EXTRUZA

UNDERWATER WELDING GUN

ALEXANDER JENSEN & SUNE FURLIG LARSEN

Aalborg University // Spring 2020
Industrial Design // MSc04 ID16

PRODUCT REPORT

FORMALITIES

TITLE	EXTRUZA
REPORT TYPE	Product report
PROJECT THEME	Underwater Welding gun
PROJECT PERIOD	3. Febuary 2020 - 3. June 2020
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PROJECT TEAM	ID16
MAIN SUPERVISOR	Louise Møller Haase
CO-SUPERVISOR	Michael Skipper Andersen
TOTAL PAGES	24

ABSTRACT

Formålet med dette afgangsprojekt er at kaste lys på Erhvervsdykkerne og med en vision om at gøre arbejdet undervand nemmere at udfører.

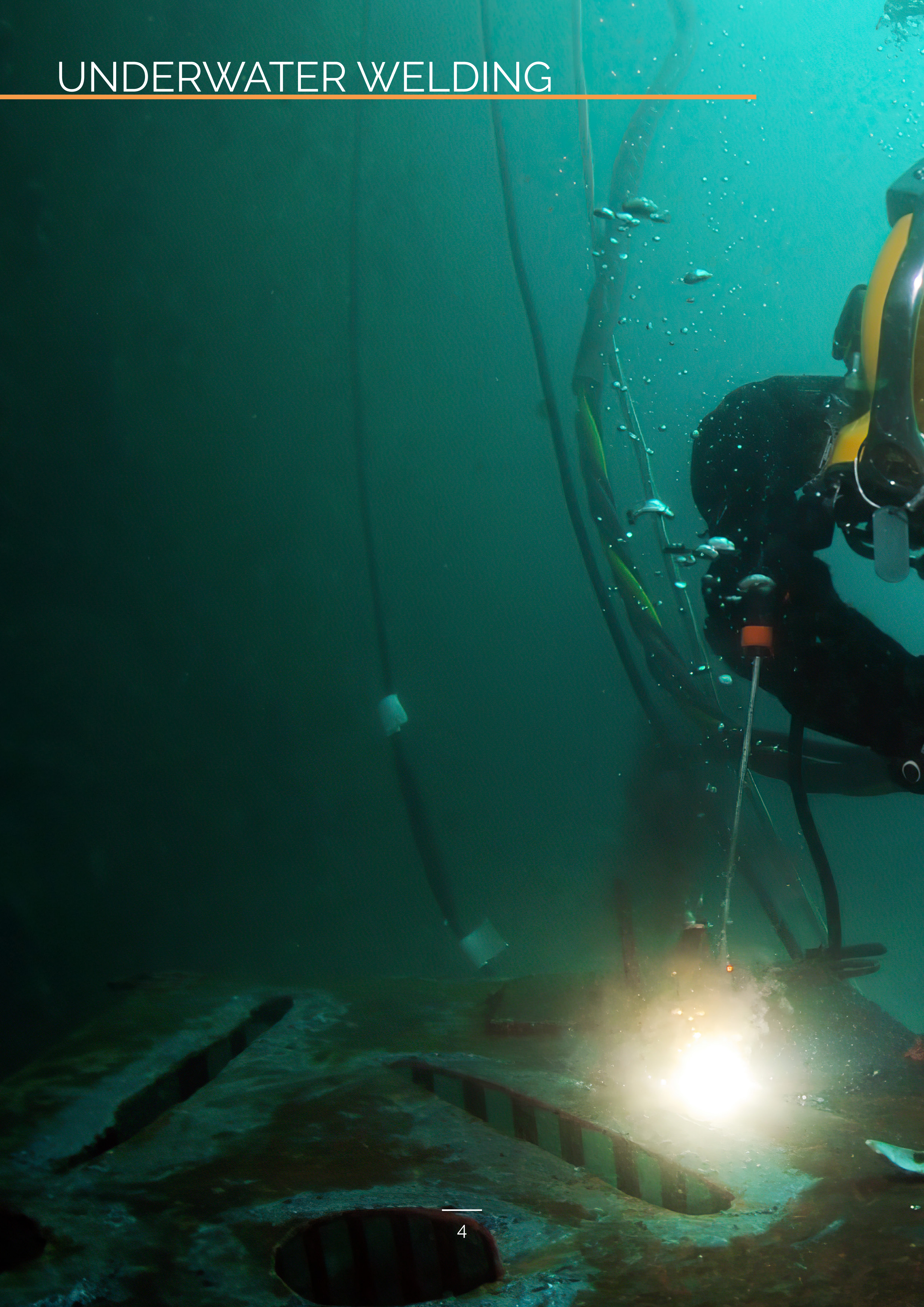
Som en niche industri, især i Danmark, er markedet ofte overset og overladt til sig selv. Det resulterer i få løsninger af udstyr og erhvervsdykkere må derfor improvisere hvis de vil se ændringer i arbejdsmetoder, tilbehør på værktøj eller værktøjet i sig selv. Oftest håndteres dette på "gør det selv "-metoden, hvor et eksisterende produkt bliver modificeret til at kunne fungere til dykkerens job. Udfaldet er dog at produkterne bliver slidte af løsningerne og det ender med en investering i nyt udstyr da det ikke kan holde til den hårde kontekst.

Her ses der særligt på svejsning, med en arbejdsform der er lang fra perfekt, i forhold til et ellers perfekt resultat der skal opnås.
Endnu videre ses der et stort problem i "smid ud" kulturen hos erhvervsdykkerne, specielt i svejsehåndtaget, der trods at kunne skiftes i enkelte dele, vælges at skiftes helt da det er en billiger løsning.
Projektet arbejder med udviklingen af et produkt der placerer dykkeren tættere på sit arbejde og derved øger præcision, giver en øget arbejdsintensitet og en ikke-destruktiv tilpasning af produktet med div. gadgets.

Alexander Jensen

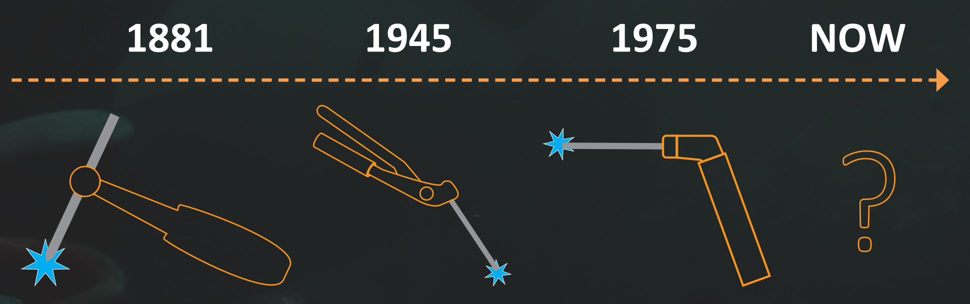
Sune Furlig Larsen

UNDERWATER WELDING



Welding underwater has never been an easy task. It requires skills developed over the many years of welding to master the field. Underwater the welder can only prepare so much as unforeseen changes in the environment can result in a change of current and no visibility. This is why it is perceived as a dangerous job as the smallest accidents can result in being fatal.

The basics of an arc welding tool have not changed in over 100 years and here it has never been adapted to suit the needs for the circumstances met while welding and diving at the same time. The tools are simple and don't last long in the tough context which requires the divers to modify the tools with a damaging effect to it or change the tool for almost every new dive to be able to perform for the job.



Extruza will start a new era in the future of wet welding where the perfect weldment is no longer only a thing for the masters in the field. It features a whole new way of welding, where the hand is always close to the weldment, and the weldment can be done only using a single hand, so it is no longer necessary to stabilize the electrode end. This gives increased safety as it is possible to use the other hand to stabilize yourself. Furthermore, the unique electrode storage system will allow the user to work faster than ever before.

EXTRUZA

FEATURES

Extruza consists of many unique features, together they are providing a whole new experience when wet welding, these will both improve the quality and reduce the time spent on the site. The learning curve for the product is kept to a minimum, by only having a few simple interactions required to use the product.

ACCESSORIES

Formerly divers would attach accessories by damaging the product. Now the divers have the opportunity to "customize" Extruza by adding pieces of equipment into the 4 screw mounts on both sides of the product.

GRIP

The grip is designed to both be used with gloves and without giving a steady and comfortable power grip so it is easy to hold an exact position while welding for many hours. A slip-proof coating makes the gripe even better in wet conditions.

CLOSER TO WELDMENT

It is often easier to weld with the last couple of centimeters with a traditional welding tool as the hand is close to the weldment, with Extruza you will be close.

RELOADING IN SECONDS

Changing electrodes while underwater can often be a difficult task especially in low visibility where precision is required. Extruza features a system where it can easily be done in a matter of seconds by pulling back the handle and turning the knob.

COLOR

The colors of the product are made with underwater visibility in mind. The orange color is easy to spot underwater. Even further when the phorescent pigments are charged with UV light from welding or the sun, the surface will emit a green glow in the dark, and thereby it will never be lost while diving.

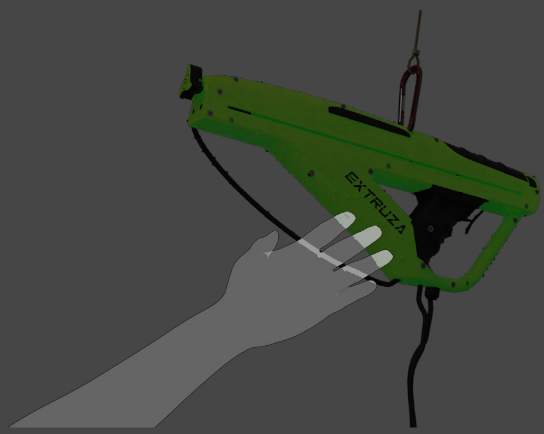
AMBIDEXTROUS

Extruza is built so it can be used with both left or right hand, the reloading handle can easily be screwed out and placed on the other side of the product.

MAGAZIN

The innovative solution for electrode storages gives the diver an opportunity to carry up to 7 electrodes down for the job. And if all are used it can easily be filled up underwater or a new easy attachable storage can be sent down from land filled with new electrodes.

USER INTERACTION



1

Extruza is lowered down to the diver, or it is brought down with him from the surface. It is easy to spot with the glowing green color.

2

The reload handle is pulled back to allow an electrode to fall down.

5

While welding the diver can adjust the extrusion speed depending on the trigger force applied, and thereby adjust the distance to the weldment.

6

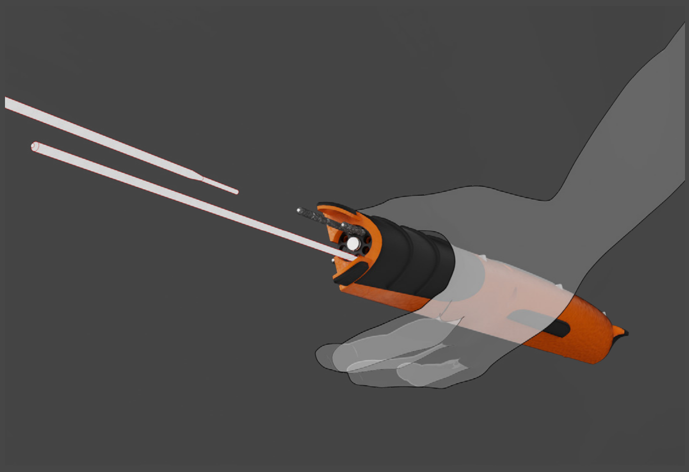
When the electrode is burned out it can be removed and discarded in a container.
Now the user can repeat step 2 to 4 to reload an electrode.

3

The turn knob is rotated one step and an electrode falls into place.

4

Extruza is now ready to weld. The user presses the trigger until the electrode comes out of the end.



7

When the magazine is empty it can be removed by pressing the two buttons on the sides of the magazine front, and pulling back.

8

New electrodes can be placed into the storage, or a new filled magazine can be lowered down to the diver.


EXTRUZA

ADD-ONS

CARABINER

The magazine can be equipped a carabiner, so it can be lowered down from the surface along with the rest of the product or alone if more electrodes are needed for the job.

CAMERA

A camera can be mounted on the sides so weldments can be documented and provided to the employer to ensure the quality of the work.

CUSTOM BUILD

The mounting system can be used to anything you desire, by creating your own custom build of accessories. It can be anything from a mount for your dive watch or a shoulder strap.

FLASHLIGHT

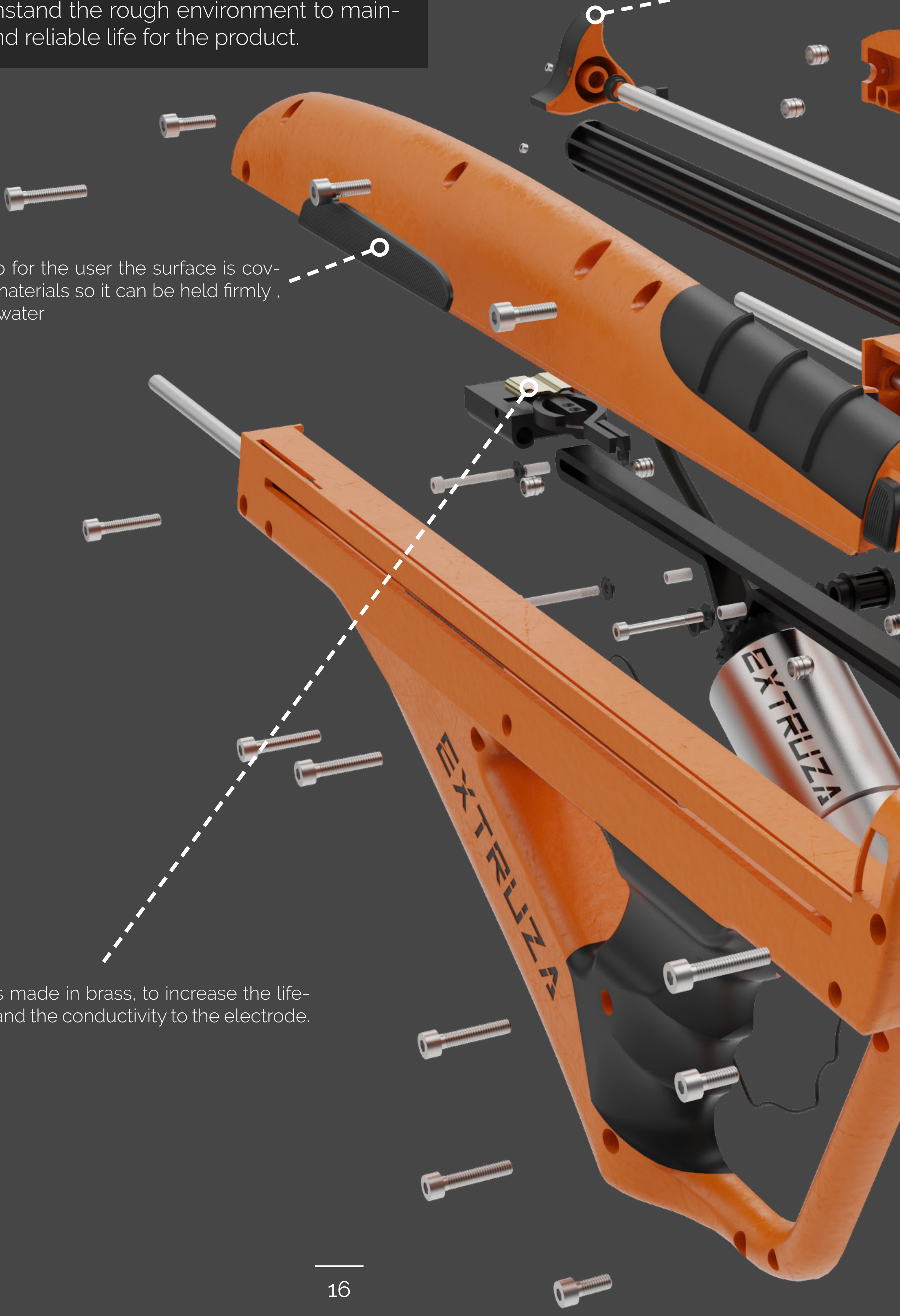
It can sometimes be hard to light into crooked areas when the light from the helmet is only pointing in the line of sight. So a flashlight can be placed on the side of the product to help illuminate a specific area.

MODIFICATIONS

Many divers are often adding modifications to the products they use, as everyone is using different gear and in different ways. Extruza features a mounting system where metric M4 screws can be used to mount different accessories onto the product, these may in the future be developed by Extruza. For now, these can easily be made using what you have laying around the workshop. To ensure a long-lasting product these can withstand up to 90 kg of force.

Exploded

In Exstruza every single part has a unique feature, everything is built with saltwater in mind, meaning they can withstand the rough environment to maintain a long and reliable life for the product.



TEXTURE

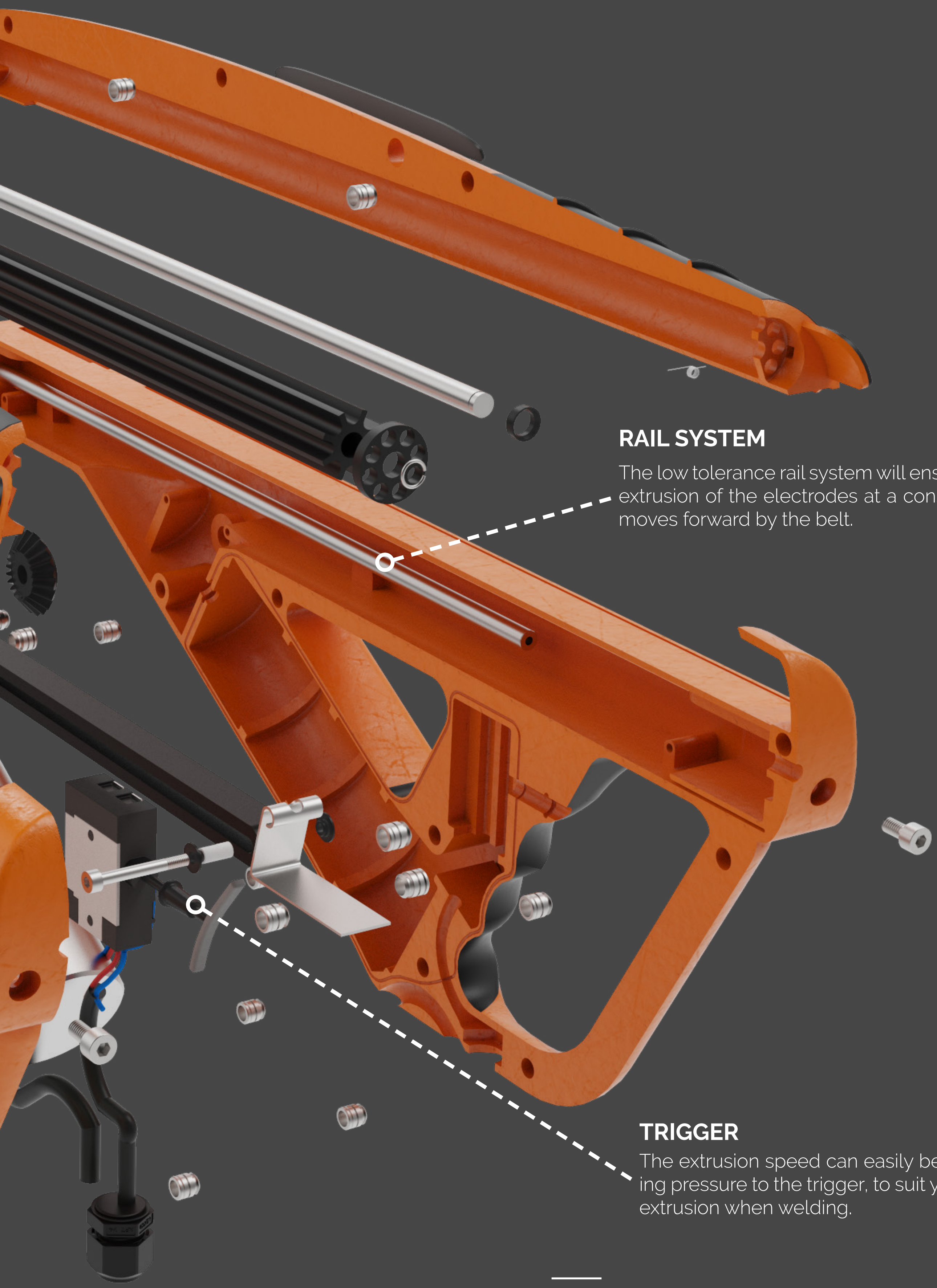
To secure the grip for the user the surface is covered in slipproof materials so it can be held firmly , even when underwater

CONDUCTER

The conducter is made in brass, to increase the lifetime of Extruza, and the conductivity to the electrode.

TURN KNOB

The knob is designed so it is easy to turn it to reload a new electrode into the "barrel" even when wearing gloves as the fingers will fit into the groves.



RAIL SYSTEM

The low tolerance rail system will ensure a frictionless extrusion of the electrodes at a constant speed as it moves forward by the belt.

TRIGGER

The extrusion speed can easily be adjust by applying pressure to the trigger, to suit your preferance of extrusion when welding.

MAINTENANCE

To have something submerged into saltwater or hazmat often, will overtime erode the product. Extruza solves this by using the best materials for function and use in these harsh condition. To withhold the already long lifetime of the product it needs some minor maintenance and cleaning to stay in perfect shape throughout its lifetime.

CLEANING

By removing the storage the product can be cleaned with a high-pressure washer or just freshwater to get dirt and salts of the product and increase the lifetime.

CHANGING COMPONENTS

As we know it is always a hassle to wait to receive the product from sending it in especially when the product is needed for work. Need new components? No problem. Just order a package of the ones you need on the website and you can easily change them yourself. The only thing it requires is a hex key that comes with the product.

WELDING CABLE

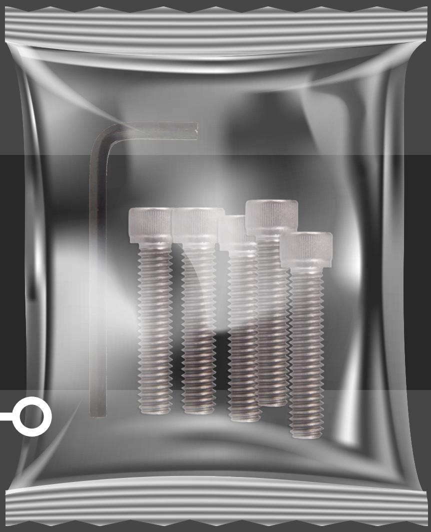
The welding cable can easily be changed with little to no struggle and if a new should be installed or the current shortend.

THE PACKAGE

PACKAGING DESIGN

When the product is received it will be in a quality box to establish the idea of a quality product, when opened up the product will immediately be present to the user.

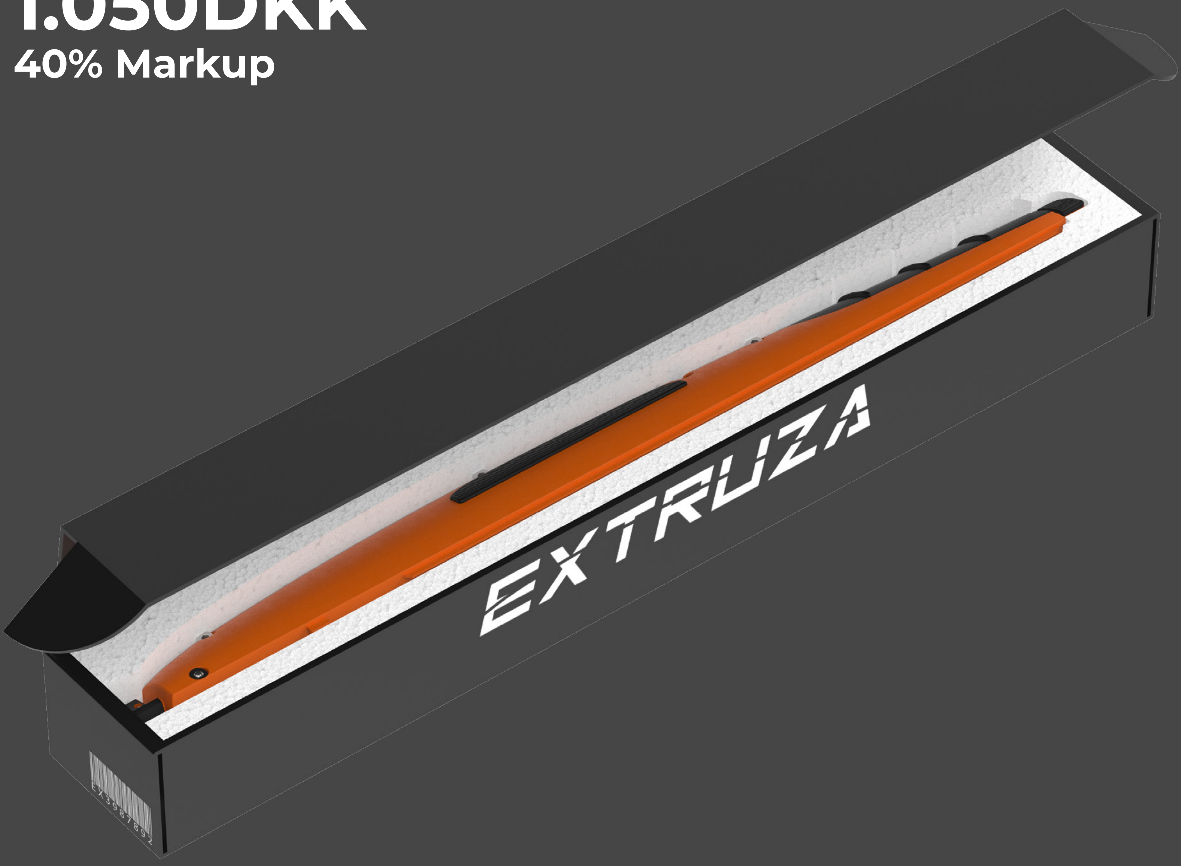
4.090DKK
40% Markup



EXTRA

The product will be received with a few spare parts, including extra screws for accessories and repairs, and a hex key to tighten and loosen the screws.

