By Erik Helleshøj, Christina Palsten & Katrine Nielsen

Product repport
Aalborg University - May 2023
Msc04 / ID 11

Nilfisk Keep

Nilfisk®

User Centered
Repairable Vacuum
Cleaner

TITLE PAGE

Title Nilfisk Keep

Theme Vacuum cleaner

University Aalborg University

Project team Msc04 / ID 11

Project period 01.02.2023 - 31.05.2023

Main supervisor Linda Nhu Laursen

Co-supervisor Benny Endelt

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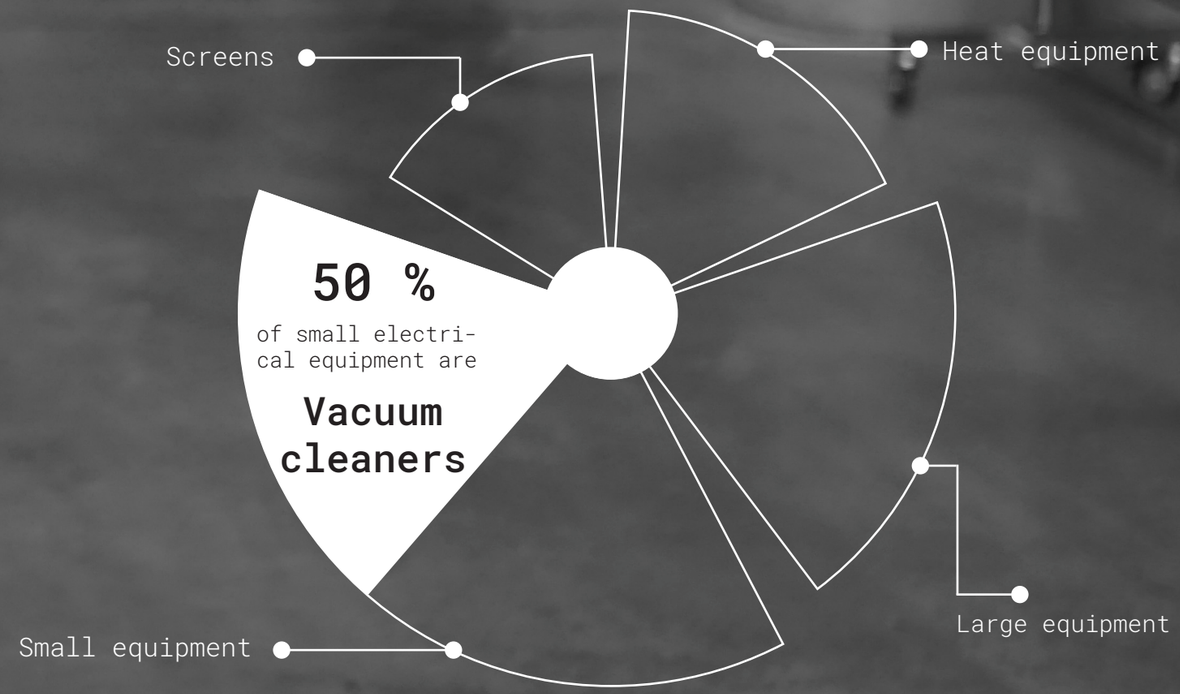
INTRODUCTION

