderately expensive, depending on the complexity of the pattern. Machine stitching is a high-speed mechanical process where textiles are sewn together using different seams. The ones used in this product are overlock, superimposed seam, and bound seam. (Thompson, R. & Thompson, M., 2014) This was decided upon by looking at an existing oven mitt.

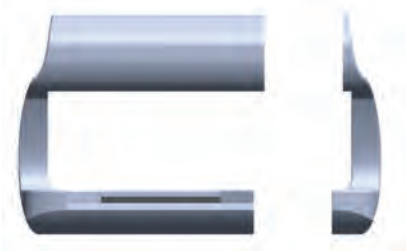
Assembling & Joints

Plastic Parts

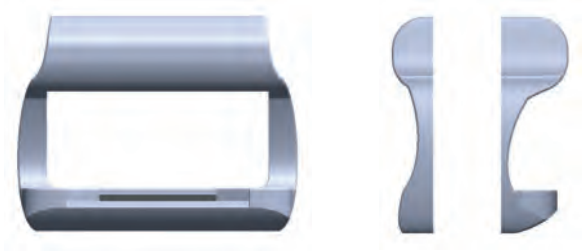
The pot attachment requires assembling of two plastic halves. It is not a requirement that the parts can be taken apart again, but the joint must be waterproof so liquids don't stay in the construction. The proposal must be able to go in the dishwasher, so it must be waterproof.
The methods discussed were welding the two plastic objects together and joining them with glue or a gasket. The cheapest option is the assemble with glue, as this doesn't require screws opposite to the gasket solution. For this reason, the glue solution was selected as the assembly method.

Adding Silicone

There is a wish to add silicone to the handle. PARTDESIGN mentioned two ways this could be done. The silicone could be cast onto the handle or molded in a separate mold and then mounted onto the handle. If the silicone gets cast onto the plastic, an extra mold will be required. If the silicone instead gets molded separately, the top part of the pot attachment must be cast in two different parts to attach it to the casted handle (ill. 226). This will, therefore, require two extra molds when casting the part, but it will also need a mold for the silicone.
Because of this, the silicone will be cast directly onto the part, as this seems to be the cheapest solution (ill. 227).
Silicone will be added to the pot attachments' top and bottom to ensure that they do not scratch when attached to the pot's handle. This is done by casting it onto the plastic using a separate mold. (app. 40)



Ill. 226 Attachment if silicone in seperate mold.



Ill. 227 Attachment if silicone is overmolded.

Mounting the Pot Attachment to the Pot

The two parts of the pot attachment requires bolts to mount the attachment onto the pot. Four different solutions have been discussed; molding a thread into the plastic, parker screw, inserting a threaded metal sleeve (ill. 229), or inserting a nut. Ultimately, it was decided to insert a threaded metal sleeve into the plastic because this was a cheaper option than, for example, molding a thread in the plastic. Furthermore, it will match the requirements of the visual expression. (app. 40)

The bolts used are standard 4 mm, where the lower part is without thread to hide this when the attachment is mounted (ill. 228).

Ill. 228 Bolt.

Ill. 229 Threaded metal sleeve.

Business Aspect

When examining the business aspect of the product proposal, cost estimation, business model, and implementation plan must be considered. Much of the knowledge used in this section originates from the interview with the case manager and research on how to obtain assistive devices (see "Getting an Assistive Device on The Market").
The following requirements are applicable to the business aspect:

The proposal should be in the price range of 200 to 2000 DKK

The collaboration company must be an existing supplier of the municipalities of Denmark.

B2B

As the case manager stated, the municipalities only buys products from experienced companies familiar with medical devices that understand the target group and the various requirements for this product type. Therefore, it is ideal to choose the B2B market approach, as the business will benefit from an existing business's position in the market and knowledge-sharing.

Aabentoft has been chosen as a possible collaboration company. They are a medical device production company that primarily deals with wheelchairs, communication aids, eating aids, etc. (Aabentoft.dk, n.d.). It is believed that they can help produce and implement the product proposal.