1.050DKK
40% Markup



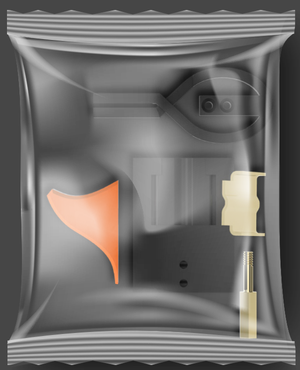
EXTRA MAGAZINE

The user will also have the opportunity to buy an extra magazine for the product as a separate unit. This is recommended for user who are often working for long durations underwater and jobs requiring more the 7 electrodes.

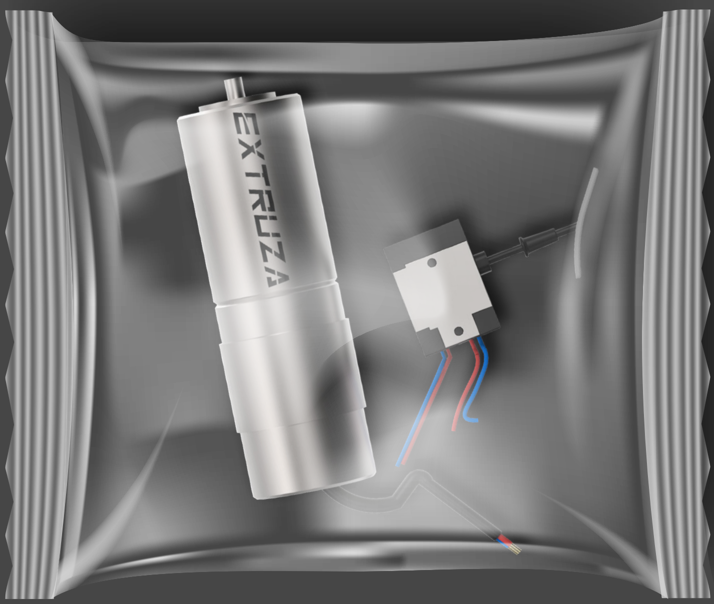
SPARE PARTS

Even though the product is made with the best quality in mind, unforeseen accidents happens when working in this industry. So this is why Extruza will provide all the parts to repair the tool if something should go wrong, and even at a fair price, so it will not be a hard decision when to change something.

RAIL SYSTEM
320 DKK



MOTOR SYSTEM
260 DKK



Handyman protection plan
490 dkk

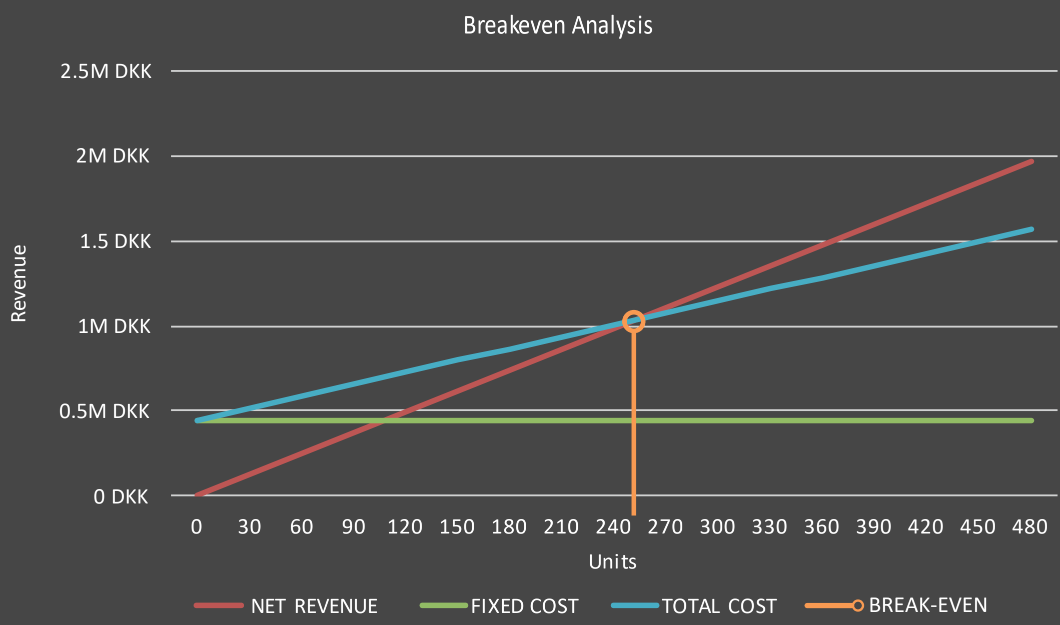
Are you a “handyman” and able to repair the product yourself? Then this plan is for you. It covers 2 year protection and the sparparts will be sent if the product is damaged under normal use.

Full protection
990 dkk

The product will be repaired by Extruza which gives 3 years of protection. As long as the product is damage under normal use.

ECONOMY

As we are hitting a niche market of Commercial divers in both Denmark and EU the product is estimated to reach out to 1 % of ~14.000 divers in Europe within the first year of sales. The expectations are that the product will spread by a great reputation within the commercial diving communities and through international fairs where the product will be presented and sold to increase these numbers.



PRODUCTION COST
2.331 DKK

STATE OF BREAK-EVEN

INVESTMENT OF 1.040.481 DKK

254 UNITS

RETAIL PRICE
4.090 DKK

SCALABILITY

The brand Exstruza is only the beginning of the new line of underwater tools, where the user is the one in focus, as we know nothing is the same when working in the depths. Commercial divers use many tools underwater, which have been poorly adapted to support their needs, so it opens up for a range of new and innovative solutions to assist in the field.

EXTRUZA

AD NYE VEJE

AALBORG UNIVERSITET

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PROCESS REPORT

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READING GUIDE

To get the best experience and understanding its recommended to start out by reading the **product report,** to get the first interpretation of the product and afterwards go through the **process report** together with the appendix to get the details about our choices in developing the product. At last look into the **technical drawings (SI units)** to see the measurements of selected parts.

If the report is read in digital version it is recomended to set the page settings to "Two Page view" and "Show cover page in two page view" both settings can be found under "view>pagedisplay" if useing Adobe Acrobat.

This is the process report containing 8 chapters: **Pre phase** - **Research** - **Framework** - **Ideation** - **Detailing** - **Material and production** - **Business** - **Epilogue**.

To keep track of new knowledge and requirements "conclusion boxes" will be at the end of some finished subchapter.

New knowledge

A statement that could lead to a requirement or a wish

Finding translated to a requirement

The references will be done in the "Harvard method" [author, year] and illustrations will be referred to as "Figure xx - description". Furthermore, worksheets are going to be referred to as [W.xx]

TABLE OF CONTENT

PRE PHASE

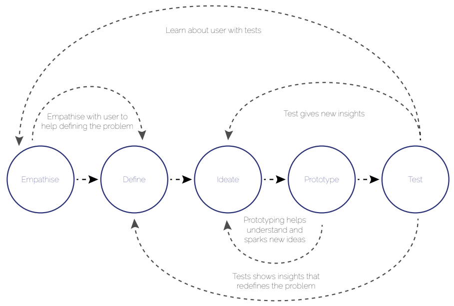
The project is developed by the group MSc04-ID16 at Aalborg University concerning the master thesis in MSc. Industrial Design. The full project is a combination of a product report, process report, technical drawings, and an appendix. The project is developed with the help of a big range of contacts and collaboratives that provided the project with important knowledge.

INTRODUCTION

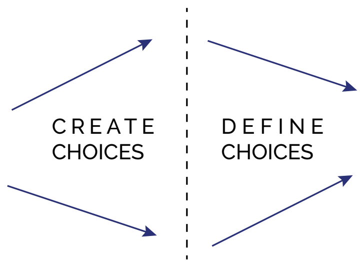
Underwater electrode welding is not an easy task, it is based on old technology which has existed for over 100 years and have never seen any innovation towards underwater use. While welding underwater it is by the use of long electrodes rods, which gives a loss in the precision for the diver.
The reasoning for the niche market of choice started out based on an interest in dangerous jobs, where commercial diving is one of the most risk full in Denmark. In this thesis, a new and innovative solution will be developed based on feedback and contact from divers all over Danmark and our own interpretation of these needs.

APPROACH

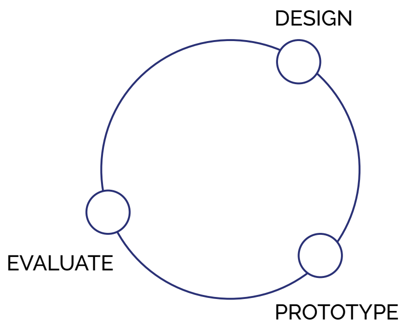
DESIGN THINKING



CONVERGENT & DIVERGENT THINKING



ITERATIVE DESIGN PROCESS

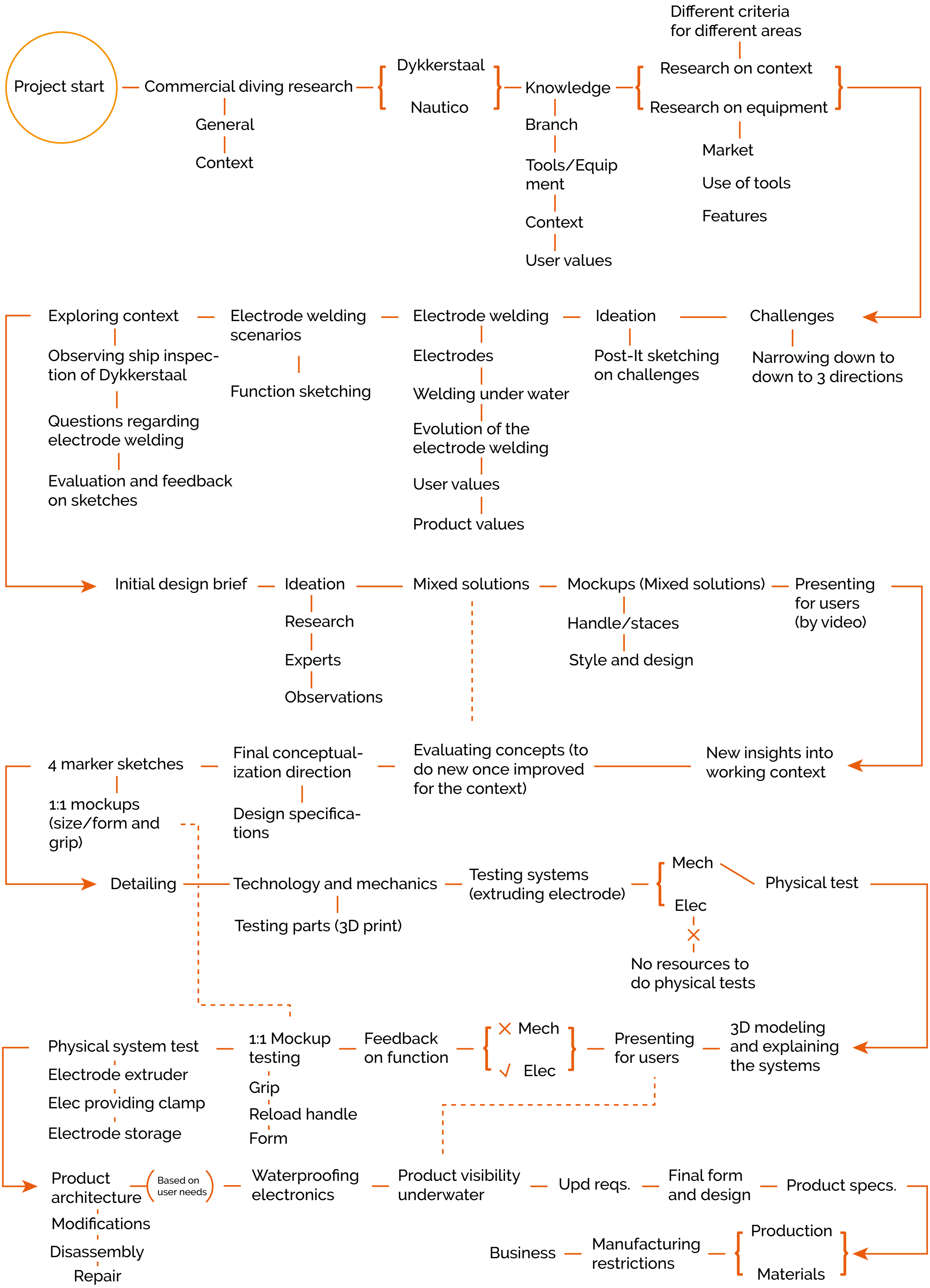


This can be seen as the core of being a designer. There are 5 steps in design thinking: **Empathize, Define, Ideate, Prototype and Test** and every time the group passes a step its with the user in mind. This non-linear process will result in a creative solution and meet the user needs with new ways.

It have been a thing throughout the report to be open for ideas and thoughts that could improve the development of the product. Having a big solution space to chose from it made it easier in the other end to frame choices which were carefully considered.

Design, test, evaluate and then do the same, with improvements in mind. In this project iterative design have been a big part, as it was made difficult to meet users due to COVID-19 virus. Tests on ourself, user feedback and knowledge is used iterative to keep the product processing and evolving by evaluating on the previous outcomes.

PROCESS OVERVIEW



RESEARCH

It's important to get an understanding of what commercial diving is and thereby be able to answer questions and solve problems in the next phases. This chapter touches on the users, what they think about being a commercial diver, gear used, and the contexts it all takes place in.

COMMERCIAL DIVING - ENGINEERING

Commercial divers are someone who is getting paid to do a job underwater, based on personal interest and contacts it was chosen to work with traditional commercial divers, which is people working underwater with welding, inspection, repairs, etc. It's basically a craftsman underwater. There are different rules around the world on how deep and what training you need, to be able to do specific tasks. There are two types of divers which are a standard around the world: Inland and offshore. In Denmark inshore consider tasks of doing welding/cutting/scanning etc. which is often done in lakes, harbors, dams, and wastewater treatment plant at a maximum depth of 30m. Usually inshore are a bit easier than offshore because it takes less time being out in the field and the danger is slightly decreased, as it's easier to dive up to surface. [W.01]

PROBLEM FORMULATION

Commercial diving is a rough and hard environment to work in, it requires a lot of training and skills to master it, as it requires high diving skills, mental focus under pressure, and craftsmanship. Diving offers many often unforeseen challenges such as changing currents, marine life, life depending gear failure and low visibility. Welding is one of the many skills often used underwater, the current solutions have not been adapted to underwater use, and making it a lot harder to use under these circumstances. Even further the design has stayed mostly the same for over 70 years, for both under- and above water use.

"The project aims to develop a tool for commercial divers that increases their precision underwater when welding while also focusing to increases their frequency of work"

PROBLEM STATEMENT

DIVING IN DENMARK

In Denmark commercial diver always has to use an attached safety rope going up to the surface where it can be pulled up by the diving supervisor in case of an emergency, this line is often connected with the air supply, electric wire, water tube or other cables. The big advantage of Surface-supplied diving is the diver can spend much longer underwater, and it is safer to do so. The diver can also use do scuba diving but a rope is still required. They mostly use full face mask or diving hats as this gives the user more moveability, compared to an in mouth scuba regulator and the ability to talk with the crew on the surface. A diver is always having an air tank on the back they can use in case of emergency if the power supply from the top should run out or stop working. [W.03]

A commercial diver works in a big array of areas, this means they have to bring different tools underwater depending on the task, often at the same time. One of the most common assignments is welders, here they are using electrode welding with the same tools used above water. [W.03]

Carrying a big array of tools ✓

Safety is high priority ✓

Often welding ✓

Dives down to 30m !

CONTEXT

This part of the research unfolds in which context the divers dive and how the circumstances are in different areas. This helps to identify if special criteria need to be fulfilled before a product can be used in certain areas. A focus is pointed against the inshore- and inland work as its where contacts are working and with a viable distance to do field research and tests.

HAZMAT

Hazardous materials can be one of the most dangerous environments to work in, here they are diving in materials which can be harmful to the human body. This could be biological, oil, or radioactive materials. This means divers are in seamless suits and are decontaminated after the work they have done. In these conditions, the diver is not able to smell anything they are diving in, as the suit is completely sealed, and the visibility can be none. (CDiver, n.d.)

KEYPOINTS
- No visibility
- Hazardous materials

Figure 1: Diver in quicksand

INLAND

Inland is when the diver is diving in human build constructions with water, which can be sewers, wastewater treatment plants etc. this is often considered to be Hazmat, as it can be waste like feces, either way, the diver must protect himself and the surroundings. But it can also be in drinking water which means they have to wear clean gear to not contaminate the water. (CDiver, n.d.)

KEYPOINTS
- Clean gear
- Hazardous materials
- Tight workspace

Figure 2: Diver in water tank

HABOUR

When diving in harbours you are not alone and there can be a lot going on, as unexpected circumstances like ships coming in and out. Jobs can vary from cutting something away from the propeller, cleaning the hull of a ship or adding anodes on harbour sides or ships, which all requires diffrent tools. Here there is also often a lack of space around the diver. [W.03]
The visibility can change a lot but on good days it is around 6-8 meter visibility in Aalborg, and can be down to almost zero. Water temperature can vary from 20 degrees down to 0 based on the season. During the winter the harbour can freeze so the diver has to cut a hole through the ice and dive under it. [Bang, 2013],[W.02]
When diving in seawater there is of cause also a bigger risk for corrosion. This corrosion need to be cleaned of surfaces before its weldable. [W.02]

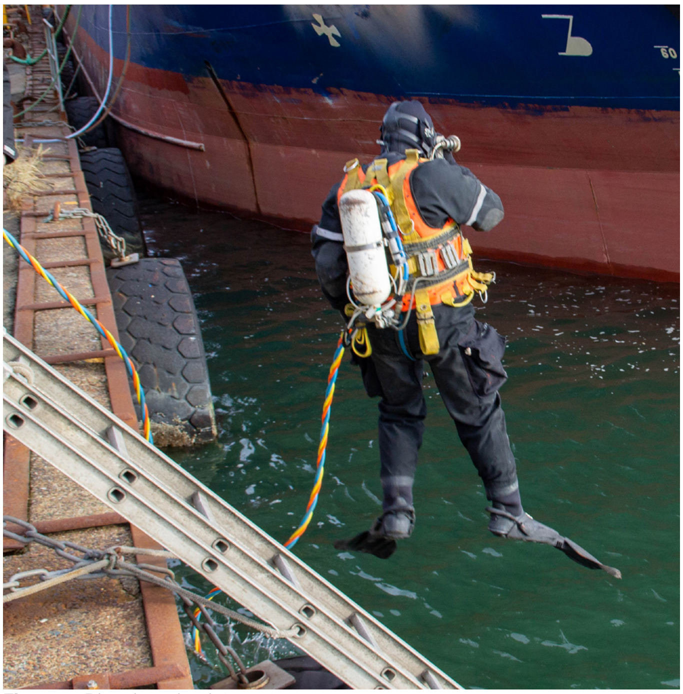


Figure 3: Diver jumping into water

KEYPOINTS
- Watercurrent
- Coldwater
- Ship activities
- Lowvisibility
- Saltwater

FRESHWATER

This diving is often in a more calm condition than harbor diving, since the currents are often not as strong. The visibility can be very clear, but due to shallow water and biodiversity it can also change a lot. These areas are most often not as filled with trash as the ocean areas, where it gets dragged in by the currents, so in water like this, it's also important to keep your job clean. [W.02]


Figure 4: Scuba diver in freshwater

KEYPOINTS
- No salt water
- Low Visibility
- No littering allowed by doing the job

SUM UP

The most noticeable aspect of diving in the danish oceans is the lack of visibility, where it can sometimes be down to almost zero. This means they will mostly rely on feeling where they are, and what they are doing. When diving in inland waters they mostly already have a good idea of what they are going into, and already know the waters conditions, whereas during dives in the sea it can be very unpredictable and change fast.

Low visability

Large array of tools currently used

Some places are very tight to work in

Hasrsh context, so cleanable and restiant materials are nesecarry

EXPERT PANEL

The purpose of the expert panel is to be able to get insights into how the two companies operate and what gear they use. Secondly, the idea is to use the panel to evaluate the concepts, prototype, and as a source of information throughout the project.

Further investigation leads to contacts with Dykkerstaal in Hanstholm and Nautico in Aalborg, the two companies seemed to be very different in their size, which could potentially lead to a bigger array of problems. Both of the companies are a part of the "Diving Firms Association"(Dykkerfirmaernes Brancheforening) which is a national association to ensure a fair and competitive market in the industry. (Dykkerfirmaernes Brancheforening, 2020)

Figure 5: Rune owner of Dykkerstaal

Figure 6: Peter owner of Nautico

Figure 7: Dykkerstaal logo

Figure 8: Nautico logo

COMPANY	
• Big company (12 divers) They do jobs all over Denmark but are made into separate "teams/stations" where they have gear, so they can operate at a fast phase. They are currently one of the biggest inshore commercial diving companies in Denmark. Operates in the seas surrounding Denmark with inshore work, which includes welding anodes in the harbor, cutting propellers on ships, maintenance of ships, etc. [W.03; W.04]	• Small company (1 diver) As he is the only diver in the company is attending all jobs and has one employee working with him from the ground while driving. He is mostly working on harbors in northern Jutland, or wastewater treatment plants all over the country. [W.03; W.06]

USER VALUES

Dykkerstaal got 2 barns full of equipment for different projects that they have been doing throughout their time. Some of it gets used quite often and some only once. As a company, they got an interest in making many of their tools themself out from spare parts. The reason for that is they feel that it gets perfectly fitted to the task and the **price** doing that is also lower than buying a product off the shelf. When it's cold they normally use a warm water-filled suit and a drysuit for more neutral waters temperature. [W.03; W.04]

All of the tools are stored in his work trailer, garage, or basement at home.
Almost all of the tools he is using are bought, and rarely make any himself. He does value the **quality of the products** a lot and appreciates if they can improve his workflow.
Peter is always diving with an AGA mask, alongside this, he is using a full-body sealed rubber suit which is especially useful when diving in Hazmat water where small leaks would be a large danger to him. [W.03; W.06]

Both companies had gear where they had **changed or upgraded** it to suit their needs, such as the AGA diving mask where they had placed metal brackets on the side for placement of lights and cameras. These masks will break over time, whereas a diving helmet will work for decades, but the helmets are larger and thereby they give less mobility. And the common tools such as pneumatic drills, welders, and power washing tools were the same for both companies. [W.03; W.04; W.06]

Rune had a job where he needed to shorten the blades of a propeller. It was with short notice so he concluded that he could make the "cutter" himself. He took a circular saw, grinded down the teeth of the blade so the saw wouldn't catch the metal, and added some profiles with a clamp-on one of them, so it could hold itself in place under the cutting of the blades. After one day he had the product ready for the task and said that it worked like a charm, and it was a **cheap** solution. [W.03; W.04] This can be seen as a way to illustrate the companies quick approach to adapt to new and unforeseen challenges.

For the past decade, he had been using a pneumatic hammer drill which cost around 35.000dkk and it still works well. But recently he bought a Nemo drill, a **high quality** battery drill (8.000dkk) which he used as much as possible as it is a lot **easier to carry** around underwater, so he appreciated the tool a lot, and was very enthusiastic in presenting it. [W.03; W.06]

SUM UP

In commercial diving, there is a large variety of company sizes where the smaller ones are often more specialized in a few areas, and the larger ones are more flexible to adapt to large and new challenges.

The company size matters as this are where they have different scopes of work through Denmark. This does not change their user values as they prioritize safety as their number one priority and from that to be able to do the job fast and with a high standard in quality.

Equipment adapts to the company size and the job. As seen Rune got a bigger variety in gear that was specified to the different jobs the company did but they both rely on the quality of their equipment. Anyhow they both like to improve their tools by customizing it by themself to fit the different jobs better.

Same products are used in many diffrent contexts	✓
Pright in quality work	✓
Confirm previous finding	✓
Function is more important then price, for reliable products	!
Upgrades and improve thier curent products	!

FRAMEWORK

Converge down from thinking big and being open for all knowledge concerning Commercial diving down to detailed framing around electrode welding and the different scenarios happening around this kind of job. Furthermore, a shadowing is done with a team of commercial divers to paint a better picture of how the different steps unfold and taking an opportunity to get questions answered.

DIRECTION - ELECTRODE WELDING

Based on research, visits, and sketching session it was chosen to work with electrode welding, based on the largest array of problems. Many different issues can be solved compared to the current product, such as getting closer and replacing the electrode, these can also potentially be combined into one product which could solve several of them in some way or another. [W.07, W.08]

VISIBILITY(Figure 9)

Often the diver will be working in murky water, where it can be hard to determine where to weld as they have to rely on there feeling alone.