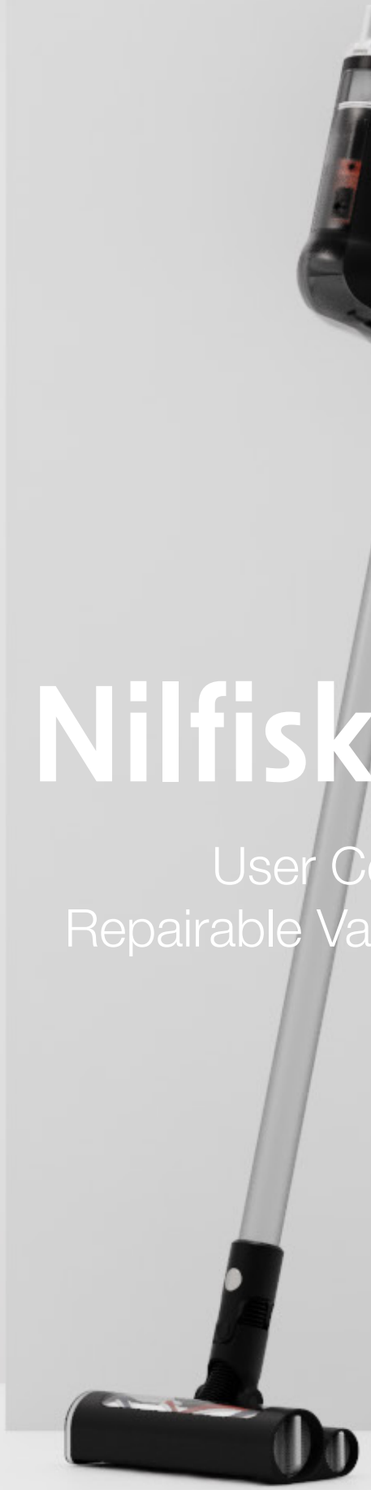
Nilfisk Keep is a stick vacuum cleaner that focuses on user centered repairability and maintenance in order to address the overconsumption and throw away products, resulting in massive global amounts of e-waste. The vacuum cleaner is designed in collaboration with Nilfisk and is meant to showcase a new way of designing for repairability. Nilfisk keep is designed to make repair easy for all consumers despite expertise and repair knowledge.

PROBLEM

Currently, e-waste is the fastest growing wastestream in the world and vacuum cleaners are a major contributor of e-waste. Today's vacuum cleaners are not designed to be repaired by the ordinary consumer and having the vacuum cleaner professionally repaired can be very expensive. This often prompts users to throw out and buy a new. Even if users dare to attempt to repair themselves, the majority don't have the required skills or knowledge.

Regulations regarding repair is scheduled which forces manufactures to reconciders how their products are repaired. This means that manufacturers eventually need to focus on this problem, and products in the future will need to implement new adaptations. One way to do this is to allow the users to repair and maintain their products on their own, prolonging the product life.



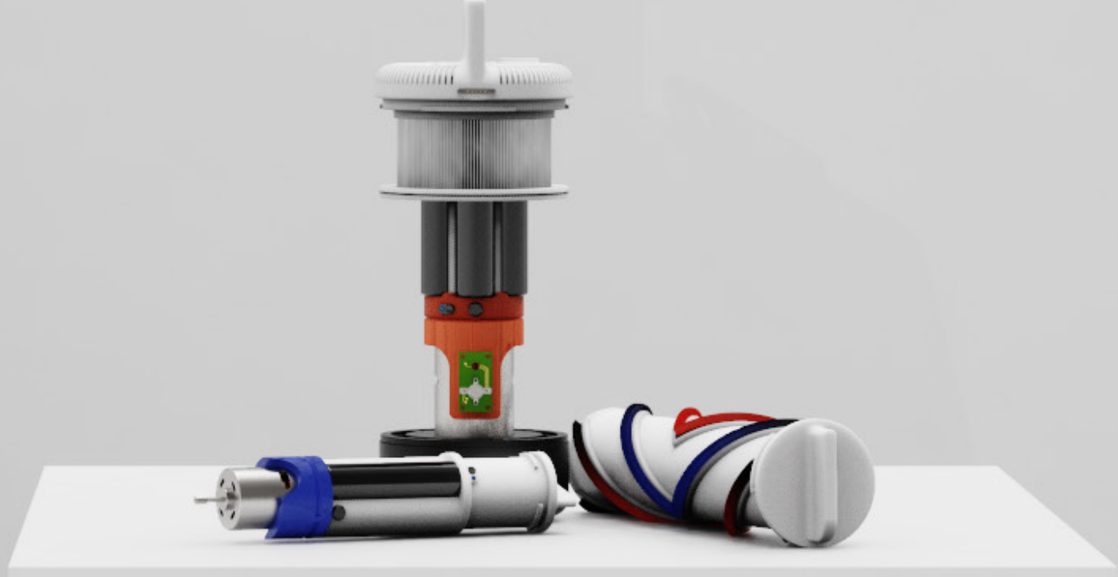


Nilfisk Keep

User Centered
Repairable Vacuum Cleaner

INNOVATION

Nilfisk Keep is a new take on a user centered repairable vacuum cleaner. It features easy access to key components that can be replaced without a hassle. The key components are collected in two electronic cylinders that can be retracted from the product with a single twist. The components in the electronic cylinder are simply unlocked and rotated off through a modular system requiring no expert knowledge to repair the vacuum cleaner. Visibility into the mechanical cylinders, as well as other important areas gives the user an understanding of how the product works and how it should be maintained.