Cost Estimation

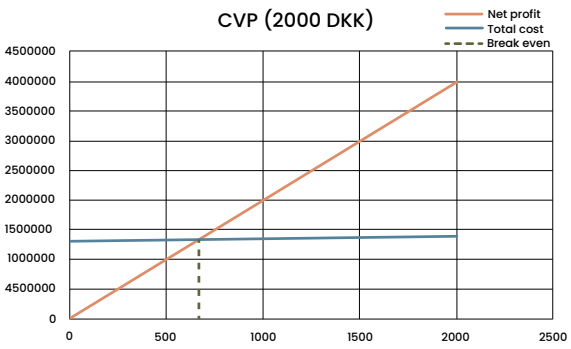
The cost estimation is an estimation of the expenses for starting up the business. It will be made based on the information gathered during the visit at PARTDESIGN (app. 40).
This is a rough estimation of the cost and will not include cost factors such as transportation, storage, packaging, salary, etc. These remain unknown as the cost has not been found. However, it is known that they would highly influence the estimation.

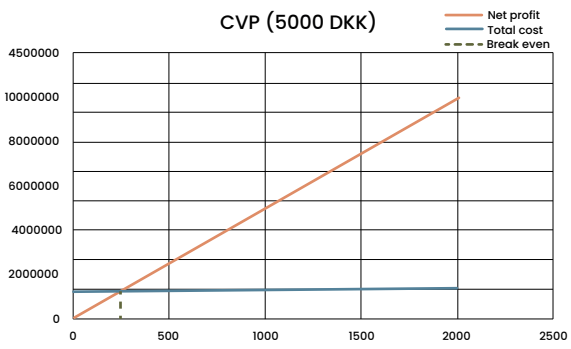
It is assumed that Aabentoft can help outsource the production, as this will be the most cost-effective solution for a start-up. Nonetheless, through the interview with PARTDESIGN, it was estimated that an investment in molds for the plastic parts would be 1.300.000 DKK (app. 40).
The material price per unit (including the arm attachment and bottom and top part of the pot attachment) is estimated to be 50 DKK (app. 40).

Variable Cost	**DKK**
Nylon	36
Silicone	2
Oven mitt (fabric)	12
Packaging	-
Fixed Cost	
Overhead cost	-
Operating cost	-
Assembly cost	-
Molds	1.300.000
Total Cost	**1.300.050**

30-35 arm/hand amputations are performed annually in Denmark (Sahva, n.d.). Therefore, it is assumed that 35 units would be sold yearly in the Danish market. However, numbers on the current number of arm amputees in Denmark have not been found. Consequently, they are not included in the calculation but would also be potential product buyers.

During the interview with the case manager, she mentioned that the retail price of kitchen aids and similar aids varies between 200 DKK and 2.000 DKK (app. 12).
A Cost-Value-Profit (CVP) is a method used to examine how variable and fixed costs affect a company's profit and how many units it needs to sell to break even (Kenton, 2024). A CVP will be made for two scenarios: one where the product proposal is made in 5 sizes, as it is now, and one where the product proposal is one sized. Furthermore, the product proposal was set to three retail prices: 200 DKK, 2.000 DKK, and 5.000 DKK (excl. taxes) (app. 42).





One Size

Retail price	200 DKK	2.000 DKK	5.000 DKK
Breakeven	1734 units	134 units	53 units
Breakeven reached	50 years	4 years	2 years

5 Sizes

Retail price	200 DKK	2.000 DKK	5.000 DKK
Breakeven	8.667 units	667 units	263 units
Breakeven reached	248 years	19 years	8 years

The CVP calculations show a significant difference between the two scenarios and the retail prices.
Based on this, it would be cheaper to make a one-size product as breakeven would be reached significantly faster. However, as proven during testing, one size does not fit all, so the product proposal will be made in five different sizes.
A CVP with a retail price of 5.000 DKK was also made to see how this could influence the breakeven point. Based on the calculations, it seems rational that the retail price for the product proposal would be 5.000 DKK excl. Taxes, as breakeven is reached after eight years. However, this will change drastically when all the unknown costs are considered. A market expansion would further improve these numbers, which will be discussed later in this section.

Business Model Canvas

Business Model Canvas (Osterwalder & Pigneur, 2010) is a strategic way of managing a company's business model. A visual chart describes the product's value proposition, customer segment, finances, and other factors and how they can influence each other. The business plan for the product proposal is illustrated below.

Key Partners

Key Partners
Municipalities (case managers)
Aabentoft
Arm amputees (users)
Material suppliers
Investors

Cost Structure

Shipment
Overhead cost
Salaries
Molds
Materials
Testing

Customer Relationship

An established relationship through Aabentoft.
Customer support for the municipalities.