The diver often uses a light on the helmet/mask to light up the working area underwater, this could also be placed on the welding tool to get a directional light, and if it is only used pointing towards the welding area it could be a stronger more focused light then the headlight can provide.
Another solution is to make it easier to get close and feel the electrode placement when welding while still having a good grip on the electrode. [W.04]

Figure 9: Low visability

PRECESSION (Figure 10)

This is what the welders call the key to a pretty/strong weld. Keeping a steady hand through the whole weld and doing the movement correctly so the two pieces of metal that are welded are evenly covered in the weld seam. Mastering this is a long journey and in water even longer. Imagine staying or floating in the ocean and trying to hold a steady hand welding something that is at the start up to 70 cm away from you. The stream is unpredictable and pushing you back fourth and the divers try to keep the precision by using their other arm to help to stabilize the electrode and welding.

To improve the stability and precision of the electrode holder, better ergonomics need to be developed. An investigation would be made into if it's possible to handle the welding with one arm so the other can be free to hold onto something or other things to keep the diver stable in the water. It's also worth looking into putting the diver's hand closer to the welding point so it's easier to see how the weld is going, and it is more controllable. [W.24]

Figure 10: Hard to keep electrode steady

CARRYING UNDERWATER (Figure 11)

The diver will have to carry the tool down when they jump in or it will be lowered down when they are in the water, there is no way to attach the tool to the diver, so it will be carried around in the hand. Futhermore they also have to carry the electrodes so they can change to a new one when needed.

This could be solved by having a clamp or something similar to the tool which can be attached to the diver's belt, harness, or other places. [W.04]

Figure 11: Carry underwater

ELECTRODE CHANGE (Figure 12)

When welding underwater it can be hard to change the electrode, as they have to screw it on or push the clampdown. This leads to the divers using long welding sticks so they don't have to change so often, but these long rods also causes the diver to lose precision. Furthermore, they have to bring the electrodes which take up space when attached to the diver or the ground crew will have to lower them down in a bucket. [w.06]

An easier way to change the electrode could be developed, and maybe the electrodes could be stored inside the tool, so they won't have to bring them along separately.

Figure 12: Electrode change

USED ELECTRODES (Figure 13)

Based on the expert panel it was often the easiest option to just throw the small stumps of electrode into the ocean floor before putting a new one in. They didn't see a problem in it because the harbors often was a mess on the bottom anyway. One of the experts thought about it when diving in lakes as it would add contamination to waters that were standing still. [w.06]

A way to prevent this to provide the divers with an option to store the small pieces of the rod without affecting their workflow. After they were done they could take the pieces onshore and automatically helping to deal with the environmental changes.

Figure 13: Trash on the bottom of the sea

BREAKING PARTS

Based on the user research the welding tool often breaks when used underwater over time, this is due to the harsh environment of saltwater. And currently, it is not feasible to change the part so they throw the old one out and buy a new one. The only part which is breaking is the conductive material inside, probably due to corrosion. [W.04]

To prevent this, it could be considered to make an easy changeable part containing the conductive material.

SUM UP

As part of the converge into a more specific field of challenges for the welding tool and small solution space of how the problems could be solved. These scenarios and solution proposals will work as the foundation for the initial design generation along with a visit to a job provided by one of our Experts. Provided feedback should lead to sketching sessions which can be developed further into mockups that can be present to the user.

ELECTRODE WELDING

To be able to understand the electrode welding and the handle a research was conducted to verify this. Knowing the technology and how it works, it will be easier to communicate using technical terms when later on speaking with the Expert Panel.

HOW CAN IT BURN UNDERWATER?

Electricity underwater can, of course, be very dangerous, the most used method of welding is electrode welding here the electric ground wire is attached to the working piece with a clamp, and the positive is connected to an electrode holder. When the electrode gets close contact to the metal piece it will create an electric arc from the tip of the electrode, which will melt, and creates a liquid puddle of metal, and when it cools down it will solidify and be a weldment. When it's done underwater a layer of flux on the outside of the rod creates bubbles which serves as a shield from the outer layer of water. The flux will also make slag on top of welding, but this helps the material to cool down slower which also makes the weldment stronger. And after it can easily be removed with a hammer. [Welding Headquarters, 2019]

During the training course for underwater welding, they will learn to change the stick when it burns out, here they will ask the advisor on the ground to turn it off the current, so they can pull it out and take a new one from the bucket or where ever they are keeping them, and place it in the holder. But from the company visits, they said this was never done afterwards, here they will keep the power on and just replace it. This will sometimes cause small electric shocks to the diver. The burned-out rods is often just thrown into the bottom of the ocean as it is already filled with junk such as in Aalborg harbour, or this was at least Peters experience, but when welding in inland freshwater and drinking water he had to take them back up. [W04-W06]

ELECTRODES

An electrode is the material welders use to weld metals together underwater or on land. They come in many different sizes and coatings. Standard SMAW electrode of the number E6027 or E7024 are around 35-71 cm in length and usually ~1.6 to~6,4mm mm thick [Wikipedia, n.d.; Cary and Helzer, 2005, Hydroweld, 2016]

The rode consists of a metal core which the electrode handle grabs onto. This core is the full lengths of the electrode. A layer of flux is around the rod which provides a protective layer for the melted core and is called "Slag". Slag help slowing down the cooling of the metal increasing a more even distribution of heat giving the weld a stronger hold.
The last layer is only applied when it is used underwater, which is a waterproof coating,

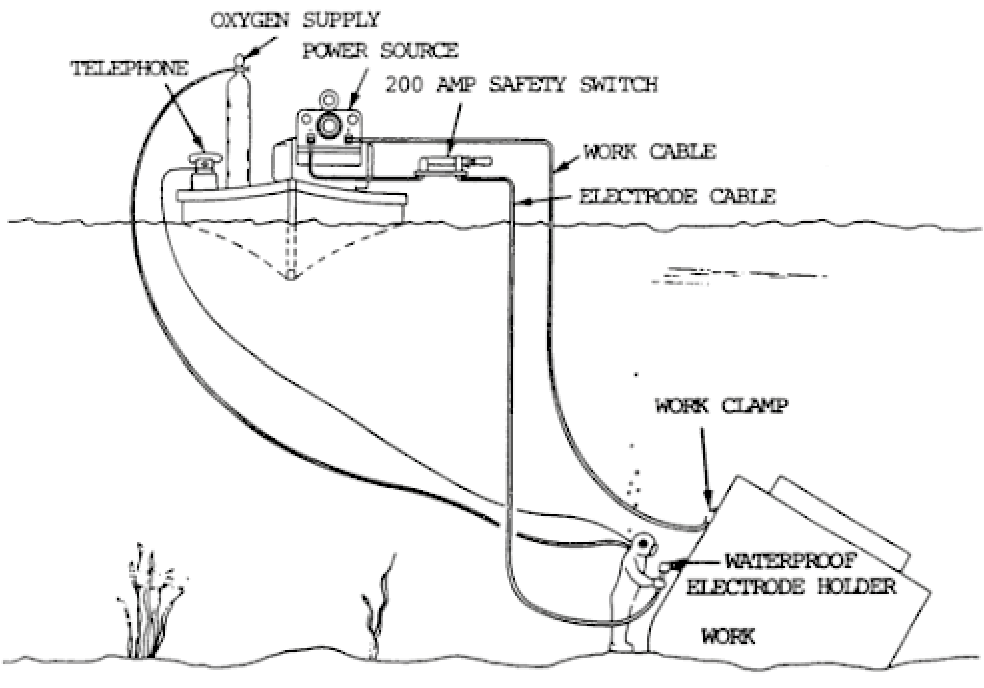


Figure 14: Underwater welding scenario

HOW HAS IT CHANGED?

The electrode was first discovered in 1836 by Edmund Davy from England, but it was first in 1881 the Russian inventor Nikolai N. Benardos who made the use of it for welding with his invention "Elektrogefest" in 1881, and in the 1885-1887 patents was made in the in England and America. This patent shows an early electrode holder, and on (Figure 16) an illustration of it from 1887 can be seen. This was an electrode carbon welder, and it become popular during 1890s and early 1900s. [Grill, n.d.]

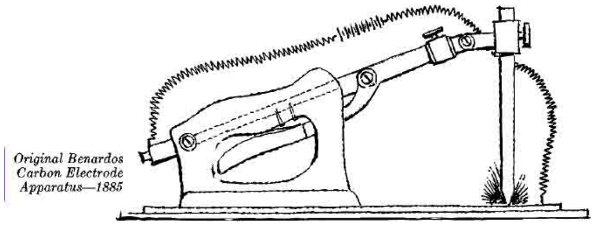


Figure 16: Electrode carbon welder

During the first world war new methods were used as the Carbon weldings were not as strong as the metal being welded but 1920s the rods started to get a flux coating which leads to the materials being stronger and more suitable and was used in many countries that was participating in the war in were they had the job of welding vehicles. Since then not much has changed for arc welding, there have been changes which improve the rod by using different materials, but the handle is similar to the first one.

The earliest image of the use wich could be found during the research was from a colorized video from 1940s during the second world war [The Kino Library, 2014] and the only simple change is an outer casing of plastic and potentially a better conductivity to the rod.
[W.11]

Figure 17: Colorized image of a woman welding from the 1940s

The inside of an electrode welder is really simple, as can be seen on (Figure 15). It's basically just a conductive material (In this case copper) with a wire connected to the surface. Here the electrode is held in place by a clamp on the top. The clamp iteslf will not heatup while welding, only the end of the electrode will do so. [W04-W06]

Figure 15: Clamp electrode handle

SUM UP

This research gave a clear understanding of how electrode welding works underwater, the length of the electrode can change depending on the diver. Furthermore, the process has not changed at all during the past 70 years.
The electrode handle overall design is a simple construction with the main purpose of being a conductive part to ignite the electrode, whereas the handling and grip is just the secondary feature of it.

- Simple internal construction
- Electrode thickness - 1.6 - 6.4 mm
- Electrode length - 35-71 cm
- Electrodes only get hot in the burning end
- Electric shock while switching electrode

PRODUCT VALUES

Here a bunch of tools that the divers use will be investigated with knowledge based on the experts and research to verify what visual and functional values the products have. This will passively indicate what things the diver like about the tools they use which further can be translated into ideas and concepts.

NEMO DRILL

Figure 19: Nemo Drill

KEYPOINTS

- Masculine design
- Robust design
- Clear assembly
- Sparparts

The Nemo drill is a new product on the market and gives a lot of flexibility to the user as they don't have to bring the pneumatic tubing underwater as with usual underwater drills. Which was an important factor according to Nautico and a very appreciated tool.

The hard metal shell gives the design a strong and robust look which indicates it can withstand rough environments, this is similar to many other tools including pneumatic underwater drills.
The design is a masculine design both in the shape with the hard and rough edges, but also in the clear view of the assembly with screws. This can also be referred to as the values given by the experts were they appreciated the ability to fix the products themselves. [Nemo Power Tools, n.d. b] ,[Durbin-Sherer, 2015]
And on the Nemo website, there is a large variety of replacement parts, this confirms the user value of makeing/reparing tools themselves since the product is specifically made for underwater use. [W.09] [Nemo Power Tools, n.d. d]

KIRBY MORGAN 37 HELMET

Figure 18: Kirby morgan 37 diving helmet

KEYPOINTS

- Streamlined shape
- Organic forms
- Takes a lot of space around divers head
- Attachments for products
- Submerge down to ~180m
- Worldwide know brand

Divers in Denmark usually choose from two brand options of masks when diving, AGA, or Kirby Morgan. Kirby Morgan provides a more technical and "diver bell" solution that protects the head. The appearance of the helmet looks like its build for deep dives and the organic shape keeps the mask simple, with a touch of an American style. The expert panel didn't like the mask for their "simple" jobs as they found the helemt to large and heavy, and thereby limiting their mobility, while providing a fixed position for the head. The weight of the helmet is 13 kg, so the diver will usually require assistance to put on the helmet. [W.09]

AGA MASK

Figure 20: Aga mask

The AGA mask is a divers preferred choice. They rely on the flexibility the mask provides as its works without a harness and isn't locked unto the diver's suit. It's also easily wearable with the "spider" which is the band behind the mask. The AGA mask is olaso often used under smoke diving by firemen and are very minimalistic compared to the Kirby Morgan. [W.09]

KEYPOINTS

- **Submerge down to ~80m**
- **Worldwide know brand**
- **Close to the divers head**
- **Simple shape**
- **Easy to wear**
- **No space for attachments**

ESAB HANDY 200

Figure 21: ESAB HANDY 200

The welding tools are all simple in their design, they does not have a focus on giving the user a comfortable and ergonomic grip. From the expert panel it can be seen they both prefer the twisted angle welding tools as these have a stronger grip on the electrode, then the clamp versions.
The handles conductive material inside breaks a lot faster for commercial divers due to the harsh environment of the saltwater, this means they either have to buy a new one or replace the broken parts. But it was seen for both companies that the replacement part was almost as expensive as the whole handle so they always bought a new one. [W.10]

KEYPOINTS

- **Replacement of defect parts**
- **Strong electrode grip**
- **Simple construction**

UNDERWATER TORCH CUTTER

Figure 22: Broco

For jobs that require cutting underwater diver use, a device called a torch. It's a welding handle but it can also supply gas, that is required for cutting. It seems like they all use BROCO that is a brand of a torch. The shell is made out of PTFE lined fiberglass and the expression is close to a water hose. It's in a colorful orange that keeps the tool visible under bad visibility. They focus on an ergonomic grip for the diver and the interaction surfaces are made very big so it's easy to use. Comparing it to the welding handles this is a very expensive tool. [W.10]

KEYPOINTS

- **Big interaction faces**
- **Easy to detect (bright color)**
- **Ergonomic grip**

SHADOWING DYKKERSTAAL

By contact with the Expert Panel, a trip was arranged to Frederikshavn in North Jutland to witness a job of a ship inspection done by Dykkerstaal. This visit allowed witnessing a customer journey of a diver preparing and doing a job within commercial diving, but in this case, it was an inspection dive for a ship and not electrode welding.
During the visit, many different topics were discussed about diving and welding underwater,
Below are the key points from the discussions, which lead to new knowledge.

Figure 23: Frederik holding an electrode handle

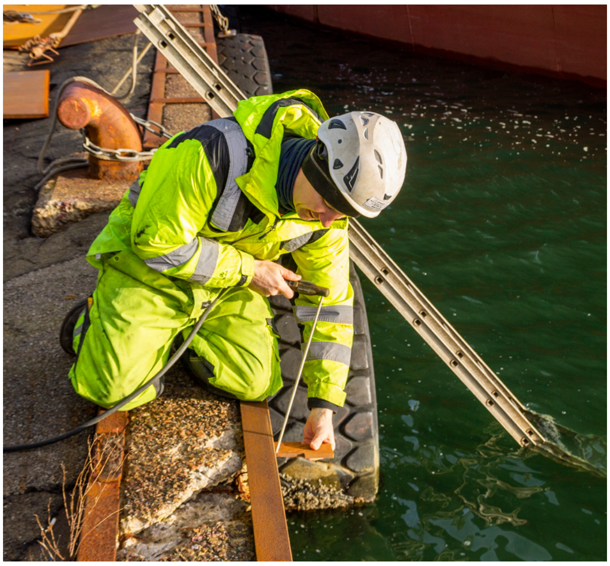


Figure 24: Discussing welding

The electrodes they are using are 42cm, but it was mostly due to personal preference and varied a lot. When bringing the sticks underwater they will slowly break down, so the diver can bring ~6 as they don't have time to weld with more if the electrodes coating gets damaged they will tear down fast and sometimes break off where the damage is. From their experience the beeswax coating they are making themselves is even stronger then the pre-coated rods they can buy, but the beeswax gives a softer and a little sticky feel to it.
When they are welding underwater the electrode works best if it is pushed against the surface unlike when welding on land where it has to stay a little away to form an electric arc. The divers are only allowed to dive 4 times a day and within these 4 times each session cant be more then for 4 hours at a time. [W.12]

Figure 25: Burnout electrode handle

Figure 26: Storage for the electrodes

The divers from Dykkerstaal used an electrode handle from the brand ESAB. It's a turning handle which the diver thinks is the best one to secure the electrode. After a few uses in the rough environment, the handle will loose its grip around the electrode. The solution to the problem is they drill a hole in the top of the handle all the way through(Figure 25), which makes a bigger "grip surface" and thereby an increase in the lifetime of the handle. [W.12]

MAPPING

Figure 27: Alex (Left), Hans (Middle) and Frederik (Right)

HANS
The diver was swimming around the ship inspecting and commenting on what he was seeing while they were following with live video and audio from the shore.

FREDERIK
Frederik was in the van on the ground watching and discussing the video and inspection with Hans and Yuri while writing down where there was damage on the ship. He also had to run out along the ship to mark where the damage was, by telling Hans to go up so he could see him.

ALEX
As the diving supervisor, he had to stay outside managing the cables for Hans, so he had some lose cable to dive with. And be ready to pull him up in case of an emergency.

YURI
Came from an insurance company to see if the damages were big enough to get the ship into dock for repairs or if it could sail for a bit longer.

Crew meeting
Dykkerstaal crew meeting to discuss what they are going to do.

Preparing gear
Getting the needed gear out of the van, and preparing it while waiting for Yuri from insurance to arrive.

ALEX
Diving supervisor

HANS
Diver

FREDERIK
Coordinator

Helping diver
Helping to put on gear and checking if everything is working

Gearing up
Getting gear on and checking if everything is working

Preparing cameras
Getting camara screens ready inside the van

ALEX
Diving supercvisor

Cable management
Unwinding cables and hoses

Supervision
Controlling that the cables do not get stuck, and is ready to help in case of an emergency

Helping up the diver
Pulling Hans in after he is done inspecting

Helping diver
Helps to take off gear and pack it down

Cleaning up
Cleaning gear, and placing everything back in the van

HANS
Diver

Dive start
Jumping into the water, and starting the dive

Diving
While diving he is discussing what he sees with Frederik and Yuri

Getting back on shore
Taking fins of, placing them on hands, and climbing up a ladder

Getting gear off
Removing all the gear, drying himself and changing cloth

Getting warm
Sitting inside the van to get warm after a cold dive

FREDERIK
Coordinator

Briefing the plan
Telling Yuri from the insurance company what the plan for the dive is

Documenting
Runs back and forth to make marks on the ship while talking with Hans and Yuri

Writing report
Writing a report of the job, to the insurance company with the ship damage

Discussion
Concluding with Yuri, if anything is missing in the report

Final meeting
The crew has a final meeting discussing the dive and if anything was missed in the written report

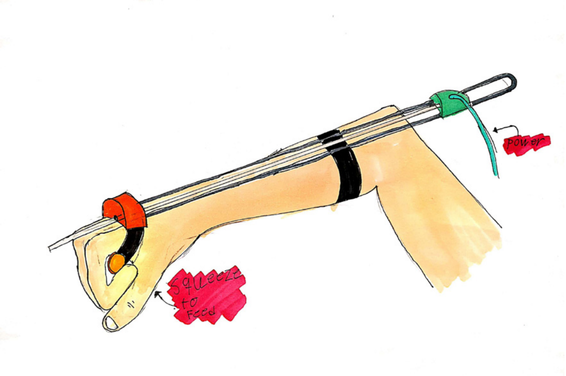
SUM UP

The visit gave insights into how quickly the divers could get all their gear on and get into the water. It was clear that they want simple equipment to use and wear as they wanted to do their job fast. "Homemade" solutions were also seen at this job. They also adjusted their electrode handle to be able to keep the electrode in place for a longer time when it got worn up.

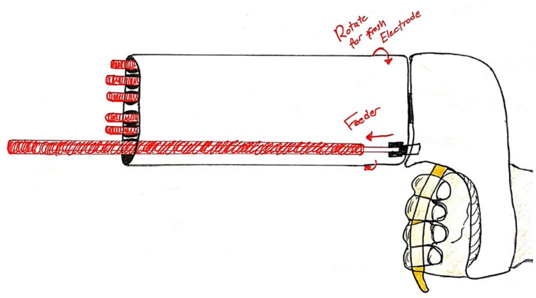
- Cleaning gear after the dive ✓
- Is never underwater for more then 4 hours ✓
- Never brings more then 6 electrodes !
- Pressing the electrode towards the surface when wet welding !
- Outer coating on electrodes is fragile !

SKETCHING FEEDBACK

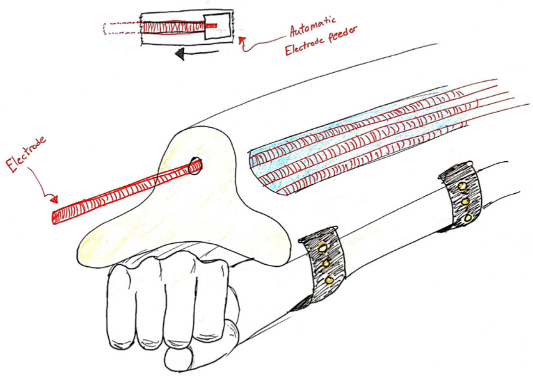
The visit also allowed getting feedback on a few sketches regarding function which was developed based on the direction of electrode welding. [W.13]



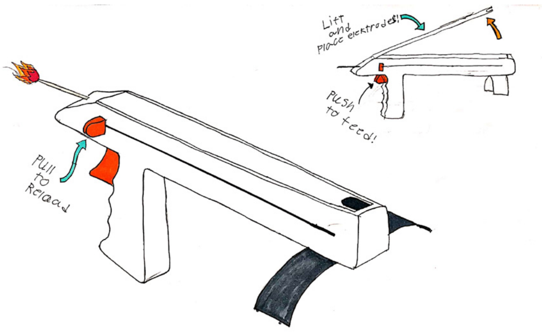
- Don't like the idea that's it strapped to the arm
- A simple/light design might be beneficial
- Unsure if the "on arm" solution is more precise than holding it.
- Few part make it easier to repair



- The big area might make it hard to see the welding
- Likes the idea of rotating it to change electrode as its quick and intuitive
- Easy to let go
- The solution looks expensive



- Dont strap to the arm
- Likes the idea of haveing a chamber to store the electrode so they don't get wet



- Likes that it rests on the arm
- Reminds him of a gun
- Easy to reload

SUM UP

Feedback was given on four concepts of the electrode handle concept. Presented were: Self Feeding electrodes, better handling (putting it on the arm), auto-reloading by having more electrodes stored, simple construction. The divers laid weight on the self-feeding mechanism and like the option to put it on the arm as long it wasn't to tightly secured. But they didn't know if it was possible so that was something that should be investigated further. At the end of our visit they divers said that they like to have a simple product, as it should be something that could be turned on and were ready to go.

Would be benefecial to keep electrodes dry !

Simple interaction is prefered !

Should not be strapped to the arm, so it can easily be removed during an emergency

INITIAL DESIGN BRIEF

The brief sums up what has been gathered of important information to build up a foundation that would lead the project in a more specific direction. Problems are described and what resources are needed to be able to solve them.

PROBLEM FORMULATION

Commercial diving is a rough and hard environment to work in, it requires a lot of training and skills to master it, as it requires high diving skills, mental focus under pressure, and craftsmanship. Diving offers many often unforeseen challenges such as changing currents, marine life, life depending gear failure and low visibility. Welding is one of the many skills often used underwater, the current solutions have not been adapted to underwater use, and making it a lot harder to use under these circumstances. Even further the design has stayed mostly the same for over 70 years, for both under- and above water use.

"The project aims to develop a tool for commercial divers that increases their precision underwater when welding while also focusing to increases their frequency of work"

PROBLEM STATEMENT

PRIMARY USER

- Inshore wet welder

PRICE RANGE

- Replacement part: 50-300 DKK
- Whole product: < 3000 DKK

SECONDARY USER

- Dry welder
- Offshore wet welder

MANUFACTURER

- China
- Our team

NETWORK

- European diving federation (EU)
- Danish diving community (DK)

SERVICE

- Webshop sale
- Sale of spare parts

CURRENT REQUIREMENTS AND WISHES FOR A SOLUTION:

These requirements and wishes are developed from previous research and dialogues with divers and with insights into their gear. Later in the process, these will hopefully be converted into product specifications and thereby be more concrete.

\ Submerged down to 30 meters – pp 9
\ Easy to control/use with zero visibility – pp 11
\ Easy to clean – pp 11
\ Can be used in narrow places – pp 11
\ The construction and materials shall withstand saltwater and hazardous elements – pp 11
\ Ability to customize the product – pp 13
\ Increase workflow – pp 13
\ Can be repaired by the divers – pp 13
\ Be able to hold onto electrode with a diameter of 1.6 to 6.4 Ø – pp 18
\ Be able to work with electrode lengths of 35 to 72 cm - pp 18
\ Reduce the electric shock when changing electrodes – pp 18
\ Can be submerged for a minimum of 4 hours – pp 23
\ Hold unto a at least of 6 electrode per dive – pp 23
\ Last longer than the existing solutions – pp 23
\ Preferable to keep electrodes dry - 23
\ Not be permanent attached to the arm – pp 24
\ Easy to reload with new electrodes – pp 24
\ Simple interaction is preferred - pp 24

IDEATION

Ideation has been done throughout the whole project but this chapter will sum up the evolution of sketched to physical models to test out different grips and handle. In this chapter designs and ideas are evaluated with the users to keep the progress on track of being user-orientated.