MAINTAIN

The maintenance guide visually implemented on the product, guides the customer through the necessary maintenance steps. These steps are essential to conduct in order to take care of the vacuum cleaner and secure a long life. A bi metal-fuse will stop the motor and light up an LED to tell the customer when maintenance is crucial.

01 START MAINTAIN STEPS

02 EMPTY THE CONTAINER

03 REMOVE HAIR FROM BRUSHES

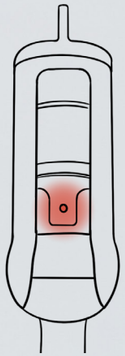
04 CHECK AIRWAYS

05 CLEAN THE FILTER

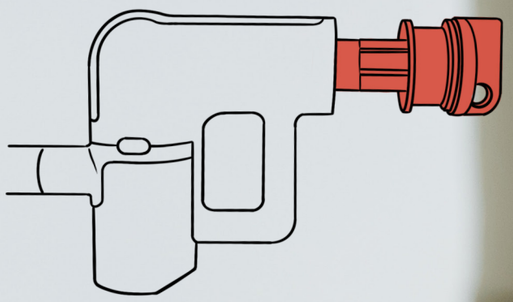
06 CLEAN THE MOTOR

REPAIR & UPGRADE

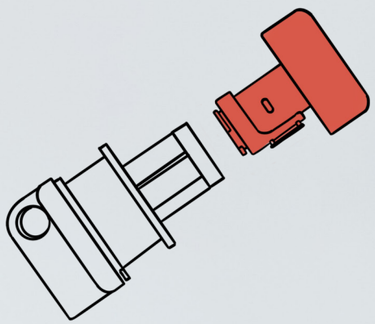
If a failure occurs Nilfisk Keep can easily be repaired without the use of any tools. This can be done by de-attaching the failed component with a single twist and swapping it out with a new component. The connections also allow for upgrades when new and better technology comes along.



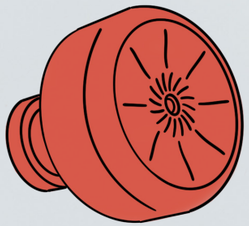
1. Diagnosis of a failed motor has been made



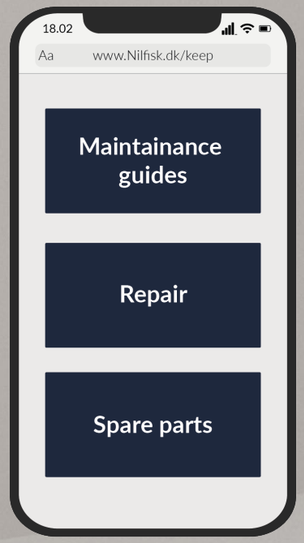
2. The cylinder is pulled from the casing



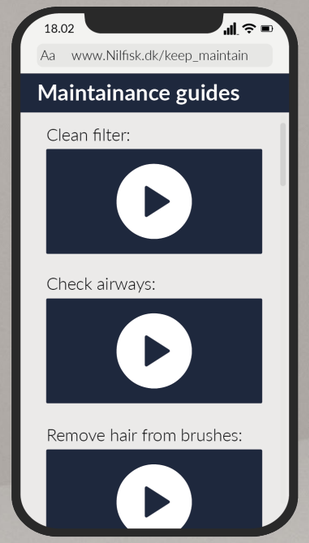
3. The motor module is removed from the other components



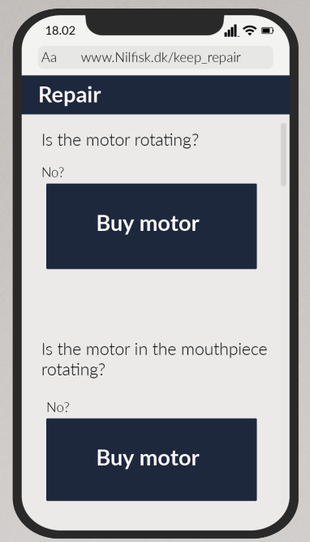
4. The new motor component is attached with a simple twist