Key Resources

Physical

Machines
Casting molds
Warehouse
Transportation
Nylon, silicone, quilted fabric

Intellectual

Patents and copyrights
Partnership with Aabentoft
Documentation for CE-marking

Financial

Funding

Human

Customer support
Production staff
Marketing

Customer Segment

Aabentoft
Municipalities (the case manager)
The arm amputee

Key Activities

Production
Testing
Approval of product (CE-marking)
Advertising at medical device fairs
Customer service
Distribution

Value Propositions

It enables the municipalities to save resources.
The municipalities gets a product that citizens have requested.
The user gets back their independence.
Risk reduction.

Channels

Partner Channel (Aabentoft)
Medical device fairs

Revenue Streams

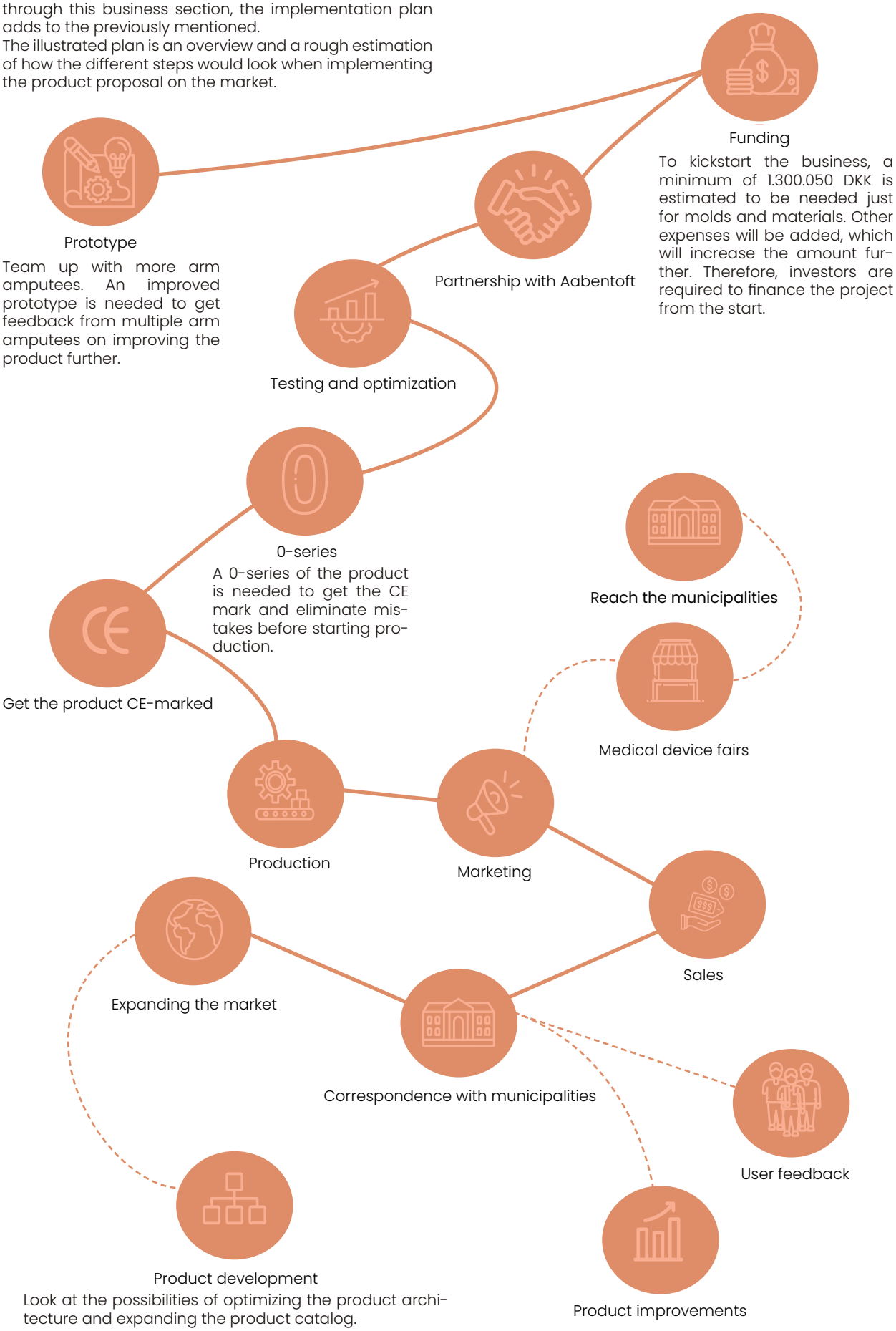
Asset sale

The business model emphasizes how the partnership with Aabentoft would influence the business, as they are involved in almost every aspect. The company would highly rely on their production and knowledge, but they will also be the key to entering the market. Furthermore, the company would continue to correspond with the municipalities as they communicate with the users.