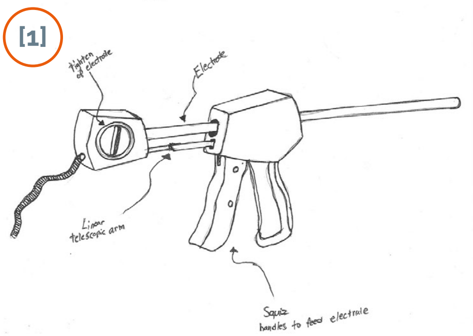
MIXED SOLUTION

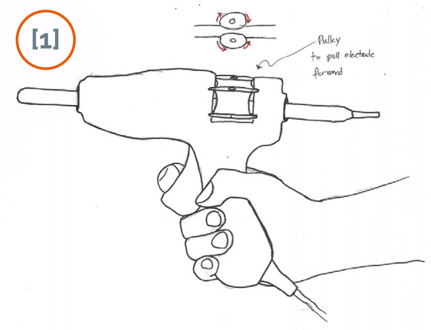
The first directional sketching is based on the direction of electrodes welding and the integration of the new knowledge along the way of researching. This sketching unfolds how big the solution space is for the different scenarios and which one comes close to have the potential to solve the problems within underwater welding.

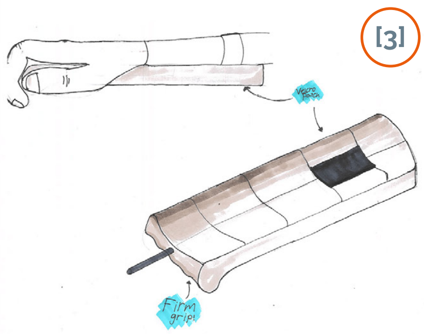
No.	what if [...]	Source
#1	...there is an emergency and the diver want to throw it away?	Expert panel and sketching feedback
#2	...the diver can not see anything?	Research and Expert panel
#3	..you want to change electrode, and get rid of old one?	Electrode welding
#4	... you want more precision?	Research and Expert panel
#5	... it should be easier to carry electrodes?	Expert panel

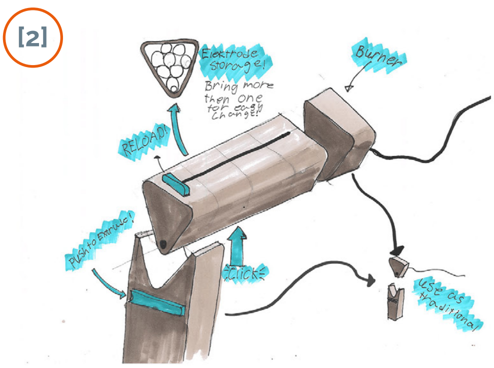
Setting the sketching round up as "what if" questions for the problems the diver most often had while diving, the sketches did open up for new ideas which can be used further on for ideations and mockups. Most of the sketches were for no. 4, but this is also the one were the biggest flaws from the current solutions are seen. [W.15]

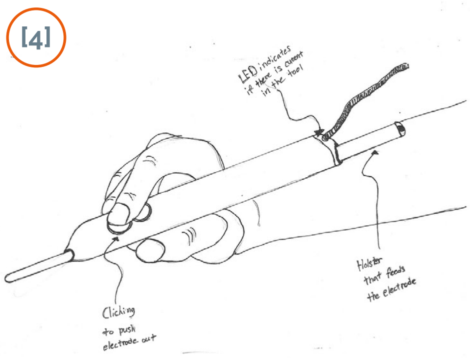
The [number] for each sketch is referring to the mixed solutions seen on the next page

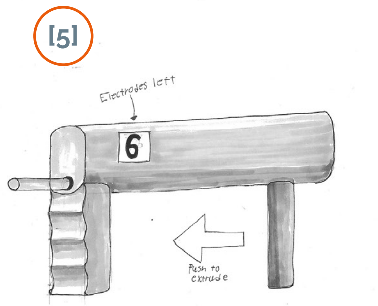












Mixing the solution space forces the group to combine different concepts together to form a new one. Doing these new areas can be discovered of how a function will work and how it will work with a given grip.
The combinations illustrate ideas with a combination of grips and features, to show a complete concept. Its distributed in 5 directions to reach a broader spectrum of concepts to test. [W.16]

Con no.	Description
[1]	**#4 - Pistol grip + # 3 and #5 - Smart way to change electrode** Gun shaped handle with a trigger that adjusts how fast the electrode is pulled forward by the pulleys. There will be a connector that is attached to the end of the rode to provide electricity to the rod.
[2]	**#4 - Modular (Traditional and smart grip) + #3 and #5 - Storing electrodes** The idea behind this concept is it consists of 3 parts, burner, feeder, and handle. The burner is the electronic part charging the rod, it can be put together with the handle to make a similar electrode welder as traditional. Or the feeder can be put in between storing electrodes and gives the possibility to feed the electrode with a button.
[3]	**#4 - Underarm grip** The grip is placed under the arm, and the front is held as a fist, and the body is attached to the arm with a piece of velcro, which means it can easily be dispatched by twisting the wrist. When the user is squeezing on the handle the electrode will be pushed outwards by a spring.
[4]	**#4 - Pencil grip (on arm or normal stance)** It provides ergonomics like holding a pencil. Inside is a function that can feed the electrode so the dive is always close to the welding spot. On the back of the tool is a LED that indicates if there is current in the tool.
[5]	**#4 - 2-hand grip** One grip is the one close to the burning end used for stability and feeling the welding location. The other grip is attached to the charged electrode, so the user can push it forward as they are welding. When it is used up it can be pushed out in the front, and with a drawback of the handle a new can be placed in, and the indicator on the sides displays how many are left in the chamber.

SUM UP

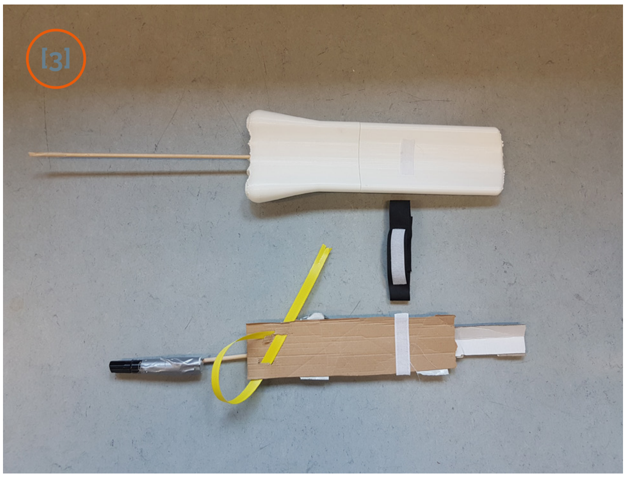
The results provided broader creativity by combining the different grips and functions to make new ones that would try to solve the problem statements from "What if". These concepts can work as a foundation for prototyping which can later be presented to the divers for feedback and further development of features. There was a consistency trying to incorporate the feeding and reloading function and almost every sketch had the idea of the diver being close to the welding point.

MOCKUPS

This chapter describes how the different steps in the mockup phase; **Size** and **shape**, handle, **handle positioning**, **style**, and **design** and **functionality** provide valuable information to figure out the best solution for the divers. Testing these will hopefully give valuable feedback from the divers which in the end will narrow us down to a specific concept. [W.17]

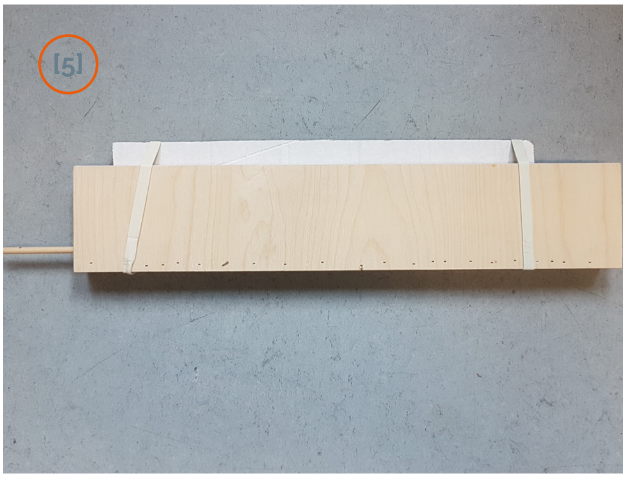
PROTOTYPING 1 - TRANSLATE THE MIXED SOLUTION SKETCHES INTO MOCKUPS

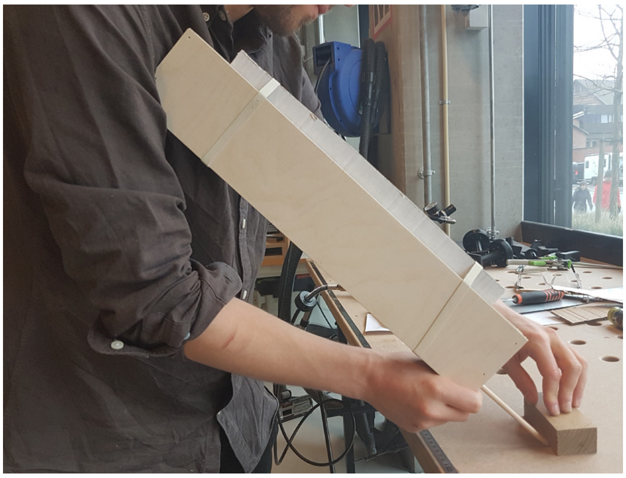
For this prototype, an ordinary glue gun was disassembled and used as a prob for the handle and the feeding mechanism. It was interesting to see if the mechanism to press the glue stick forward could be used as well for the electrodes. The problem right now is the feeding function needs a lot of "pumps" to just move a few centimeters. In real life, this needs to take bigger strokes. Power gripping makes the handling very comfortable but as the electrode gets longer the precision reduces due to imbalance.



The first model here was made in cardboard, it did show the initial idea of the product, but it was still hard to visualize due to the weight and the thin edges. So to get a better understanding of the design a quick CAD model was created and 3d printed, here it was made so the grip had groves for the fingers and the body is rounded to wrap around the bottom of the arm. This grip was not as ergonomic as it was hoped to be due to the shape of the model, and the weight of the armrest is too heavy which causes a lot of strain on the arm as its pulling the handle down.

The pencil grip model was made in cardboard. The size is estimated that it should fit an electrode in the middle and estimated to hold up to 6 electrodes around the inner structure. The idea is that when the inner cylinder with the 6 electrodes is rotated a new one will fall into the middle and be fed out.





A simple model in the wood was here made to show the concept, this was just as much a focus on the function as its able to extrude an electrode and when the electrode is burned out, a handle can be pulled on the side to place an new one. This model, will also be used to "test handle" placement to figure out the best stance for a higher precession.

SUM UP

These 4 concepts gave a general understanding of the different grips and functions. None of the concepts will be discarded at this point and will all be worked further on in parallel as they all showed some potential. Some of these can also be tested with the user, and receive feedback. Each concept will be investigated further to fit the shape, handle placement, and thereby giving an ideal working possession.

Power grip was most comfortable

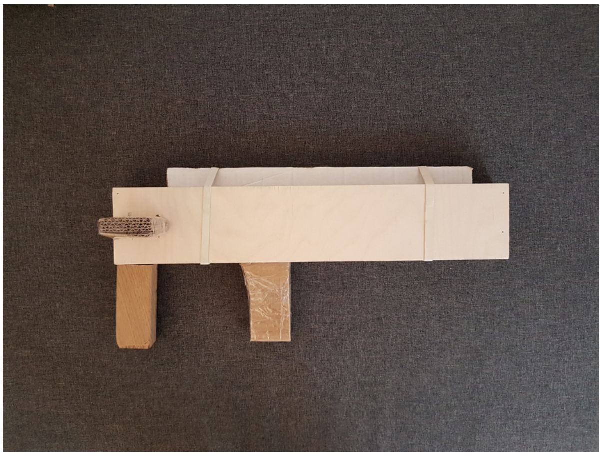
Testing handles and stances are important to understand which grip has the best control and what stances is the best for welding.

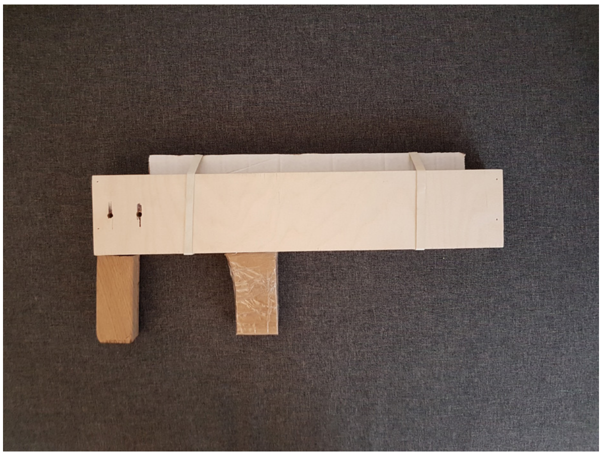
"A checklist for handel design" describes 6 different grips from where we are utilizing 3 of the grips: Power grip, External precision grip and Internal precision grip. (Patkin, 2001)

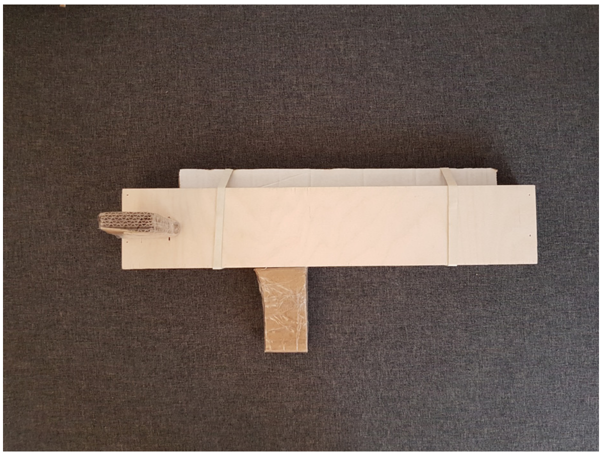
Utilizing the power grip give the user the ability to grip and hold heavy tools, by using the bigger muscles like the forearm, upper arm and shoulder [1 and 5]. This isn't as precise as the precision grip but still with a steady control. The length of the shaft should be around 10 to 15 cm and with a diameter of 30-50mm to fit an adult. [W.17] (ccohs, 2015)

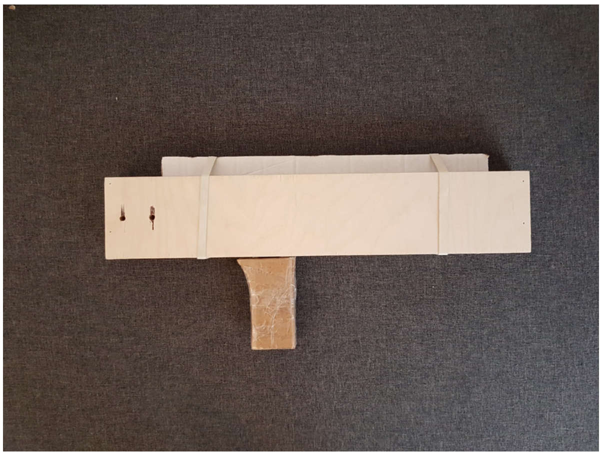
Internal precision grips enable the user to get precise in their work which is highly required when welding [4]. The external option also utilizes the palm as a support when for example guiding an object backwards [3].

Some of the concepts also utilizes a shoulder pad to improve control in the movement of the tool, this was not initially the idea of concept [5] but due to the shape and size of the prototype it made sense to investigate it as a feature. Due to the construction of the mock-up it was hard to test the handle design as the weight was uneven. But it did show that, by using two hands the mobility was more restricted, so only using one hand is preferable.









SUM UP

The grips are implemented in the different concepts which give different ways to handle the tool. Concept 4 have the opportunity to test 5 different handle positions out. Testing these positions on ourselves gave an idea on how the power grip can be used in different ways while maintaining precession. Where it is preferable to only use one hand.

A disadvantage of using two hands

PROTOTYPING 3 - STYLE AND DESIGN

So far the sketches and models have been focusing mostly on functions, and the aesthetics of the design has not been integrated into the designs. So to get a better understanding of the aesthetics, which could be integrated into the different concepts. This will be done by using "style cards" that illustrate the products they are currently using, and products with design similarities.
This could provide an aesthetic aid to the rough concepts and hopefully, the users get a better understanding of the design and thereby give better feedback on the next contact, furthermore, the design cards can be presented and discussed and see the direction in styles that they like or prefer. [W.17]

SUM UP

The 5 design cards show the aesthetics of design seen in gear and tools that the commercial divers use in everyday jobs. Questions will be asked of what kind of design the divers prefer compared to the direction of the concept that is made.

FEEDBACK V.2

Due to the outbreak of COVID-19 in Denmark, it was hard to visit the current expert panel. So to get feedback on the concepts and design cards it was chosen to present this through a small video, which would be sent to 20 commercial diving companies around Denmark. The feedback would be received through digital meetings over phone or Skype.

00:00 - 01:24
Introducing ourselves and a demonstration of the current problems for electrode welding based on current knowledge from research and interviews.

01:24 - 04:03
Design cards presentation, and short voiceover description.

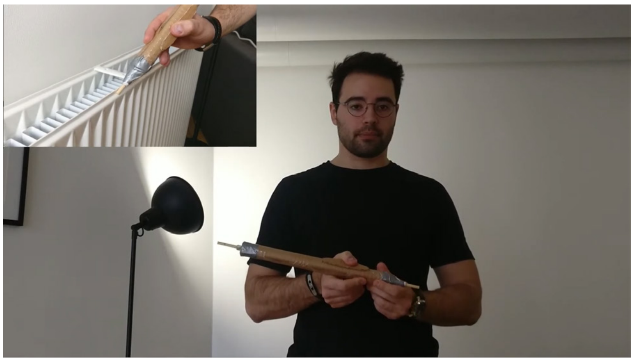
04:03- 06:12
Introduction to each concept, with videos and sketches showing design and function.

06:12 - 07:20
Explaining which parts we want the feedback on and if it could be done by phone (to get a conversation going)

From the video 5 companies responed, sadly not including the former expert panel Nautico and Dykkerstaal. The feedback from the video content on each concept was narrowed down to the most essential. [18]

CONCEPT 1 (PENCIL GRIP)

- Looks really **smart** and could see how it can **improve precision**.
- Could maybe be **exhausting to hold** on for **long periods of time.**
- Could see a **problem providing electricity** to the electrode. [W.18]



CONCEPT 2 (UNDERARM GRIP)

- It might be **beneficial that it's locked onto the arm** when the diver is **welding large surfaces** with a lot of space, such as on a ship.
- The diver will probably be **too locked in the positions** when welding **when it's attached under the arm.** [W.18]

CONCEPT 3 (PISTOL GRIP)

- If it **extrudes fast enough** it could seem like a **great concept**.
- Able to **adjust how much of the electrode gets out** when the button is pushed.
- Some were **sceptical on the idea of a not constant flow** for the "pumping" exstrusion
- Try to keep the number of **small parts to a minimum**.

CONCEPT 4 (RIFLE / POWER GRIP)

- Pressing **against the shoulder** will **make you float away**.
- Should only **use one hand**, as you are sometimes using the **other one for holding on to something**.
- It **limits mobility a lot** when it's **pressed towards the shoulder**.
- The diver needs to have the **option to bend the electrode**.
- **Great idea** with a **magazine to store and reload the electrode** from.
- Would be nice if most of the **surface were with a bright color**. [W.18]

GENERAL FEEDBACK

There was a common agreement that a specific context within welding underwater should be found. Every diver said that their stances and positioning would vary depending on the context of the job they were doing. The most common ones was anode welding and armouring of quays. [W.18]

DESIGN

The divers want something functional and easy to use. **(visible interactions and big interaction surfaces + big screw for disassembly)**.
From the interview, two things can be drawn out from the design cards: **Colorful and interaction**.
As for now, the divers buy something called "Hammer finish". They buy this in a very bright color (it could be yellow) to be able to see the product if they drop it and when in murky waters. [W.18]

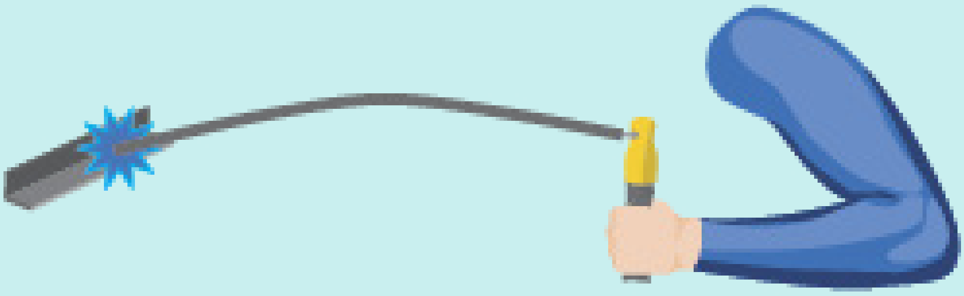
- Extrude electrode at a constant speed
- Keep the moveing parts to a minimum
- Big part of the product in a bright color
- Visible assembly and disassembly
- Large interaction surfaces
- Tough build

- Can hold position of electrode when pushed
- Corrosion resistant materials
- Manual electrode extrusion
- Divers can repair the product by themself
- Power grip - for endurance and grip strength
- One hand use (user should have flexible wrist movement)

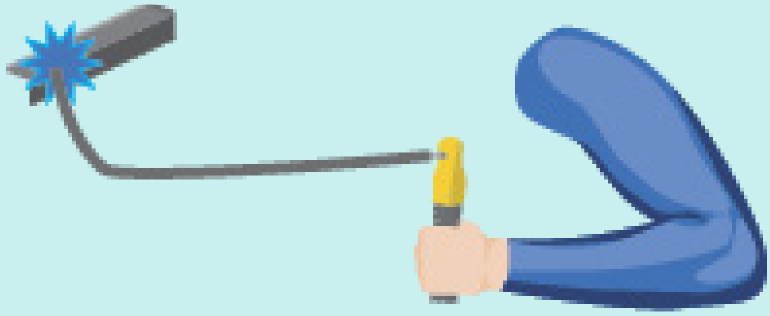
SPECIFYING WORKING CONTEXT

As a conclusion from our feedback talk with the divers, every diver recommended choosing a specific welding job context to focus on as there was a big variation of positioning and stances connected with a job. Furthermore, a more specific array of interaction scenarios was recommended as something that was common for the divers to work with.

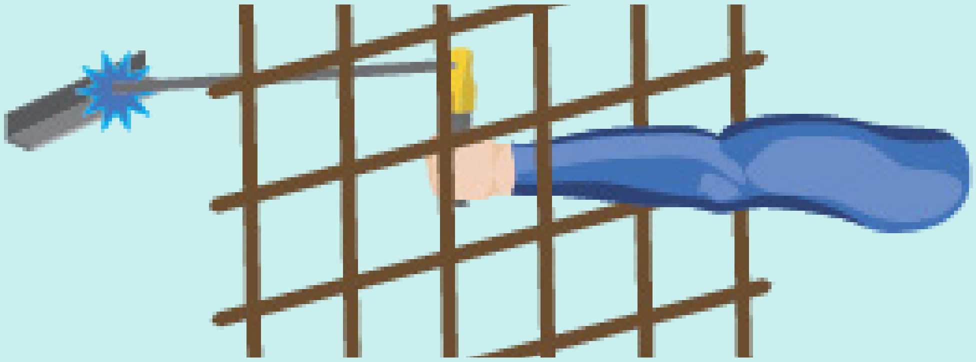
Starting electrodes
When working with old and corroded metals it can often be hard to ignite the electrode, this means the diver sometimes press so hard against the surface that the electrode will start to arc. This often occurs in old and worn constructions. [w.18]



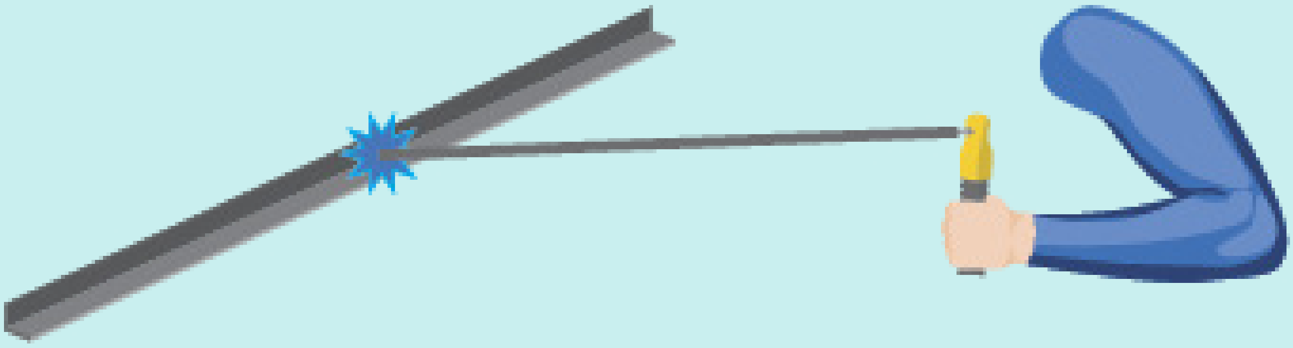
Bending electrodes
When trying to reach areas where there is not enough space for reaching with a straight electrode they sometimes have to bend it, but it does lead to an unprecise weldment and the electrode easily burns up at the bend. This scenario most often occurs when welding along the harbor. [w.18]



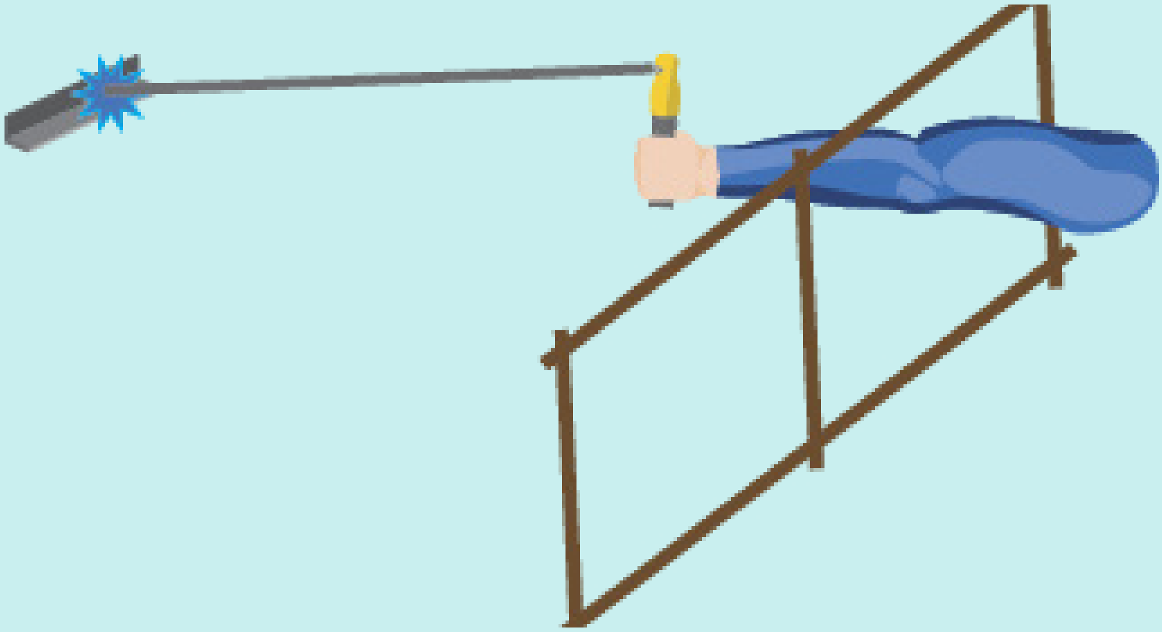
Tight spot
This scenario often appears when welding reinforcement for concrete quarries. Scenarios like these expose the diver for many different positions where getting behind a grid and doing a weld that requires a small and flexible tool. [w.18]



Easy to access
This scenario most often occurs where the diver have a lot of space around and it's easy to get access to the weldment. This is often on ship reparements. [w.18]



Long reach
When the diver has to weld something which can be hard to reach they may have to use a long electrode or even a straight arm to reach it. Often using the tip of a new electrode to reach and then switching it to a new one. [w.18]



SUM UP

By the giving interaction scenarios the only scenario that will be excluded is the "Tight spot". Divers welding in these circumstances is in need of a small and flexible tool, which they already have. Competing against it would be difficult and unnecessary as the current solution fits for this kind of job. Pushing the electrode against the surface should be possible if the area is corroded and hard to ignite. It will also be beneficial for the product to get an electrode out manually, and bend it if a place is hard to reach in few circumstances. [W.19]

4 scenarios common as general when welding ✓

Chosen not to focus on tight spots ✓

FINAL CONCEPTUALIZATION DIRECTION

To specify a direction for the product it was chosen to set up a requirement specification based on the knowledge gathered so far, this will give a clear direction for the last sketching process which can lead to concepts that has a more defined design form that later will be presented for commercial divers. [W.20]

Design Specifications (for conceptualization)	Info
Close to weldment	The diver should get closer to the weldment, which should provide higher precision and a more stable hand.
Electrode storage (minimum 6 pr. dive)	The storage will store 6+ electrodes which is enough for most jobs.
Big part of the product in a bright color	Most of the product should be in a color spectrum that will be visible down to a depth of +30m.
Utilize a power grip	A power grip gives a high endurance and a solid grip strength. Furthermore, it is the same grip type in the current tool, which will minimize the learning curve for the users, as it is more familiar.
Visible assembly and disassembly	They often repair the gear themselves, so if it is visible how to take it apart if something should break it's an advantage if it easy to see.
One hand use	To be able to hold onto something and should provide the dive with flexible wrist movement.
Large interaction surfaces	The product should be easy to interact with when using thick gloves.
Option to move handle at <30 degrees, horistontal and vertical	Having the option to move the whrist to fit the right angle for welding when in different positions.
Tough build	Build of impact-resistant materials.

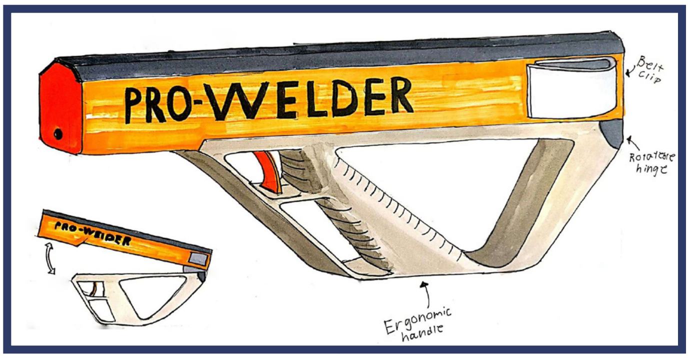
Four concepts were illustrated by marker drawing to show form and design functionality from the specification developed from the divers feedback and previous knowledge.

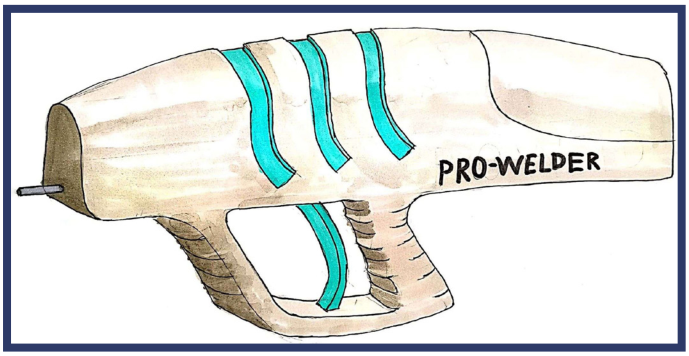
Concept 1

The shape of the barrel is kept simple in shape, but in sharp orange color, the grip features a large ergonomic with finger protection in the front. On the side of the product, there is a belt clip that makes it easy to snap into the belt or another place, when not in use. In the back, there is a hinge giving the user the ability to angle the electrode in the desired position.

Concept 2

Here the shape was taken a little further to more organic design, to try something else. In the back it has a big hatch that can be opened up, to load in electrodes. The blue lines on the surface are a see-through area to see the electrodes left inside.



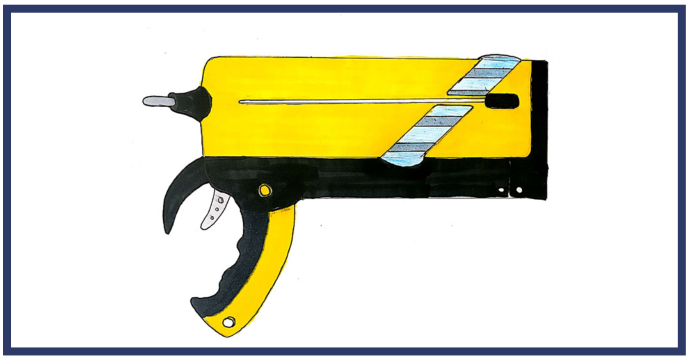


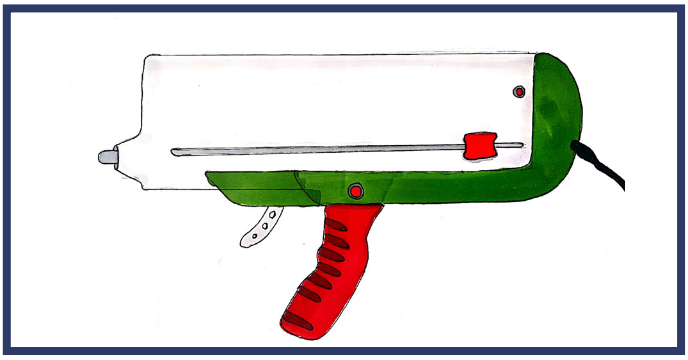
Concept 3

Positioned with a handle upfront this concept takes the diver as close as possible to the welding spot. The handle can rotate by pressing on the button above the handle and moved to the desired angle to fit the welding.
The hatch at the back is the access to the inside where a drum of the electrodes is located. It will turn every time a new electrode is needed to be extruded.

Concept 4

The green plastic base which is where all the mechanics or electronics will be places is snapped to the metallic cylindrical core where the electrode is placed in a circle. The handle can be moved in a range
of angles to fit the divers need for a specific positioning when welding.
By placing the extrusion of the electrode at the bottom and close to the handle it will make the connection to the technology more practical.





SUM UP

Looking at the concepts there is clear variation around the shape which also leads to different handle designs, and placements of it. Though it's very different in form the concepts still got some key values from the requirements in common which give us an idea of a more framed design.
The markers only gave a style and idea of how a product could look like, but no insight into how big it actually will be and how it will be to use it.

1:1 MOCKUPS

To be able to get a physical understanding of how the marker concepts looked and felt holding, a range of different shapes and handles were made, based on the sketches. The measurements were made from knowing the electrode length, the handle thickness for proper ergonomics, and the quantity of electrode that should be stored in the product. The handles focus on the positioning, and the design of it and not the shape of the grip itself as if its round or fitted to the fingers.

Concept 1 - Finger protection and space for technology

Overall the size was reasonable, but the user was a bit far away from the welding spot. The handle was good to be holding on with the added protection for the fingers. The back of the handle was in the way of the wrist and forearm, which reduced the mobility of it. The reason for the area in the back is it should contain the electronics/mechnics.

Concept 2 - Finger protection

The concept looks smaller than the previous due to the smooth edges. By placing the handle closer to the working point the user will get more visibility of the work. The user gets a lot of control in the grip and the forearm is right under the barrel.

Concept 3/4 - Basic grip 2

Physically these concepts got a lot different from the sketch as there should be space enough for the electrodes. The concept itself is minimalistic which could be an obstacle if the electronics inside take a lot of space. The mockup also shows when the handle is approximately 30 degrees and by that design, it would cause a lot of strain on the upper wrist. [W.20]

Concept 5 - Side grip

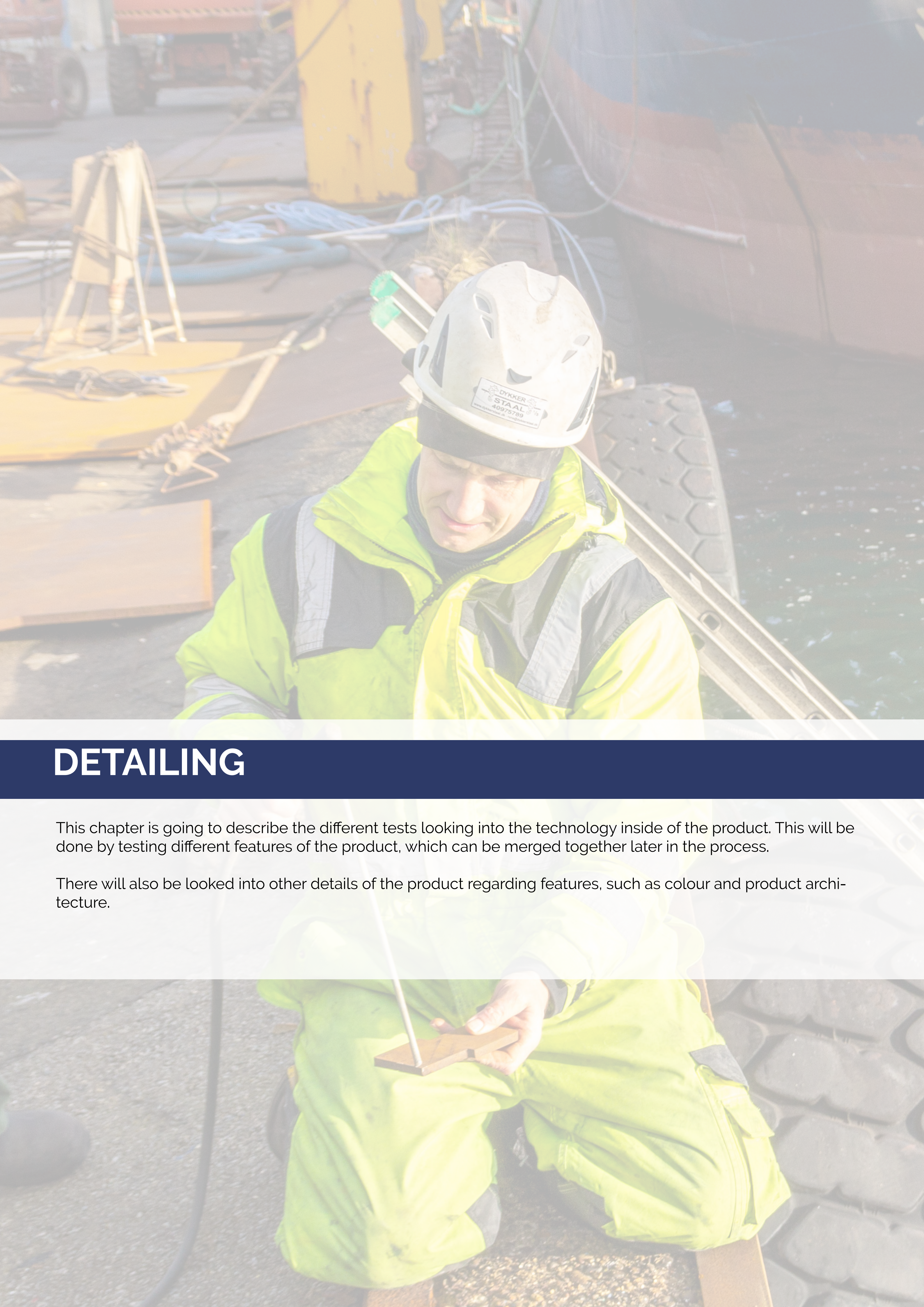
Based on the four concepts, two new variations were made to improve the grip and form of the design.
In the first variation the thump only uses a hole, this gives the possibility to have inner parts below the finger. And along with the rounded curve, it gives mobility, so it can be rotated almost freely in the horizontal plane.

Concept 6 - Technology in front

The grip is near the middle of the base form and the "technology" will be placed in the front, giving a lot of mobility for the hand and forearm to move freely under the base of the barrel. The disadvantage in the form is that it look unproportional as everything is pushed into the front. And this could also be a problem with undistributed weight.

SUM UP

If there is a need for more space then what can fit inside the handle the best solution will be to use the space below the thumb as seen in concept 5- Side grip. And it should be possible to twist the wrist horizontally with small limitations. Furthermore placing the grip and handle closer to the front increases the visibility of the work area, like concept 4 and 5 shows..
Before getting further into the form design of a final concept the inner technology and mechanical parts needs to be researched into as they can define how big the product is going to be compared to what is possible.



DETAILING

This chapter is going to describe the different tests looking into the technology inside of the product. This will be done by testing different features of the product, which can be merged together later in the process.

There will also be looked into other details of the product regarding features, such as colour and product architecture.

TECHNOLOGY AND MECHANICS

For the solution, several requirements are conducted throughout the project. Something to note is that the product should, of course, be water-resistant, unless it can be encapsulated in a watertight shell. Here there will be looked at two different solutions, one is a electric and another is a mechanical.

FUNCTIONALITY REQUIREMENTS

- Can hold position when pressed against a surface to start the electrode.
- Be pushed forward in a constant speed of around 1 cm/sec, but it should be adjustable depending on the electrode, amp, temperature and/or position. This should be done by pushing a button based on former user interview [w.s 18]
- Should be able to be pulled back, so a new electrode can fall in place.
- The pullback can be done manually.
- Can be extruded far out, so the electrode can be bend.

ELECTRODE EXTRUSION

General components used in both systems

Belt and pulley
Belts will be used to power transmission between pulleys. The belts could be made of Polyamide or Polyurethanes (PUR or PU) rubberized material to increase their durability in salt water and be able to withstand friction for long periods of usage. The belts will connect a rotating source that will spin it around and turn the pulley to move the system. Furthermore, the belt will also be the one pulling the cart with the "ignition clamp" for the electrode.

The pulleys are made of High-Density Plastic, to reduce the metal parts inside the system due to corrosion and wear. [Bando USA, n.d.; bolton, 2020]

Figure 28: Pulley

Figure 29: Belt

Linear ralis
While the electrode is getting pushed forward its important to keep it straight. This will be done with linear rails in stainless steel to make sure it can go in a straight line, with low friction, these should run with ball free bearings as the small parts are not suited for underwater use and in places where there might be a lot of dirt which can get into it. [igus, n.d.]

ELECTRIC DRIVEN

It can be electrically driven by using an electric motor, powered by a battery or electricity from a cable from land, as the electricity used for welding is not suitable for electrical components due to the high amperage. A battery is already seen in the existing drill "Nemo".
One of the divers mentioned that his Nemo drill broke due to the small pins for the battery got corrupted over time, which lead to the product not working anymore. But this possibly since they changed the battery underwater, which the new version should be capable of, but there could still be problems.

DC Motor and gearing
The motor will be the component to extrude the electrode by driving the system, the motor will have to move at a slow rate which is achieved with a gearbox.
The torque the motor should provide is very low due to the fact the electrode should only touch the surface of the weld piece and press against it while welding.
From previous interviews [W.18] it is known the extrusion speed should be 10 mm/s. These calculations have been done with 9mm pulley gears where it would require a motor with an average of ~21 rpm. So the motor chosen to be used will have an extrusion speed of 7,94 mm/s to 14,84 mm/s, depending on the voltage supplied, which is regulated on how hard the trigger is pressed. [W.23]

This motor will require a sealed area as it is only drip-proof, but it is possible to get a motor that can be submerged and work well in water. But it was not possible to find one with such a low rpm speed. [W.21 W.23] [Etonm Motor Co., n.d.]

Figure 30: Motor with gear

Cable
A PVC cable will provide the necessary electricity to the motor and the trigger switch inside a water-tight closure. A battery has also been considered, which of the options to go with will be decided later on by revision from the divers. [W.21] [Alibaba, n.d.]

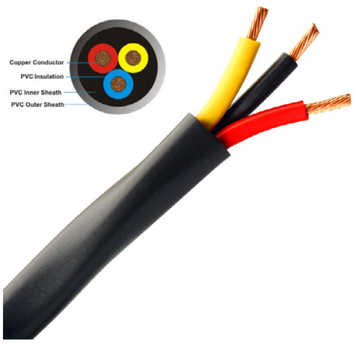


Figure 33: Cable for electronics

Trigger switch
The trigger switch that is going to adjust the speed of the extrusion of the electrode similar to the one used in drills. Overall the component consist of a MOSFET that is going to control the voltage and the current from the cable that provides electricity to the system based on how much the trigger is pushed in. The other part that is inside is a potentiometer. This will tell the system how much the trigger is pushed in and thereby increase the speed of the extrusion of the electrode. [AliExpress, n.d.]

This build is considered to be driven without elec-

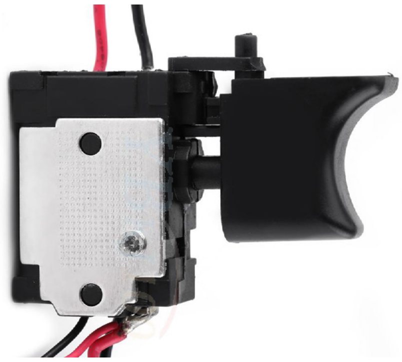


Figure 34: Trigger switch

tricity. Using different gears, springs, magnets, etc.,

MECHANICAL DRIVEN

a system can be created where the users press a button to move the electrode forward. This will have the advantage over a battery as it can not run out of power, and more mobility if it is surface supplied.

Ratchet gear
As mechanical solutions, a ratchet gear will be very useful as it can go in one direction, but not another, unless a lever is pressed, this will make it possible to press the electrode forward and lock it when it should stay in place. So this can be used in many different combinations with other solutions. Both the ratchet and the pawl can be made out of HDPE to fit the tough context the best.

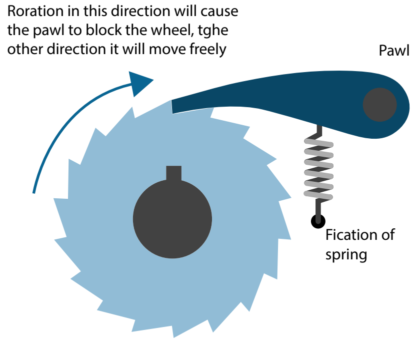


Figure 31: Rachet gear mechanics

Flat spiral spring and "Eddy Current"
A flat spiral spring can be used to press rotate the pulley system, but it has to be kept at a low speed so it does not go too fast. This could be done by using "Eddy Current". This is done by spinning a metal disc around, and when a magnetic field gets close to it, it will slow the spinning down without touching, this means if there is a constant force on the disc it can be slowed down to a lower speed depending on the distance to the magnet itself. [Associated Spring, 2014; Stadsvold, 2017; Head Rush Technologies, 2016]

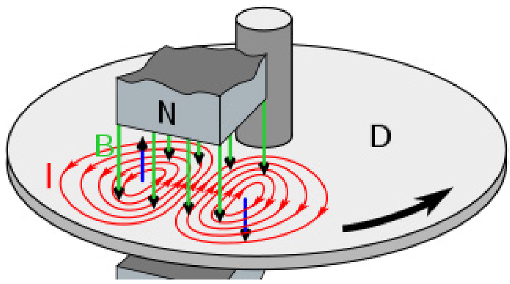


Figure 32: Eddy current

SUM UP

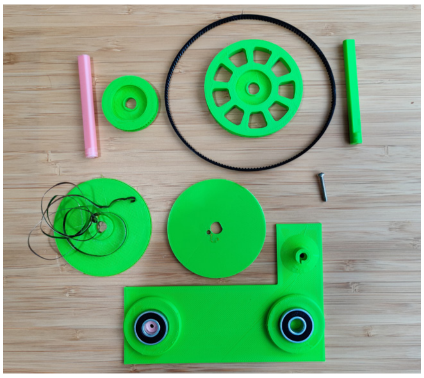
Having these two systems lined up by components next to each other shows the difference in these two systems builds. A functional test of the mechanical system will be done to get a feeling of size and function, to see if it's something that would make sense to implement inside of a tool. The systems will be put in shells inspired by the previous form test and there is a possibility that a further increase in size will be done to fit the system.
Both systems will be shown to the divers to get feedback on the extrusion of the electrode by the two systems, about the shape of the concepts and which will have the greatest benefits to be used underwater from a commercial divers point of view.

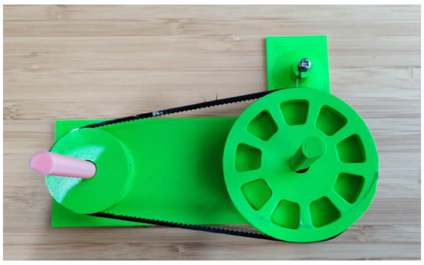
TESTING SYSTEMS (EXTRUDING ELECTRODE)

Utilizing the knowledge gained through the system chapter, the intention was to create both systems digital and physically and be able to confirm if the systems would run in the desired constructions.

MECHANICAL SOLUTION

Testing the extrusion method is being done by using 3d printed parts, belts, and springs along with magnets and metal discs from a hard disk to use as eddy current which hopefully should slow down the movement of the electrode. It will be placed on a foundation to keep its place and in an enlarged model so it's easier to adjust and handle for a testing purpose.





<u>We ran into several problems building this system:</u>

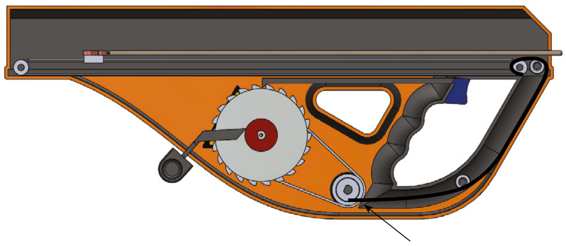
1. Testing "Eddy Current" couldn't be done like we wanted to as we couldn't get the disc to spin with enough force and for a long period of time.

2. The hard disk discs got destroyed in the process, as they couldn't withstand being installed into the printed parts.

3. The spiral spring was impossible to work with as the one that could be bought only could be spun back that much, and for our system, it was only enough for a revolution of the gear is was underneath.

Conclusion

The results were not something that could be shown to the divers, but it gave our self an understanding, that the system could be working, as of the system itself could be constructed together, just without "turning". Therefor a workaround was made in Solidworks (SW) with explanations explaining the different parts and their role inside the system to be able to explain it to the divers. Since the system takes a lot of space it is mostly located in the lower part of the concept, making the product bigger than the electric system.