The model has created an overview of the activities needed to start the business and all the key partners with something at stake.

Implementation plan

With the business model and cost estimation in place, a plan for implementing the product on the market has been made (ill. 230). Based on the information gathered through this business section, the implementation plan adds to the previously mentioned.
The illustrated plan is an overview and a rough estimation of how the different steps would look when implementing the product proposal on the market.



Ill. 230 Implementation plan.

Market Expansion

When the product has been implemented in the market, it would make sense for the business to look at the opportunity to expand the market. During the development of the business model and cost estimation, the focus has been on the Danish market. However, by expanding to the international market, more units could be sold yearly, resulting in the reach of breakeven much faster, as 3 million worldwide have an arm amputation (osu.edu, n.d.).

Further market expansion could also involve developing a product architecture that would expand the products to which the pot attachment can be attached, expanding the product catalog. Likewise, expanding to other user segments could be an opportunity, as people with arthritis or temporary conditions such as a broken arm could also benefit from the product proposal.

Environmental Considerations

When designing a product, a part of the process is considering the environmental impact. There hasn't been a significant focus on this throughout this product proposal because, with a medical device meant for the user to use for the rest of their life, it isn't as big a concern as consumer products. However, with this mentioned, there are some considerations regarding making it a durable product through the material chosen to ensure that it will last many years.

A part of the product that may not last as long as the plastic parts is the mitt. The mitt can be changed over time because it can be slid off the arm support. This also makes it possible to wash the mitt when needed.

The silicone is not changeable because of the mild environment the product proposal is in. The most challenging environment it will meet is the dishwasher. From earlier research, it is known that there are lots of kitchen equipment made from silicone that also goes in the dishwasher, and therefore, it is assumed that the product proposal will not be harmed by this.

The production of the product also has an environmental impact. One of the ways that this is lowered is when using injection molding; the scraps can be directly recycled and used in the product proposal (Thompson, R., 2007). Furthermore, a computerized system ensures the most efficient use of the fabric when cutting it (Thompson, R. & Thompson, M., 2014).

At the end of the product proposal's life, it is possible to separate the silicone from the plastic (Lawrence, 2010). Thus, there will be two separate materials that can be recycled: plastic and fabric. This will contribute to a circular economy.

When talking to PARTDESIGN, it was mentioned that they would send the production to China because of the small number of products that would be produced at the start. They already get their molds made in China and test the molds.
However, producing it in China will demand considerations about transporting the product proposal to Denmark. The parts are compact in size, and the mitts are highly compressible, allowing for tight packing to minimize the volume of air transported within the packages. Also, how they are transported to Denmark can be considered when choosing the transportation method with the lowest pollution.

Epilog

Conclusion

Cooking can be challenging for individuals missing an arm, making it difficult to fulfill a basic need. As a result, arm amputees often require assistance when cooking or simply choose not to cook. All arm amputees wish to feel independent and not have to ask for help. They want to be able to do what they could pre-amputation.

Through collaborations with arm amputees, occupational therapists, physiotherapists, and a municipality case manager, an understanding of the challenges faced by arm amputees and how the body reacts after an arm, or part of an arm, is removed has been developed. Interviews and shadowing have also provided insight into the process of acquiring assistive devices for arm amputees.

Based on the knowledge gathered, Eac was developed. Eac makes it possible to grip, lift, carry, place, and let go of a pot using only one arm, enabling individuals to cook meals for themselves, their families, and guests without needing help.
Furthermore, the design of Eac allows users to perform these tasks while building their strength and preventing overuse.

Eac is designed to prioritize functionality, ensuring that the device meets municipal regulations regarding the grant of an assistive device. It is developed in five sizes to ensure the product comfortably fits different body sizes. In addition, it visually complements the kitchen environment rather than standing out as an apparent assistive device to encourage arm amputees to use Eac.

Eac consists of two attachments: a pot attachment and an arm attachment. The pot attachment includes a handle and a casing to connect it with the arm attachment. The case manager will mount the pot attachment on the user's existing pots to ensure it is correctly installed. The arm attachment will be kept in the kitchen and functions as an oven mitt that is put on and taken off during cooking. It will be used in conjunction with the pot attachment when the user feels the need for more support when lifting a pot that they perceive as heavy. When the user doesn't perceive the pot as heavy, for example, if it is empty, they will just use the handle on the pot attachment.

Eac brings arm amputees a step closer to the independence they had pre-amputation.