ELECTRIC SOLUTION

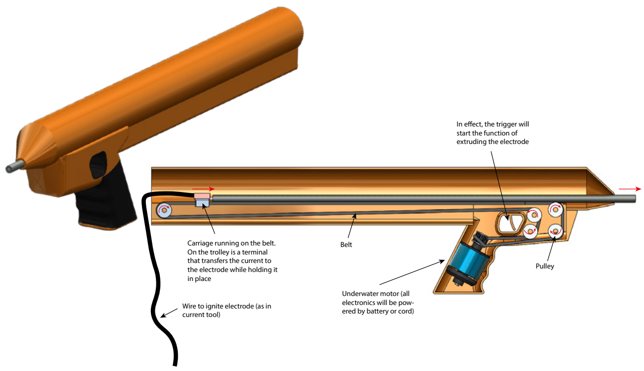
Without components, this build was difficult to construct. Instead, the information about the different components inside the electronic system build was used, and thereby we could confirm that in theory it would work together and the system would run. [W.22]

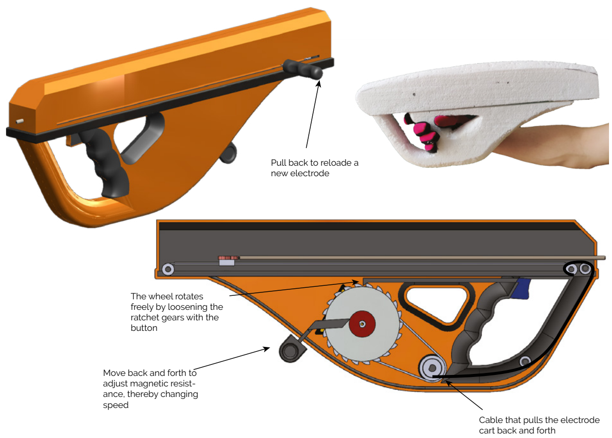
Conclusion

To emphasize how the system would run SW was again used to construct an informative 3D model that showed how the motor together with the other components could extrude the electrode. By building this system it was possible to decrease the size of the product as the components inside didn't have to be as big as the mechanical solution.

FEEDBACK ON THE SYSTEMS

Due to limited access to workshops and materials to build a physical functional system a workaround was done by creating the systems of mechanical and electronic solutions in CAD. Motion arrows and text boxes are made to explain the function of the concepts. Both systems were sent to the divers to get their feedback on if they think some of the functions are unnecessary or if they think that something is missing.





The evaluation and feedback was done through a phone call, discussing the mail we sent the divers with the picture of both systems and questions regarding the desired functions that the product should solve. They were open about both ideas, giving pros and cons on each of the systems.

ELECTRIC SOLUTION

The electric system did have the most support from the divers, as it was simple and easy to understand how it was used. The use of motors underwater is not something they have much experience with, only from the Nemo drill. Were Odin diving mentioned that they broke down really quick as the battery pins would corrode and thereby not deliver electricity. But they also said a battery would not be necessary and only causing problems as it would make the product heavier. The divers refereed to the Nemo Drill again weighing 3.2 kg, which can be heavy over time. A better solution would be to just use run a cable for the motor along with the welding cable, either in one cable or taped together by themselves depending on the price difference. [W.24]

MECHANICAL SOLUTION

Both were interested in the mechanical system but did have a fear it would include many parts making it unsuitable for underwater use (too many parts to maintain). It had to be made so it was easy to assemble and disassemble as they would always try to fix the product themselves if they had the tools and knowledge which would be an advantage. The rendered concept shown was too big and would make it too clunky to carry around underwater, so it would have to be smaller and more compact to be usable [W.24]

Based on the feedback, it was chosen to work further with the electric system, as it is the most compact and can be integrated into the product which makes it a reliable solution. [W.24]

SUM UP

Now by only having one system in mind, the project can be focused on the other part of the concepts, like the electrode igniter and electrode storage. Next up a specific form can be shaped were the technology can fit inside, as well as a design to fit the different interactions that the diver is going to use when working underwater.

- Smaller construction - fewer components, reduced the overall size of the concept ✓
- Lower weight (<3,2kg)- No battery, reduces the weight a lot ✓
- More reliable - fewer parts that can break inside and thereby reduce the maintenance ✓
- Unlimited power - A cable to the surface can power the concept until they are done with their work ✓

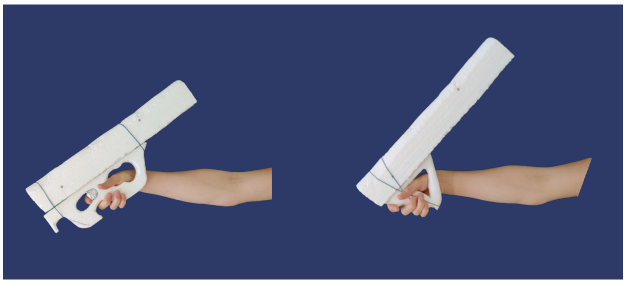
FINAL FORM DIRECTION

By having the system in place the next step is to revise the form and design in a restricted way with a second mockup, to study the grip and ergonomics within. The reload grip will be made in various designs to test out the grip when its pulled back. To round it off consideration about the direction of the product design has been looked into as it had been a struggle to work around the product being unproportional.

GRIP

From the first mockup, it was confirmed that a handle placement was important to have up front, so the diver could get as close as possible to the welding. Furthermore, the grip should provide a lot of horizontal mobility for the hand and wrist to move. To decide the final grip a second mockup was made to test out grip and form, improving it by including the values from the first round.

Test 1 - Range of movement downwards



A **B**

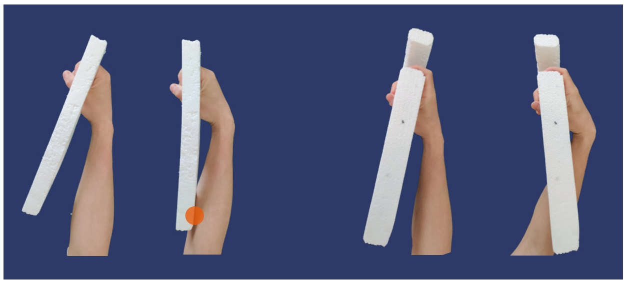
Shape A got limited mobility compared to Shape B, because of a more advanced power grip. Using the thumb to grip in this way reduces the Shape A mobility downwards.
As the hand is already rotated more downwards with shape A when its held horizontally, it can't be moved as much downward without straining the wrist.

Test 2 - Range of movement upwards

A **B**

Upward the mobility is close between the models, but there is more control in the grip of the Shape A, as the grip is over a bigger surface then shape B. And as the hand is rotated more downwards when in the natural position with shape A, it can cause also be rotated more upwards until straining the wrist.

Test 3 - Range of movement horizontal



A **C**

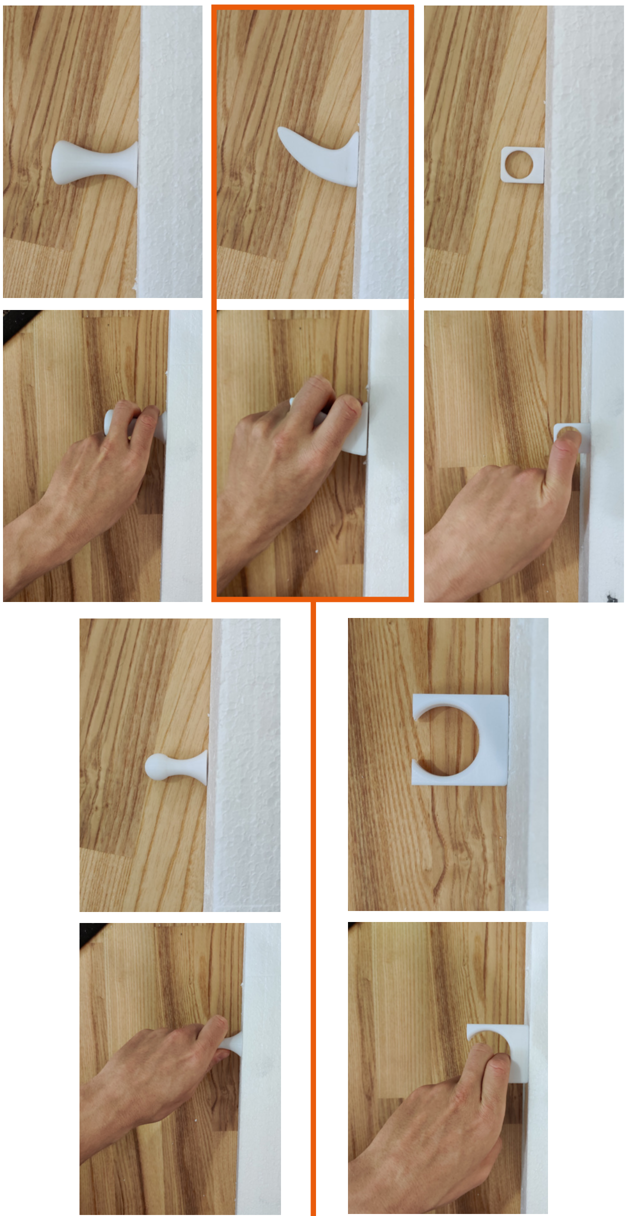
To do this test the Concept 5(C) model from the previous mockup session was used to see how much of the horizontal movement there can be achieved. The part that hit against the foram was the back of the handle shape. As Shape C got a sharper curve it, therefore, allows a greater range in the horizontal motion, and is pressed against the arm close to the wrist.
The test wasn't compared with Shape B as it already had a full range of motion.

Conclusion

The mobility of the hand in all directions is substantially better in shape B and C. This is due to the less of a restricted power grip than shape A got. As the users work in different positions the handling should also allow a variety of adjusting of how they positioning their hand.

RELOAD GRIP

To get a sense of shape and function of the reload handle, a test was made with 3D printed 1:1 prototypes. The shapes themselves are inspired by common knobs we interact within everyday life. The sizes are measured after the placement of either one or two fingers, as the handle should not be to large as it could get in the way, or catch on to the diving gear. The forms are tested by putting them against a core that should illustrate the product and by securing them to it, it can be tested how it feels pulling the grips towards yourself.



The best feeling was in the "Sharkfin". When pulling the fingers got automatically pushed down towards the product and thereby increased the grip on the reload handle. For the final grip, it needs to be fitted to the whole product but still with the same shape functionalities so the users always got a good grip onto it.

FORM DIRECTION

As the handle will be placed in one end and the electrode storage will go further back, this may make it difficult to make a very clear direction as it seems more neutral that the long storage would go forward, but some of the previous models did have a sense of direction. Looking at concept 6 it is giving the direction forward with the angled handle and finger protector and is very clear as the handle is in the front. This can also be seen in concept 5 were the shape is a little more neutral, it has to point in the right direction but is a little broken from the long curve going to the back, but here it is blocked from the sharp vertical line in the back, compared to the other direction where it's curved as a soft arrow.

Concept 5

Another way to illustrate the direction is to use details with shadow grooves, color change, and material change. This way of doing it has not been investigated as much as the focus has mainly been looking at the function and shape of the product.

SUM UP

The rotation in the horizontal plane can be limited a little where it's up close against the wrist when rotated, but not against the forearm as it has to limited movement.

The reload grip should be formed in a way so it will push the user fingers towards the product, and not slip off.

The grip will have a forward-pointing direction and so should the end of the electrode storage in the front.
The defining lines to create shadow grooves, will be the first ones to be incorporated so it makes sense compared to how the product easily can be assembled, interacted with, and the functions. Afterward, other details may be added to give a defined aesthetic appearance if it makes sense.

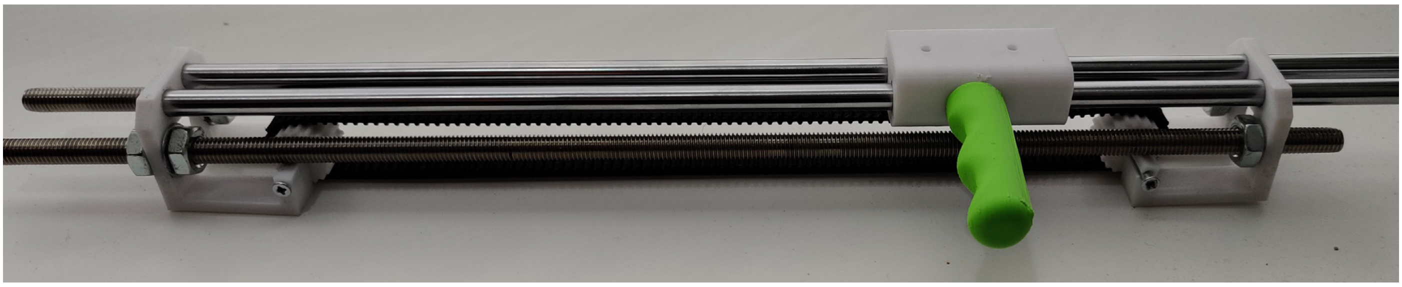
Designing the final product will have slight variations in the design compared to these results if it makes sense compared to form and function.

PROTOTYPING - ELECTRODE STORAGE

The product has begun to unite and have a direction towards something where design and technology will soon define the final result. This prototyping test different functions of the product and with the capabilities of 3D print it was possible to get a physical size and working prototypes. The different functions of the product is divided into different areas which are tested, and these will be combined in the final product.

ELECTRODE EXTRUDER

A module should transport the electrode forward by pushing the trigger. A prototype was constructed to test the function between the card, the belt, and the pulleys. With the belt having teeth on both sides, turning it will grab unto the teeth beneath the cart and move it forward. To reduce motor jamming and do the movement manually, the cart will go off the belt so the motor continues to turn the belt without resistance. To get the cart back for reloading the user will pull the green handle to force the cart back by turning the belt manually back. The cart will, like in this prototype, be running on rails to be able to have a linear movement. The liniar screws underneath are just in this model to stabelize the construction.



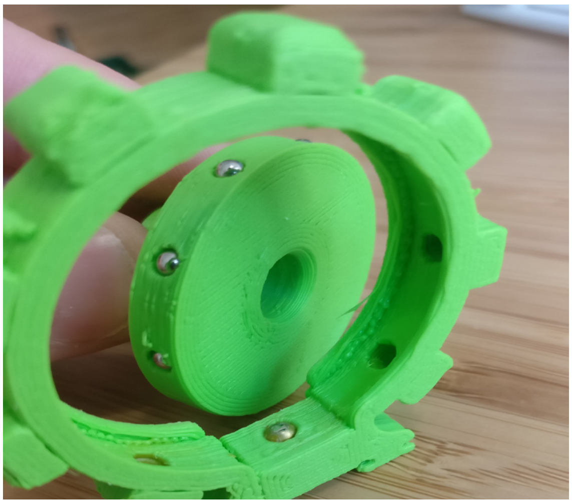
ELECTRICITY PROVIDING CLAMP

For the design, it was mainly focused on the compliant mechanism as an advantage was seen where there are no mechanical moving parts, and thereby less prone to breaking. To get an idea of these functions, 3d printed parts were found online using this function, these gave insights into how it could be shaped and have a reliable function. And from these, a custom one was created to fit the specific need for the product. [BYUCMR, n.d.]
The desired scenario is to have the user pull the reload handle all the way back until it clicks into place (which again can be released when pushing the trigger). Some centimeters before getting into place the clamp will open up by narrowing the path were the cart and the clamp runs in and thereby a new electrode can fall into the clamp. Moving the reload handle which is connected to the cart, forward, will close the clamp again and hold the new electrode in place.

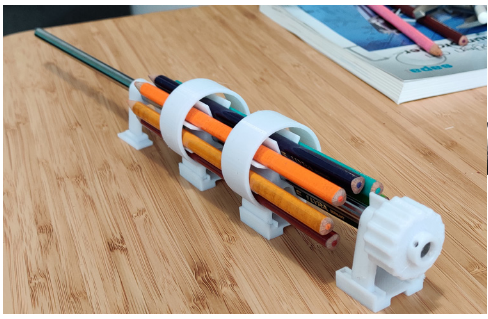
ELECTRODE STORAGE

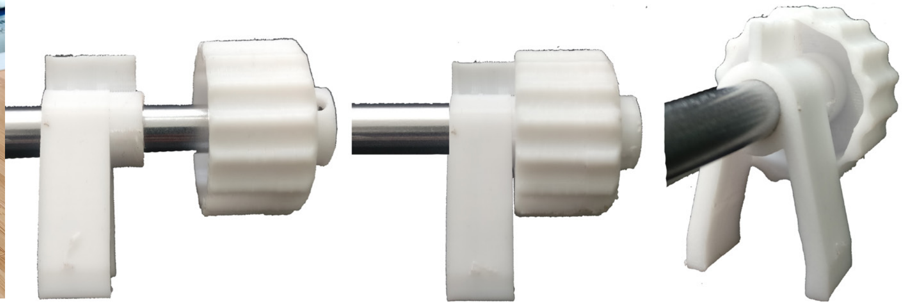
To make it simple and reduce the amount of moveing parts underwater, the storage for the electrodes were decided to be manuel to keep the overall system simple. The main function of the storage is to provide the user with a quick reload of a new electrode and should be faster than the existing product.
The system is can be divided into two diffrent assemblys. Firstly the outer shell is a part of the whole product and encapsulates the function, here its made in seperate units so the inside can be seen and to lower the print time. The second construction which is the inner parts that store the electrodes.

On one end there is a knob, which will snap in place in 8 postions useing magnets, the center is connected to a axis end, alog the axis star shaped pieces are placed to hold the electrodes in place. When the knob is turned the electrode that reaches the gap falls down, to were the “cart clamp” that extrudes the electrode forwards. will be.



Based on this version changes were made to create a version which was easier to work with, and to illustrate the concept better, were the tolerances also were more precies. In this version the tactile feedback was also changed to be a plastic piece which will deliver the tactile click, this is done by a thin piece moveing inside a groved area of the knob, as this should be cheaper then placeing magnets, and magnets can also be damaged and break when they get impact if the product is dropped.





Sometime their job could reach up to 4 hours underwater if this scenario occurs when welding, then more than 7 electrodes will be needed. The storage can, therefore, be taken out and be replaced with a spare one reloaded from above. It can aslo be done by the diver himself with 7 fresh electrodes while underwater, but this would also require to get them sent down from the surface.

This final prototype of the storage system worked well and delivered good results, this function will easily be implementet into the product, where it will use one long profile instead of section as it will secure the electrodeds better and make it easier to place electrodes inside.

PRODUCT ARCHITECTURE

This chapter defines the architecture of the different parts that the product contains. By implementing knowledge from our users these sections of the product can be made to fit the diver's criteria and also help to increase the lifetime of the product.

MODIFICATIONS

They are often making their own modifications for the products, so it could be an advantage to make it easier to do so, without damaging the product.

It could be done similar to what is done with cameras where a standard type of screw thread is used for different mounts. These attachments could be for a camera, so the tool can be used for pointing at a weldment in areas that are difficult to get into to document it to people on land, or it could have a flashlight attached to it.
To solve, this metal threads will be installed in strategic places on the product where a camera and a torch can provide enough cover and not be in the way of the diver. It's done so with a soldering iron, that heats the treads so they can melt into the already cut hole in the shell. This way of inserting the threads is a lot cheaper than placing them inside the injection mold itself if thats the choise of manufactureing, but it still provides a stong conncection. A symmetric placement of the treads on both sides will give the user the ability to use the product for both hands. It can will aslo be used for holes keeping the product together with screws as it should be stronger then threaded holes in the part. [Adafruit Industries, 2019]

Figure 35: Thread inserts

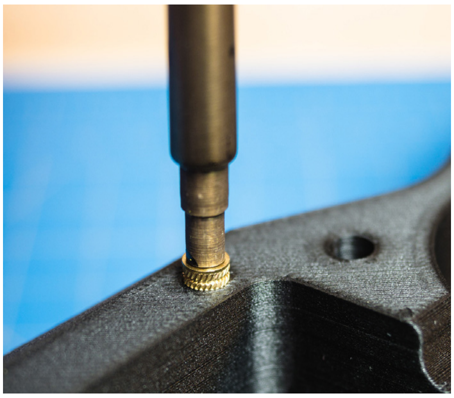


Figure 36: Soldering ironing inserts

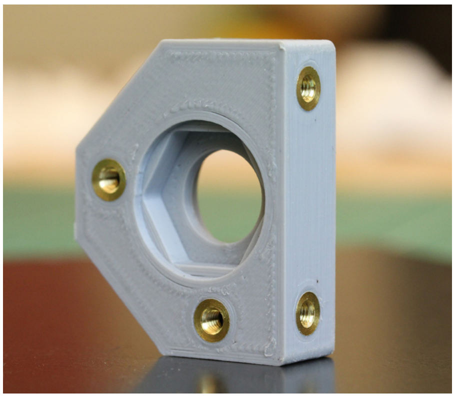


Figure 37: Example of inserts into plastic

DISASSEMBLY

Opening up the product should be made easily accessible for the divers. This is solved by having the screws in the open, so they are easy to access and with a standard bit size that most divers have laying around in their car. Inspiration can be taken from how BROCO does it with their Cutting Torch or other power tool for underwater use.

Figure 38: BROCO-22

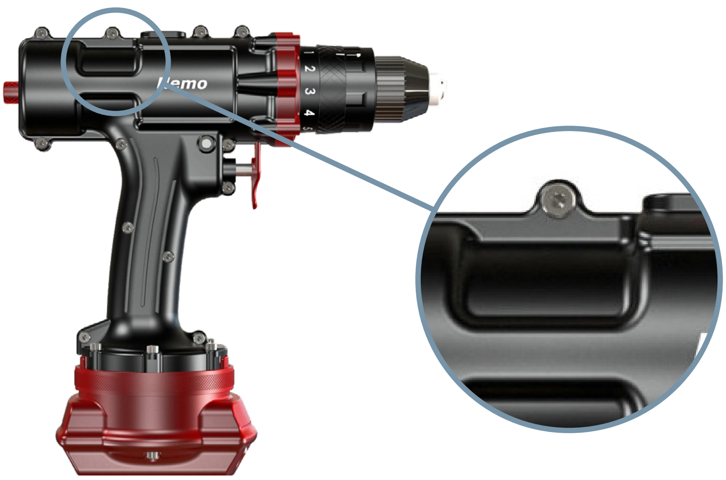


Figure 39: Nemo Drill

REPAIR

Fixing parts by the divers themselves is something that seems to be a lot of interest in, for the commercial diver's community and this can also be confirmed by Nemo's website where spare parts for their products can be bought. They even have separate "Handyman Protection Plan" for users where they will receive spare parts so they can fix the tool themselves if it breaks under normal use. [Nemo Power Tools, n.d. a]
If a solution like that could be provided for the customers of this product, it would be a great option for both parts.

It's estimated that the inside of the product got a product lifecycle of a minimum of 1-2 years with the electricity turned off when the user is not welding. This conclusion is based on two diver companies that used a BROCO BR-20 (With a brass conducter) for underwater welding. In one company the product could survive 1-2 years by having the divers turning off the power every time the had a pause away from the welding. The other company did not like the product as it got destroyed like every other handle although it was 16x more expensive. The reason for that is they kept the electricity on until they were done welding the job. So a long product life should be possible to acchive if the product is used according to the manual [W.04 and W.18]

Use the product according to the manual and take care of it

No service in over 1 year

Casing (for electronics)
To ensure nothing gets inside the housing the desired IP of 68 will be achived by useing "O-rings" between the two shells sealing the electronics from water. IP 68 is often seen in waterproof mobile phones, GoPro's, and housing for cameras for underwater use. [DSM&T, n.d.]

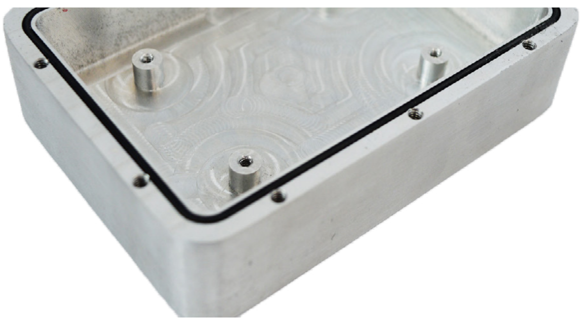


Figure 40: Example of sealing

Shaft seal (motor)
To seal the motor shaft from allowing water to penetrate inside the casing with the electronic, a PTFE seals the motor shaft.
The rings are designed to be low friction and by also working as a spring, by the material specification, the material can push against the motor shaft and thereby block out the water. [AHPseals, n.d.]

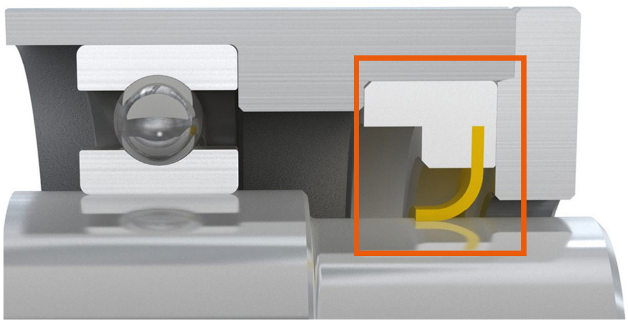


Figure 41: Rotary Shaft Seals

SUM UP

It's important to split the product up in sections to get an overview of what it contains and this would also help the divers to locate where the problem is when repairing. It should be simple in construction and easy to access.
This made it possible to implement the requirements that the divers had and also the problems we saw that would damage the overall product.
By improving the construction it will hopefully be easier to asses and clean the product and attach accessories without exterior damage. Furthermore it should be possible to make a sealed area for the electronics, even with a motor shaft going out.

Customizable the product without damaging it

Soldering ironing inserts (cheap and durable option)

Inside of the product made easy accessible

Min. IP 68 to waterproof electronics

PRODUCT VISIBILITY UNDERWATER

Research is made to define the reasonable amount of visible color that covers the product surface, to stand out visible enough even under terrible visible conditions. It is also important to look into how color visibility changes as the product is submerged in water.

CURRENT USE

Right now some diver adds colors on their existing product to brighten them up even more with a special "hammer paint" which is made for tough environments. Some of the divers said that the "Nemo" drill with a black and red color was not bright enough when in murky and deep waters and would require more color. The divers would, therefore, appreciate if the concept had more visibility than their existing products. By calculation the surface area on the Nemo it was found out that the visible color (red) was around 30% of the product and the rest was black. [W.24] Based on this it can be revesered so approximitly 70% or more of the surface should covered.

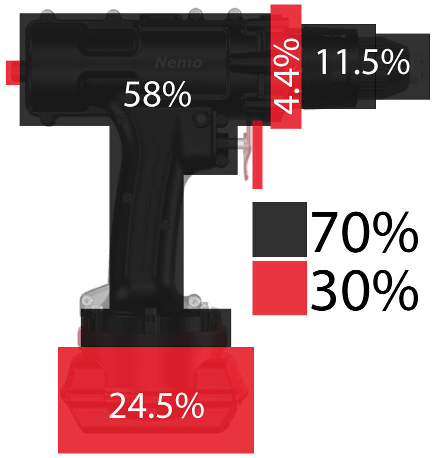


Figure 42: Nemo drill with color overlay

THEORY

When looking at color charts the best color should in theory be blue as it reaches depths down to 25-45m, but when looking at videos illustrating the concept (Figure 44) it was chosen to focus on the colors orange and yellow, since these seemed to preserve the color best and were easy to see as they did not merge in with the surroundings as easily. Furthermore the diver from Odin Diving also mentioned that he prefered the yellow color on his tools more then the red on Nemo drills. The yellow color is also used for the emergency regulator for scuba diving, due to the same reasoning, as it's easy to locate from a distance. [W.24]

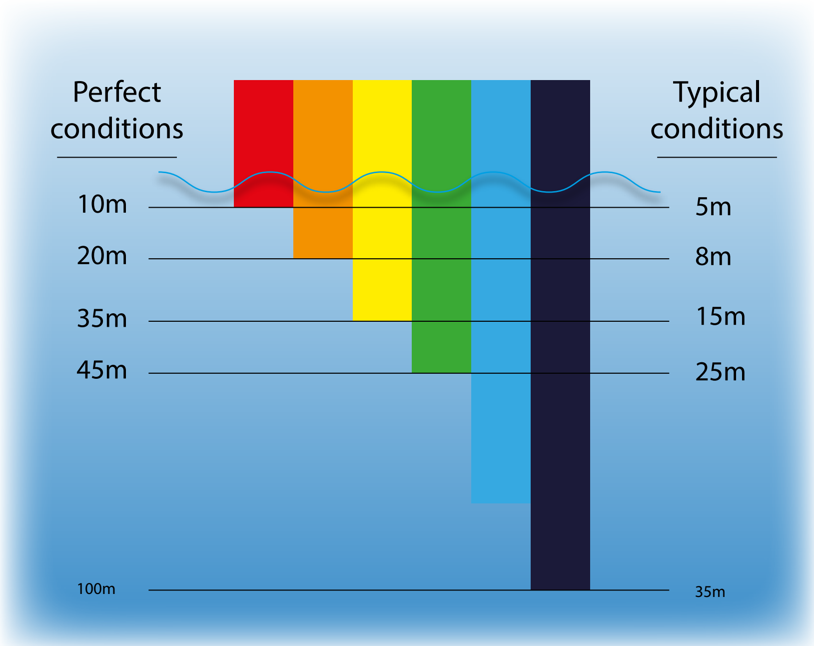


Figure 43: Color theory

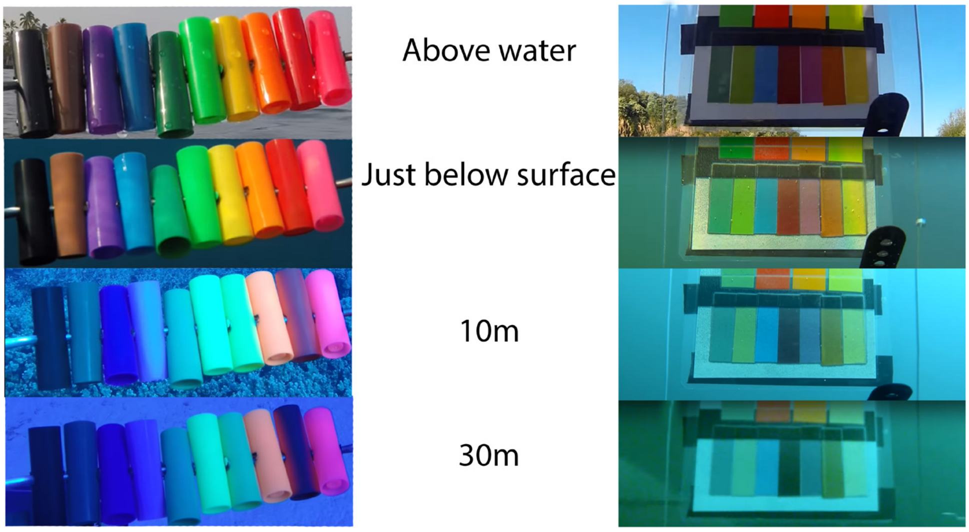


Figure 44: Color change underwater demonstration

LIGHT EMESSION

Adding reflectors could give the diver an even easier way to locate it. As the diver always carries a flashlight with them they could use it to light around and the reflective material will send the light back at them.

Another solution is to have a phosphorescent painting so it lights up in the dark when “charged” with UV lights which there is a lot of from the welding light. Therefore a test was conducted by using Montana nightglow spray paint applying it on a 3D printed tile with a smooth surface to see how much of glow it had in the dark. It came out brighter than expected and that was only with a layer of paint so it should be possible to use phosphorescent painting on the product. [Montana Cans, n.d.]


Figure 45: Reflective strips

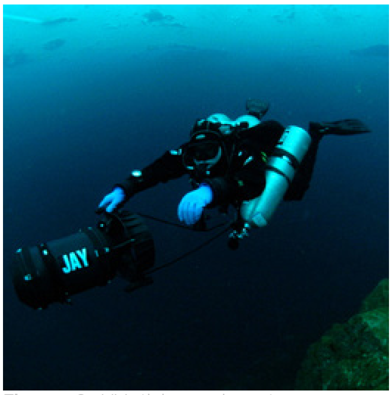


Figure 46: UV sticker underwater

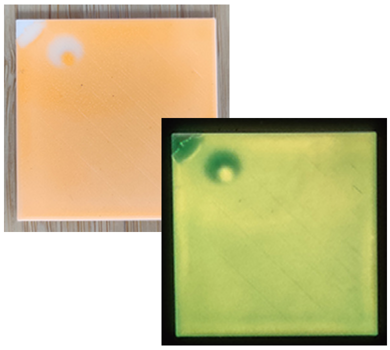


Figure 47: Spray paint test, in light and dark condtions

RUBBER COATING

For the areas where the user is interacting it is chosen to use a black rubber coating which, as it provides a tough surface that is resistant to saltwater, algae, and UV light. This will provide a softer touch and a slip-proof surface to secure the user a comfortable grip and interaction. [The Home Depot, n.d.; Benjamin moore, 2017]

SUM UP

The tool should be in either yellow or orange and with a colored surface of ~70%+ of the surface, so it's easy to distinguish in murky water and water depths around 35m. Furthermore, coverage of UV emitted material or phosphorescent paint would support the product visibility further.

Yellow /orange is easy to locate underwater

Large colored surface area (~70%+)

Reflective material or phosphorescent makes it easier to see underwater

UPDATED REQUIREMENTS

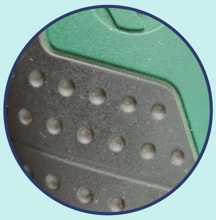
A scheme of updated requirements and wishes is created and updated from the first requirements. The content is created by previous insights and new research and testing with the users. The list will be the last one before proceeding into the Detail phase which in the end will transform requirements into product specifications.

Requirements	Wishes
Weight balance should be in the grip, as the space for the electrodes sticks out in one end - pp 30	Holding down a trigger for electrode extrusion - pp 34
Power grip is the best to prevent fatigue and best for control - pp 30	The product should be made for a specific working context - pp 36
The product should not immobilize the divers to a specific working position - pp 34	The product should be assembled by big screw and visible assembly - pp 34
A trigger should control extrusion speed - pp 34	Storage and reloading of electrodes - pp 34
The product should be used by one hand and both left and right - pp 34	The diver should be close to the welding spot - pp 34
It should be possible to pull out the electrode manu-aly, by hand and bend it - pp 34	Turning off the power to the electrode increase the life of the product - pp 34
Most of the product surface should be in a visible bright color (underwater) - pp 34 and 52	Using a cable instead of a battery to decrease weight and unlimited power - pp 44
The hand should have the mobility of 30 degrees in Y, X and Z direction - pp 34	Make the construction as small as possible (optimizing the inner space with the components) - pp 44
The product should be built tough, as divers do not treat them well (corrosion and impact resistant) - pp 34	The clamp holding the electrode is made from a com-pliant mechanism - pp 47
Visible interaction and the size of the interaction sur-faces are fitted to be used with gloves - pp 34	Turning the electrode is manuel with tactile feedback - pp 47
The “driver” should prevent the electrode to retract into the tool when pushed against the welding spot - pp 34	It should be possible to change the whole storage of the electrodes - pp 47
Placing the grip in front increases the visibility of the work area - pp 34	Colors of the product can be yellow or orange (to be greatly visible at 35m) - pp 51
Use components inside the product that got increased durability in saltwater and be able to withstand corro-sion for a long period of time - pp 34	The product should be covered in phosphorescent paint or reflective material (to further increase visibility) - pp 51
The product should be equipped with threads so the diver can use accessories - pp 49	
It should be possible to repair the product, by buying spare parts - pp 48	
Motor and electronics need to be sealed watertight - pp 49	

FORM AND DESIGN

The aesthetic expression will furthermore be defined but now with a closer result to the final product appearance. The style direction was first to make the product not to be overwhelming for the diver comparing it with the already known welding handles and give the product a clear direction in the way of the welding. To reach a specific design the product has been modeled in 3D CAD and visualized to give it a more realistic look.

SHARP EDGES

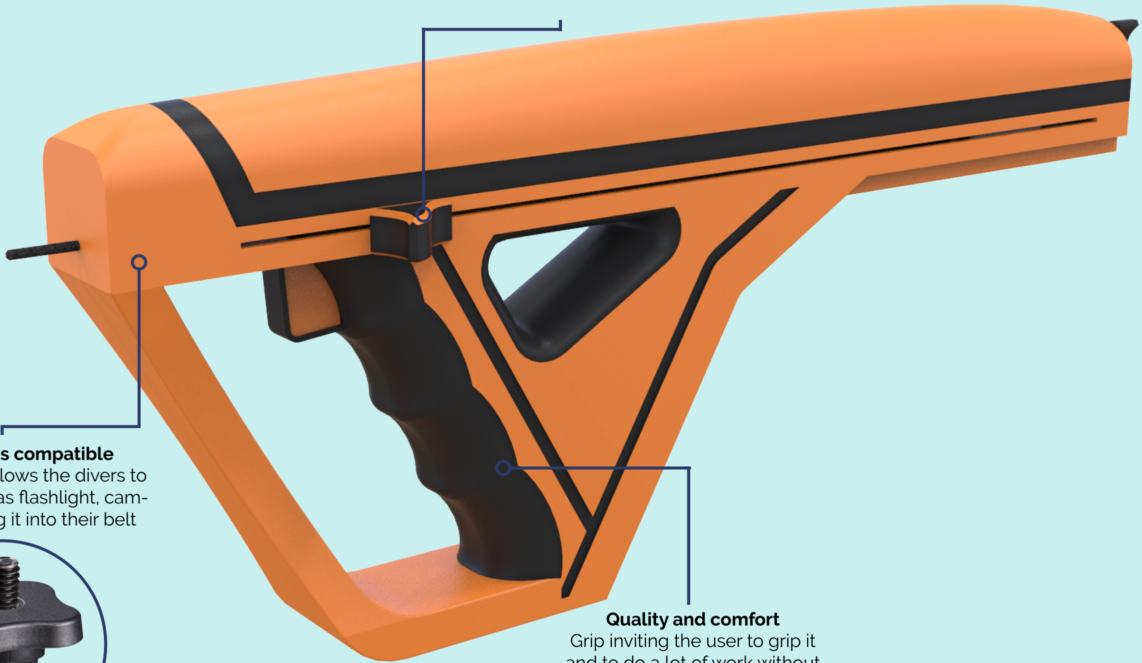


Tough
The product should be looking like something the divers should not be afraid to grab and start working with. Bumper, bulky, etc.

Contra weighting
As the product sticks out a lot on one side because of the electrode, a form design is used to give the product a direction in the opposite way.

SOFT EDGES

Smooth transition
Reduces the chances of getting entangled in the surroundings.



Accessories compatible
The product allows the divers to add gear such as flashlight, cameras, and hang it into their belt

Quality and comfort
Grip inviting the user to grip it and to do a lot of work without getting fatigued.

PRODUCT SPECIFICATION

Category	Requirements	Units	Marginal value	Ideal value	Reference
Working context	Submerged underwater	Meters	70	<50	pp. 9
Product	Build of materials that can withstand salt water	Binary	Pass	Pass	pp. 11
Product	Build of materials that can withstand hazmat	Binary	Fail	Pass	pp. 59
Product	Easy to clean	Binary	Pass	Pass	pp. 11
Wishes	Used in tight places	Binary	Fail	Fail	pp. 33
Product	Able to add attachments without damaging the product	Binary	Pass	Pass	pp. 48
roduct	Can be repaired by the diver himself	Binary	Pass	Pass	pp. 48
Electrode	Electrode thickness	Ø mm	Ø 3.2 mm	Ø1,6- 3.2 mm	pp. 18
Electrode	Using electrodes with a length of 350 mm	Binary	Pass	Pass	pp. 18
Wishes	No small electric shocks	Binary	Fail	Pass	pp. 17-18
Context	Submersion time a day	Hours	4	+16	pp. 21
Product	Store electrodes	pcs.	1 <	7	pp. 21
Product	Few small components moving <10cm2	pcs.	10 - 20	<10	pp. 18 & 44
Product	Diver can see the weldment while welding	Binary	Pass	Pass	pp. 24
Product	Easy to reload new electrodes	Binary	Pass	Pass	pp. 24
Product	Interaction points	Points	8	5	pp. 24 & 34
Wishes	Keeping the electrodes dry	Binary	Fail	Pass	pp. 24
Product	Product surface of bright visible color (underwater)	%	~70%	70%+	pp. 20 & 50-51
Grip	Length of grip	mm	10 mm	12-13 mm	pp. 31
Grip	Diameter of grip	Ø mm	30 - 40 mm	40 - 50 mm	pp. 31
Product	Visible disassembly	Binary	Pass	Pass	pp. 34 & 48
Product	One hand use	Binary	Pass	Pass	pp. 34
Grip	Left and right hand use	Sides	Right	Right and left	pp. 48
Grip	Hand mobility	Degrees	30 degrees	Freely	pp. 34, 39 & 45
Product	Impact resistant material	PSI	2000 PSI	3500 PSI	pp. 34 & 59
Product	Trigger with adjustable speed	cm/s	1 cm/s	0.8 - 1.2 cm/s	pp. 34 & 41-42

Grip	Center of gravity above thumb (Vertical distance)	mm	10 - 75 mm	<10 mm	pp. 30
Product	Manual electrode extrusion by hand	Binary	Pass	Pass	pp. 34 & 47
Wishes	Turning the power off to increase the life of the product	Subjective	< 1 year	> 1 year	pp. 48 & 67
Product	The motor should be able to hold the electrode in place when pushing against the welding spot	Newton(N) + Kg	< 19.61 N (2 Kg)	19.61 N (2 Kg) - 49.04 N (5 Kg	pp. 34 & 41
Product	Maximum height, width and depth	mm	180-220, 450-500 and 50-60	<180, <450 and <50	pp. 24 & 34
Product	Steps to reloade electrodes	Nr. of steps	2 - 4	1	pp. 47
Product	It should be possible to change the whole storage of the electrodes	Yes/No	No	Yes	pp. 24 & 47
Product	Motor and electronics should be sealed away from water	IP	IP68	IP69K	pp. 41 & 49
Product	Color visible at greater deeps	Color	Orange	Phosphorescent orange	pp. 50-51
Product	Weight of product (On land)	Kg	3,1-5 kg	<3,1 kg	pp. 29 & 44

MATERIAL & PRODUCTION

In this chapter materials with great specifications for the harsh environment are compared against each other to find the best one for the given context.
Investigating methods of production for the specified materials opens and closes possibilities within each material and the given production method by having the expenses in mind.

MATERIAL SPECS AND PRODUCTION

The materials will be justified based on the criteria that the context requires. Different options will be considered for the production of the product, as it depends on the quantities and thereby the price.

MATERIAL REQUIREMENTS SUM-UP

Saltwater exposure: Due to being submerged into saltwater for long periods of time and not being rinsed from every job they do, because of the lack of fresh water to clean with, the product therefore should have a low water absorption and should be corrosion resistant. This helps to increase the overall life of the product.

Hazmat exposure: If the product is used in hazmat environments which can contain a chemical that can be harmful to some materials it should be resistant to these. This includes some kinds of acids, oils, and bacteria.

Welding exposure: Areas the diver could be touching should not be a material with a high conductive as it could be dangerous while welding, it also produces UV light which can damage some types of plastics

Strength: Many divers are often in a hurry and throwing around their products inside their car therefore it will make sense to have a relatively high impact resistant. It should not be damaged by a drop from 1 meter on land. [Mizera, Chalupa and Hudec, 2017]

Visibility: It will be an advantage if the material can be colored in the process so it will not wear off over time. Or else it can be coated afterward with paint. [UMC, n.d.; GSE Environmental, 2012]

Based on these criterias two materials were selcted to focus on based on research which are PVC and HDPE these were compared with each other to see which one could fit the context the best. Both are plastic, which makes the product lighter and increases the range of production methods. As corrosion and degradability is the most important criteria to increase the life of the product the HDPE will win the test. As it has the lowest water absorbation and heat resistant compared to PVC. [PEK Co., n.d.]

HDPE

Saltwater exposure: LOW water absorption (0.10% for 24 hours submerged). HDPE is often used in construction that got contact with water and is often used on ships.

Hazmat exposure: Brought chemical resistance. It has excellent resistance to hazmat materials, and are often used for septic tanks. One of the users used to dive in a treatment plant in biological materials which HDPE is excellent against.
[CP Lab Safety, n.d.]

Welding exposure: UV light and non conductive. This material will be perfect for the conditions the users are in. By adding a black carbon pigment into the material it will not take any damage from UV.
[Sangio Pipe, n.d.]

Strength: High impact strength. From a test done by an Izod Impact (hammer with a pointy end, swigs into an HDPE part, to see how much energy (J) it requires to break the material) show that the material can sustain 5.00 - 80.1 kJ/m^2. The average value is 35.7 kJ/m^2. Comparing with PVC the maximum impact strength is 2 times as strong as PVC. [Omnexus, n.d.]

Visability: Various color options. Color pigments can be mixed into the plastic before processing, also with Phosphorescent pigments, but it can not glow if milled or sanded as it will break the crystals. So if thats the case an option is to color coat the HDPE with paint [UMC, n.d.; GSE Environmental, 2012

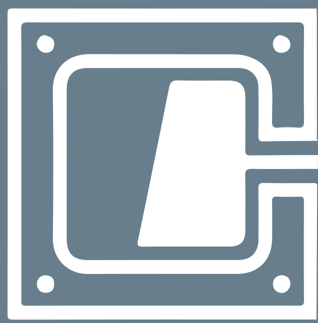
Other materials
All metal parts except for the conductive material should be made in stainless steel due to the low price and corrosion resistance.

Its chosen to focus on CNC milling and injection moulding as both are two commonly used methods and both should be able to deliver the desired product specifications regarding quality. This will be based on the price for the manufacturing process, using HDPE.

CNC MILLING

The advantage of CNC milling is the low tooling cost but it does have a relatively high startup cost and it also depends a lot on how many units are going to be produced. An advantage of the method is the good prototyping capabilities, so a sample can be ordered and tested to see if it works as attended. This also allows changing smaller design features without having to make a new tool after product launch for newer versions with small improvements which are often seen in the startup industry. It cost approximately 820 DKK/ pr. hour to run an Indexed 5-axis CNC milling. Manufacturing by this method is often used for volumes of 10 to 500 pcs and by making around 10 identical pcs the unit price is cut by 70% compared to producing one part. [3D HUBS, n.d.]

INJECTION MOLDING



Injection moulding is the most commonly used process for plastic parts, due to the low price of each part when mass producing (more than 1000 pcs), here it's the high tooling cost which is a setback. [VendOp, 2016; form labs, n.d. b]
The mold consist of minimum 2 parts. Molds start around 13.000 - 34.000 DKK where they CNC machined out of aluminum or steel.
For low quantities of products and prototypes 3D printed moulds can be used to faster and low efficient production. [form labs, n.d. a] This newer technology also makes it possible to produce molds out of 3D print (SLA) though it only can produce around 30-100 pcs pr mold depending on the material being molded. [3D HUBS, n.d. b; Redwood, n.d.]

The two productions method differs the most on the price, which is based on how many products need to be produced. If it's a small quantity then the CNC milling will make sense both in price and also on not being dependent on a mold, which costs a lot in injection molding. If there is a relatively big market then injection molding will make sense. Something to consider is that the production can start as being produced by CNC when it's still under development and when a final version is in place it can start to be mass-produced. The final method will be chosen in the Business chapter where the market is defined.

There are different guidelines in both production method that needs to have complied before the product is possible to be produced by the machinery. This is important to know when placing the components inside as well.

CNC MACHINING

CNC part is done by removing materials from a block of all kinds of materials. It's an easy setup as it only requires a CAD file and some machine adjustments. The CNC milling that is going to be used for the product is going to be a 5-axis as it gives more freedom to mill the product difficult places without manually rotating the product than a 3-axis can. [3D HUBS, n.d. a]

Restrictions

- 90 degree corners cannot be achieved because the tool is cylindric. So a given radius should be implemented.
- Standard tolerances for CNC milling is ± 0.125 mm.

Guidlines to minimize price

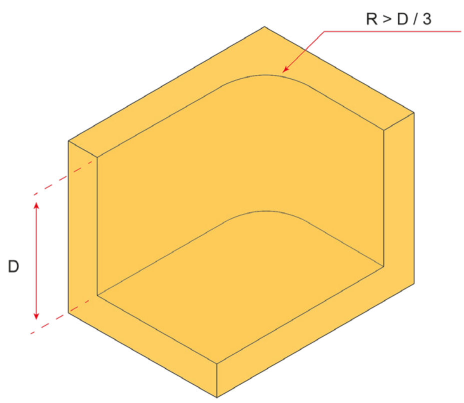
- Min. Wall thickness of 1.5 mm.
- Cavities depth should be 4x cavity width.
- Inner edges should have a larger radius than 1/3x the cavity depth.
- Threads should be as large as possible. Min. size is Ø 2 mm.
- Using the same radius keeps the cost lower as fewer tools are used.
- Minimizing the number of machine positions to reduce cost.

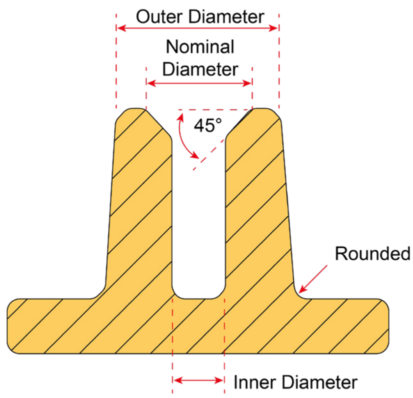
INJECTION MOLDING

This production method is often used to get results with good tolerances when mass producing products. Basics of this method are polymer granules that get melted down and by presser filled into a mold. Here the plastic cools down and the runners are cut off which is the passage to get the plastic into the mold. [3D HUBS, n.d. b; Redwood, n.d.]