Reflection

In closing, the different aspects of the product proposal have been reflected on. As the final product is only a proposal to the problem, various parts of the product proposal could be improved.

Testing on Multiple Users

The team has been in contact with multiple arm amputees when performing interviews and gathering information, but during testing, the prototype was only tested on one user. This resulted from some of the amputees living on the other end of the country, and one could not be contacted after the first interview.
Ultimately, the single user's point of view could have influenced the final product proposal. Instead of having multiple users' responses to the ideas, the team only has one user's feedback. If the product proposal had been tested on more users, a more nuanced picture could have been created, making the team aware of more aspects. However, relying only on one user's feedback has also made the team more critical of what was said, as it was only a singular point of view. The statements made by the user were constantly tested, and experts were asked about their expertise on the matter.

Applying and Removing the Mitt

The user's concern during the last visit was whether she could change the mitt on the arm attachment. When designing the mitt for the product proposal, garment closures were avoided to ease the application and removal of the mitt. Instead, the mitt is slid onto the arm support. This solution is made on an assumption and has not been tested. Testing is needed to determine if this is the right solution and if changing the mitt only using one hand is possible.

Designing a Pot Instead of an Attachment

Towards the end of the process, it was questioned whether it would have made more sense to design a pot with the attachment welded on instead of making an attachment to the pot handle. The user believed the municipalities would buy pots and pre-install the attachment instead of installing it on the citizens' pots at their homes, making the pot with the attachment welded on more sensible.
To further develop the pot, a layer of silicone could be added to the bottom. During shadowing, the user was observed using a silicone mat under the pot when placed on the stove. This would eliminate the silicone mat on the stove and add another property to the pot. However, designing such a pot would force the user to replace their existing pot.

One Size vs. Different Sizes

From the beginning, it was known that making a one-size product would be cheaper as it would require fewer casting molds than making different sizes. This was emphasized further during the Business Aspect when it became clear how the many molds affect the CVP. However, it has been proven that one size would not fit every user. It can be discussed if making a one-size would create a better business, but as the users must use the product proposal for the rest of their lives, the fit of the product proposal has been prioritized.

Furthermore, the CVP has been calculated based on the Danish market, where 35 people get their arms or hands amputated every year. However, considering the limited number of users, aiming only at the Danish market is unrealistic. Expanding to the international market is much more realistic, as this would create a better business. Further product testing could be necessary because countries have different medical device regulations.

The Sizes

The sizes calculated for the arm attachment have yet to be tested thoroughly. The measurements for the different sizes have been estimated based on one size, which was assumed to be a size medium. As seen in the clothing industry, standard sizes do not fit everyone, and the same can be applied to the product proposal. A person can have a size large arm, but their hand is a size small. Therefore, the sizes can be off, resulting in the arm attachment not fitting. Furthermore, it would make sense to look into the need for five different sizes or if three sizes could be tolerable, which could lower the production cost.

The Baking Dish

When the team designed the product proposal, it was also meant to be applicable to baking dishes. Nevertheless, the team focused on perfecting the pot attachment, which robbed time to design the attachment for the baking dish. Ideally, an attachment was designed for the baking dish, allowing the user to use the arm attachment on these.
Considering what the case manager said about the simplicity of medical devices and how more complex devices can be complicated to grant, it is questioned whether the product proposal would have been more complicated to grant if it had been applicable to more objects.

If the product proposal were to be made applicable to baking dishes, the arm attachment would have to be redesigned. During the FEA, it was discovered that the arm attachment's construction would have a displacement of 2 mm when subjected to a weight of 8 kg. Consequently, the construction is not believed to withstand the weight of a baking dish with multiple kilos of content.
A change in the construction of the arm attachment would be needed. To withstand the weight applied to the square going into the casing, the attachment must be thicker than the 3 mm it is now. Enlarging the square would result in an enlargement of the casing, which would mean an enlargement of the whole pot attachment. This could result in the pot attachment getting too prominent on the pot.

Another solution would be to change the material of the arm attachment. Making the attachment from metal would strengthen it and minimize displacement when weight is added. However, it would make the attachment heavier on the arm, defeating the purpose of the product proposal. Instead, the nylon could be reinforced with a thin steel plate, strengthening the attachment but complicating the production and adding some weight.

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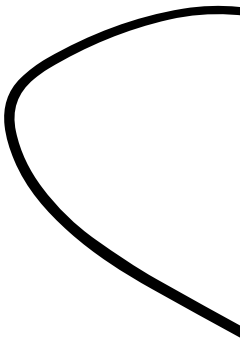

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