Restrictions

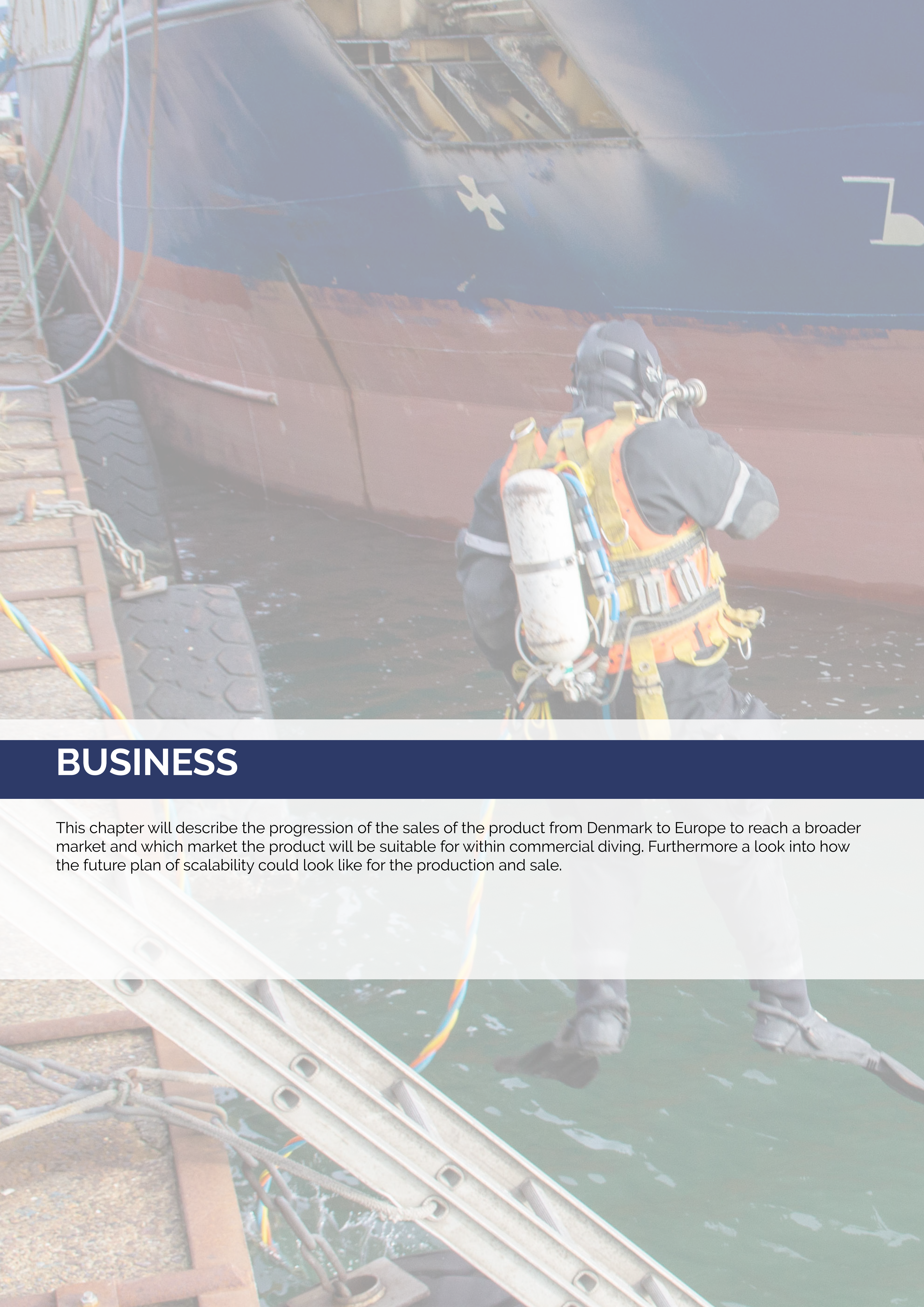
- HDPE - wall thickness - 0.8 - 3.0 mm.
- Keeping a constant wall thickness to prevent wrapping (internal stresses in the material).
- Keep design thin. Thick wall can result in sink marks (core cooling faster than walls). Adding ribs to improve stiffness.
- Optimize design so the plastic can flow through the mold without making "air pockets"
- Use chamfer or fillet (length is 3x the difference in thickness) to make smooth transitions if different thicknesses occurs.
- Draft angle of 2 degrees to vertical walls
- Design around undercuts (can't be done by a "straight pull mold).
- Bosses for threads for screws should be standalone and only connected to the outerwall by ribs. In our case the outer diameter should be 2x to the inserts nominal size.





SUM UP

Both methods got their specific requirements when going into detail. As for production the CNC milling got fewer requirements than injection molding, but the price will be the determining factor as it got the effect on their retail price.



BUSINESS

This chapter will describe the progression of the sales of the product from Denmark to Europe to reach a broader market and which market the product will be suitable for within commercial diving. Furthermore a look into how the future plan of scalability could look like for the production and sale.

Business Model Canvas

Key Partners

Shenzhen Xielifeng Technology Co.
- CNC production

Danish Diving Community
- Networking

European Underwater Federation (Europe)
- Networking outside Denmark

Investors

Key Activities

- Design development
- Prototyping & testing
- Technical development
- Production
- Marketing & distribution
- Customer support
- Customer contact
- R&D
- Networking

Key Resources

- "Bootstrapping"
- Office space
- Design engineers
- Product assembly
- Mechnical engineers
- Marketing
- Network

Value Proposition

- New and innovative soultion
- Improved electrode reloade
- Improved storing of electrodes
- Better workflow
- Simple interaction
- Quality feeling of product

Cost Structure

- Production
- "Bootstrapping"
- Office space

Customer Relationships

- Self Repair and maintainence by the user
- Able to buy the product from webshop

Customer Segments

- Small companies
- Large companies
- Denmark and Europe
- Future in worldwide associations

Channels

- Companie contact
- Exhebetions
    - DEMA show
- The Diving Companies Industry Association (Danish)
- Official product website

Revenue Streams

- Product sale
- Spare parts

VALUE PROPOSITION

Creating an innovative tool that will ease the workflow of underwater welding. The product will help the divers to do their weldment without the difficulties of being distances from the welding spot, having to store electrode in a separate container and with a faster reloading of a new electrode. Furthermore the availability to repair the product removes the environmental impact that "throwaway mentality" had before.

CUSTOMER SEGMENT

The product will indeed hit a niche market, with few commercial divers in Denmark it will be silly not to expand to the rest of the European countries. The retail price will be something both small and big companies can afford and thereby the chances of promoting the product increases.

REVENUE STREAMS

The revenue stream will mostly be coming from selling the main product. But there will also be a revenue made on users maintaining their products. Offering a "handyman" solution so the diver can repair their own product by making a simple product structure inside. Furthermore there will be the option to buy another magezine for the electrodes.

CHANNELS

These will be a marketing strategy and way to promote the product. Some will be to gather contacts through exhibitions in Europe where this "new tool" will be introduced to commercial organisations and divers. Later on contacts based on these exhibitions and other promotions will build bridges and thereby forming a network.

CUSTOMER RELATIONSHIP

Making the product easy to acsses by having it in a webshop and give the users the ability to buy spare parts that allows them to repair their own product. This would reduces shipping time and cost if they had to ship it to a certified workshop to get it fixed.

KEY PARTNERS

Companies and manufactures will help to get the production of the product running. In our case a big part of the partners will be communities of commercial diver associations that can promote and help us to get a stable network of companies and suppliers that could see an interest in this.

KEY RESOURCE

It will require an office space where the company can work on selling the product, but also developing new and improved tools based on the feedback and experience gathered from the current product.

KEY ACTIVITIES

Are the activities that takes place through the development of the product, but also afterwards like keeping on to promoting and having stock of the repair parts. Processes that is not our field will be done by the partners.

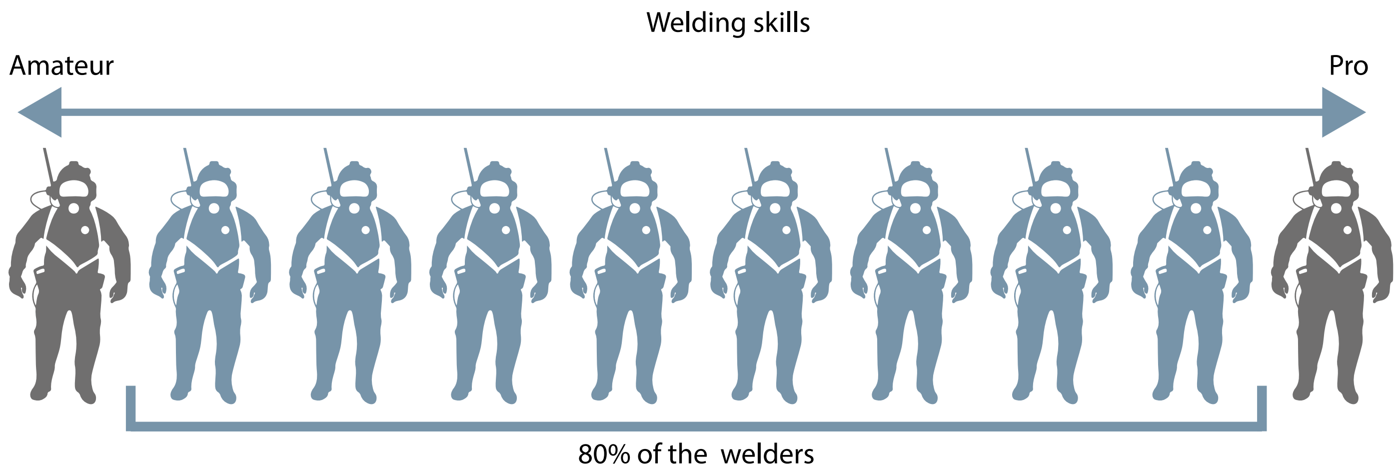
COST STRUCTURE

The company will at first only be run by us, where everything from marketing and assembly will be done through investments. This will be used for salary, R&D, office space, marketing and assembly.

MARKET

USER

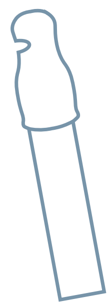
The product will not have an interest for all wet-welders if we are looking at some of the best wet-welders in the world, which is estimated to be the 10% that already using the current tool to perfection, and would not be interested in a new product as they are familiar with the one they are using and can already provide near-perfect weldments. Furthermore there is also the bottom 10% which are the welders that just want a quick weldment but do not care how good it is, as long as it will hold, this is often on quarries or similar rough work. This gives 80% of the divers as potential customers.



COMPETITORS

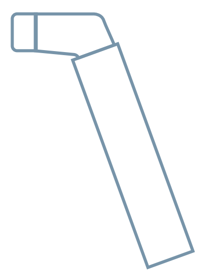
When looking at the market of competitors the outcome seems low. Our product is going to compete with the already known welding handles that the diver use.

ESAB a well-known brand of these simple and low budget electrode handles that the diver uses to weld on quays, ships, and other fast jobs. The handle is made for land use, which explains the fast decomposition of it. The divers use one handle for around two jobs before switching to a new one. Doing this they know that they need to buy big volumes to get them cheaper. Users we talked with could get a handle around 100 DKK pr. pcs. This "throwout mentality" is a bit of an environmental problem as it is only one small part in the handle which gets damaged and this is something that could be replaced but is not something the users do as it is almost cheaper to just get a new one.



Competing with this regarding the price is not possible as the price is very low for a handle. Divers using these are often doing jobs in a quarry where the quality of the weldment is almost irrelevant and it can be hard to get access with a larger product, which is estimated to be 10% of the jobs. But it can still be an improvement for those using it for ships or other places where a quality weldment is preferred.

BROCO is a high-quality brand that also makes products for military and firemen. Their series of welding handles are specified for underwater use and cost around 1.600 DKK which is another price class compared to the ESAB handles. The user that is a certified underwater welder use a BR-20 handle for around 1-2 years before switching to a new one. The jobs are also different from the other divers as it's a more precise workflow and they need to have a specific weldment before it can be approved. The user said that they also turn off the electricity when they do not weld to keep a long lifetime of the product.



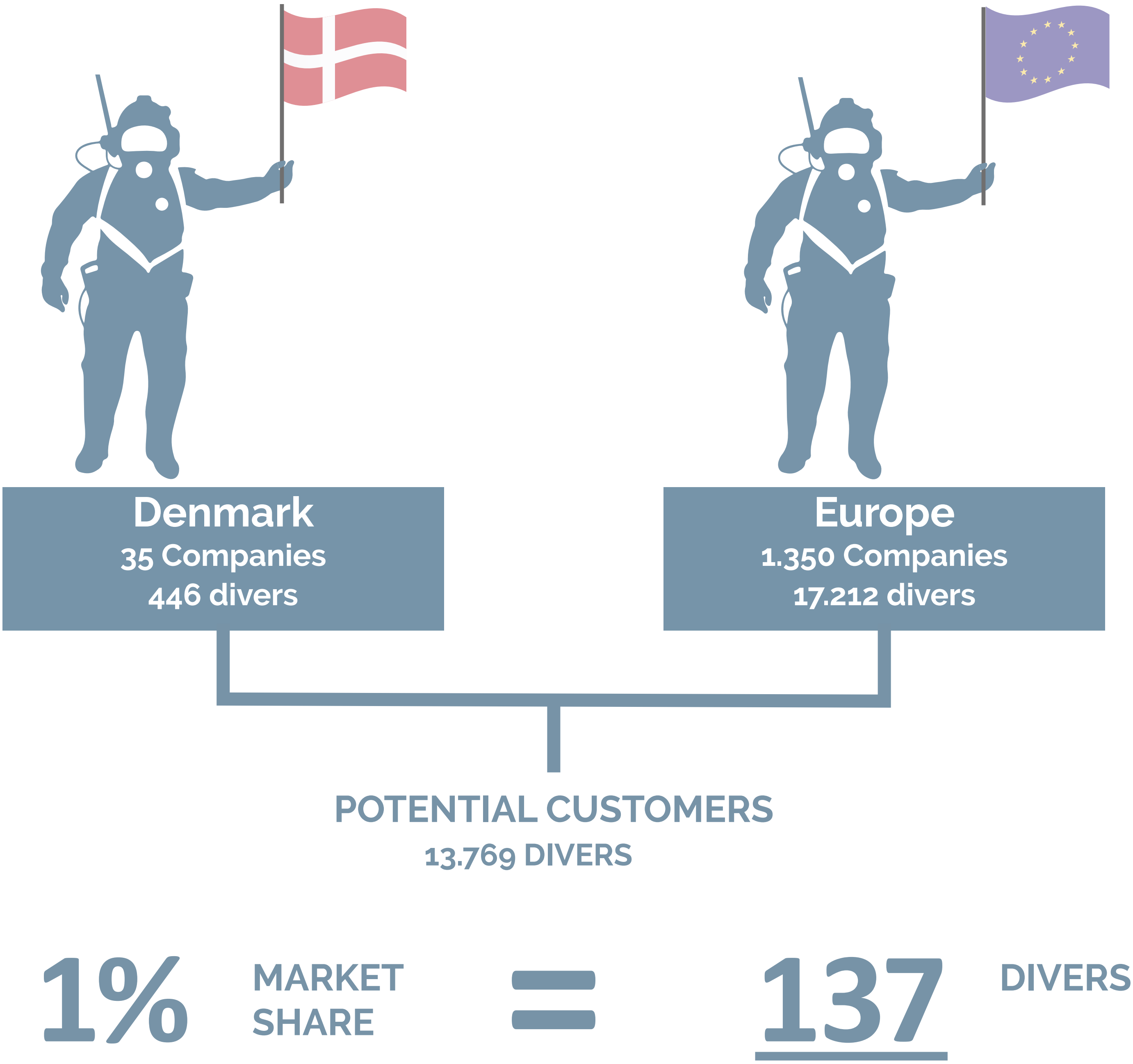
Our product will be closer to competing with BROCO and its users. These users seem to care more about their products and investing in high-quality equipment, rather than just buying the cheapest. Here it will be optimal to work with 80% of all divers, the divers as the top 10% are top professionals which already devoted to working with a tool of their preference and masters welding with it. As welding got a very steep learning curve to master it, we do not want to interrupt it for the top professionals.

COMMERCIAL DIVER COMPANIES

In Denmark there are 35 commercial diving companies, according to the Danish Education Ministry, which does not give the oppetunity to sell many products, so it is chosen to expand the sale outside of Denmark, to the rest of the EU.

There is a worldwide list for companies looking for commercial divers called *finddivers.com* here 225 commercial diving companies are listed in Europe, but when looking at the numbers in Denmark only 5 companies are listed, so only 1/7 companies of what is stated at the Danish Education Ministry [FindDivers, n.d. ;UddannelsesGuiden, 2020] In the UK there are at least 19 companies [Seaplant, 2017] and 5 is listed on *finddivers.com*, so only a little under a quarter. Based on this it is estimated that 1/6 of the companies in Europe are listed on *finddivers.com* which gives a market potential of 1.350 diving companies. [FindDivers, n.d.]

In Denmark, there is a wide range of sizes of companies as the smallest companies have 1 diver and the largest have above 30. Based on this and other known companies it's estimated that there are 12,75 divers for each company and the same is expected for the other companies in the rest of Europe. Which gives a total of 17.212 commercial divers in Europe, including 446 in Denmark. As previously mentioned the product is not for everyone so only 80% of the users which makes the final potential customers in Europe to be 13.769 with 356 based in Denmark. It is roughly estimated that it can be sold to 1% of the 13.769 which is 137 divers in Europe the 1. year. The sale will first off be targeted on Denmark as there is already made contact here.



TOOL EXPENSES

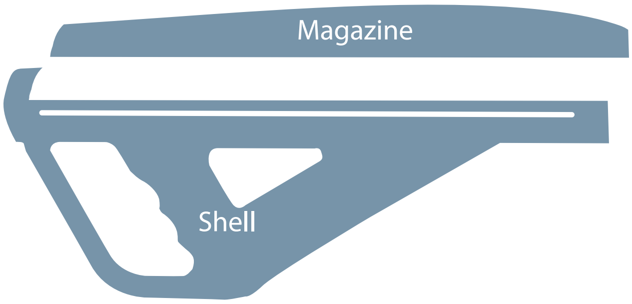
On average 63.000 DKK is spent on gear every year for each diver, whereas half is spent on heavy tools specifically which includes, welding tools, electrode cutters, drills, etc. equals 31.500dkk that is spent here.

Some of the tools the diver only got a few of because of cost and usage, therefore they keep these tools inside their cars so they can share them with their colleges.
Here the most expensive tools are hydraulic tools such as drills with the cost of ~30.000dkk [WS09]
This high expenses also means that they are willing to pay a high price for something that works, and as previously mentioned some users even saw product in the 5.000 - 10.000dkk price range as cheap products due to the other expenses they have.

YEARLY TOOL EXPENSES
31.500DKK

PRODUCTION AND PRODUCT PRICE

Pricing for the product will range depending on if the production is high or low volume and will be determined by the number of units that are going to be produced, which is also the factor that will tell which production method is fitted our volume.



The calculations are based on the requirement to produce four parts as two shell for the shell and two magazine for the magezine.

Injection molding will require a tooling cost whereas CNC milling only has a price for the production, and when more parts are produced the less each part will cost.

These calculations are based on the data from 3dHubs which can be seen in [Appendix page 8-16]

	CNC	Injection molding
Units:	137	500 (Min)
Tooling cost:	0 DKK	458.091 DKK
Unit cost:	1231 DKK	68,70DKK
Total investment: Tooling cost+(units*unit cost	156.440 DKK	492.775 DKK
Price for 1 product: Tooling cost/units+unit cost	1.231 DKK	985 DKK

When looking at these prices it can be seen that to tooling cost for the production with injection moulding is high and will result in a high investment. And it will also give many more products then what is excpted to be sold in the first year of production. As the investment price is over 3 times as high with injection moulding it can be estimated that around 3 times as many CNC milled units before it would make sense to change production method to injection molding seen from a financial view. The CNC milling is also easier to work with for startups as the prototypes can be ordered in the exact same quality and specefications as the final product.

The product will mainly be sold through our website, but also with direct contact with diving companies as we are introducing the product to them, during marketing, prototyping, and fairs.

Evaluating the price of products and components the product will cost 2.307 DKK to produce, which are the variable costs, this is based on prices for a product near the final, so it may differ a little compared to the BOM found in technical drawings. [W.33]

Variable cost

CNC Milled parts:	1.141,90 dkk
Components:	751,00 dkk
Custom components:	337,48 dkk
Spare parts:	76.82 dkk
Total:	**2.307,20 dkk**

Fixed cost

Marketing:	30.000dkk
R&D:	30.000 dkk
Rent:	60.000 dkk
Salary (2 employess)	327.456 dkk
Total:	447.456 dkk

The desired markup for the product is set to 40% this gives a retail price of 4.079,90 DKK based on the production cost from variable costs. [Carney, 2020] [W.33].
This value will be rounded up to a retail price of 4.090DKK which will give a profit of 1.758,89 DKK for each product sold at the price.
This gives a required investment of 860.812 DKK to produce 137 units in the first year, this high investment cost is mostly from salary but also due to the fact that 137 piece of the custom made parts will have to be produced, and ordering a lower quantity would result in a higher price for each part.

The growth over the first 3 years are set to be doubling each year for the first 3 years, this will result in total turnover in the company of 3.361.980 DKK and it will start generating profit during the 3. year. These calculations are only based on selling the product, and categories such as spare parts or future products are not taken into account.

	Year 1	Year 2	Year 3	total
Units sold	137	274	411	
Turnover (units sold*price)	560.330,00	1.120.660,00	1.680.990,00	3.361.980,00
Variable cost (units*productioncost)	319.361,77	638.723,54	958.085,31	1.916.170,62
Contribution margin (turnover - variable cost)	240.968,23	481.936,46	722.904,69	1.445.809,38
Balance contribution (-fixed cost + contribution margin)	-206.487,77	34.480,46	275.448,69	998.353,38
Balance (Break-even 3. year)	-206.487,77	-172.007,31	103.441,38	

To break even duing the first year it would require to sell 259 units and an investment of 1.044.064 DKK,

Break even (1 year)	254	Units
Break even (2. year)	509	Units
Break even (3. year)	763	Units

SCALABILITY

The production of the product will continue as improvements on the main product with the business moving along and with the possibility to expand into other segments. The advantage of useing CNC milling is also that changes can be made on future versions without having to make a large investment in a new tool. And the prototypes recived will be the same as the ones from mass production.

The first steps in the expansion for the company will some of what be close to the core product, like make another version of the product that is scaled down to be used with small electrodes only, but this will also require a new special electrode for underwater use in this size, as the ones now for underwater use are only made in larger sizes.

EPILOGUE

Product and project evaluation and last thoughts of the outcome.

CONCLUSION

The project has been built upon a user-oriented foundation of research and interviews together with commercial divers in the field. In cooperation with the divers, the focus was pointed against the welding tool. Commercial diving is a field were most innovation is the one made by the divers themself, which often are based on old technologies.
It was early in these findings that we saw that the welding tool had never been adapted to underwater use, and was based on the same functions as those used on land. The divers had trouble keeping the precision in the fierce waters which result in a reduced workflow.
Through the process the group has been in contact with commercial divers all over Denmark to discuss their usage of gear and welding tools and thereby frame the problems. These contacts were also used to validate concepts, prototypes, and research to ensure results that were user-oriented.

The final product called Extruza gives the users a whole new way to weld underwater which should give the divers a faster workflow, while also giving them an easier way to make good results. The product provides the user with better ergonomics, easier reload, and many other features never seen in welding tools before.

REFLECTION

USER FEEDBACK

Through the process it has been hard to maintain good contact with divers due to their strict work schedule. Furthermore spending time with them when they are working for an employer the time used would not only affect the diving company but also the employer paying them to do the job as fast as possible, while delivering good results. To adapt from this most of the research is based on their experience and what they see as the problems when they are doing their work, and by presenting the concepts to them through discussions. A workaround was made with videos, pictures, emails and phone calls to, which of course was not optimal, but was still giving us something to work with.

TESTING

Through the process it would have been beneficial to have the diver's test prototypes underwater, but due to the restricted access to the universities workshops and limited visits with the contacts it has been hard to develop models to test underwater in the actual size which would not take damage from the use underwater. The tests that would have been relevant to test are:

- **Improved workflow -** How many seconds or minutes could our product reduce within working with it.
- **Weight test –** Does our weight make the handling of the product uncomfortable?
- **Mobility of the product –** Are the surfaces of the product to big and would it make resistance when working with it underwater.

FINAL PRODUCT (TECHNICAL TEST)

The final solution brings many new features compared to the welding tool they are currently using, and the idea does have a general interest from the diving community. The tool would require user testing to see how well the extrusion system works and would require fine-tuning to insure the correct extrusion rate and if it would require a higher torque from the motor.

CLEANING

The rough environment the product will be used in can lead to dirt or other small particles getting into the product. As it is now the products inside can only be flushed by doing it through the "drip holes" which is used to lead water out of the product when its take up from the water. This way of cleaning isn't too thorough and opening the whole product will expose the electronics. So here it would be beneficial to separate the product so only the water exposed parts can be cleaned alone.

WATERPROOFING

Waterproofing a product is not easy and there is no standard way of doing it, as it depends on many different aspects of the product. In this case, it is solved by using the most common way with o-rings but it would have to be tested how well the sealing works, and when a new o-ring is needed.

MOTOR

It is unknown how much force is required to pull back the reload lever, as the information of the torque is not provided by the supplier. It is estimated that it should be less than 5 kg of force, but it would have to be tested. If it is higher it could also be done by placing a button to disengage the bevel gears so the cart can move freely.

Even though it is possible to get DC motors working when submerged in water, these were not available with the desired RPM as they are mostly used for thrusters for R.O.V's, they got a high RPM, so it could be investigated further as a solution with contact to manufactures.

PRODUCT LIFETIME

The life expectancy of the product has been hard to estimate as similar solutions are not seen in the context. So it is mainly based on the current electrode welding tool to give an estimation on how long the product should last, as it would require extensive user testing to get accurate results and see what would require changes to be optimal.

FURTHER DEVELOPMENT

The main product could further be developed and made into future versions based on new research and user tests. Other versions could be to make a product that would use smaller electrodes or try make products into other segments like the cutting torch.

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