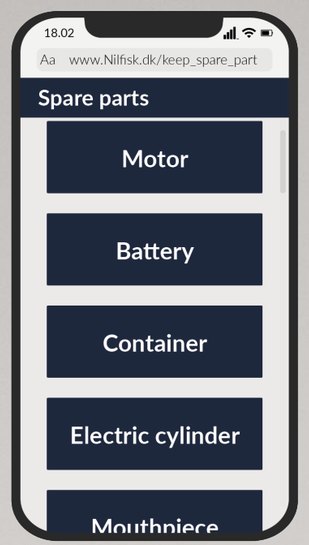
1. When the QR code is scanned the start page opens. The start page consists of 3 topics: maintenance, repair or spare parts.



2. The maintenance page will provide videos guides of how to maintain the vacuum cleaner.



3. The repair page will help to understand which part is broken and needs to be replaced.



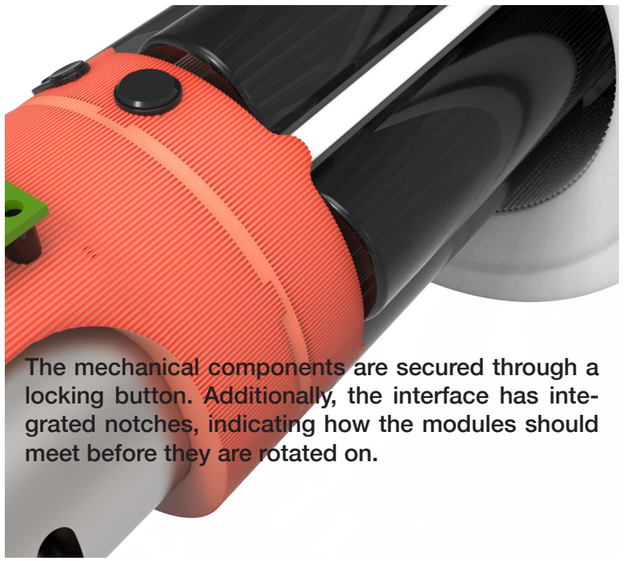
4. The sparepart page will have all the suitable spare parts available for the model.

SPAREPARTS

Spareparts are bought directly from the Nilfisk webshop. The QR code on the stick vac will take the customer directly to the maintenance, repair and spare-part webpage for the exact model, making it very easy to order a new component.

INTERACTION

A slider controls the vacuum power, turning the vacuum off at the bottom, and max power at the top.



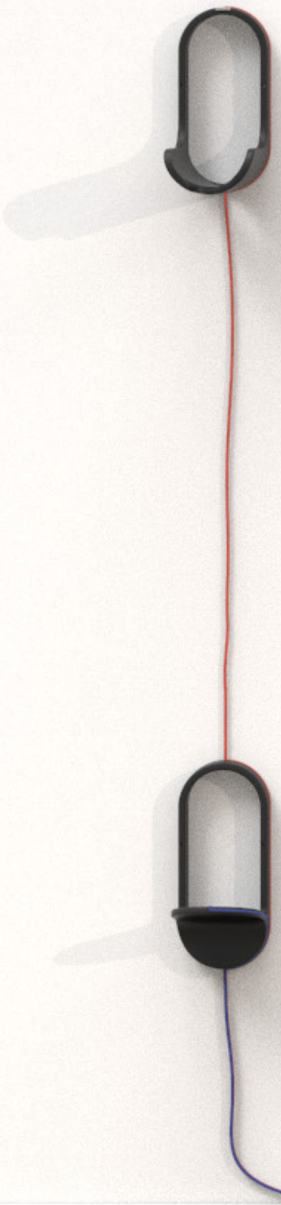
The mechanical components are secured through a locking button. Additionally, the interface has integrated notches, indicating how the modules should meet before they are rotated on.

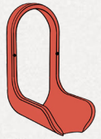
The two electronic cylinders function simultaneously through bluetooth. The cylinders are paired by holding down each bluetooth button until the light turns on.

MOUTHPIECE

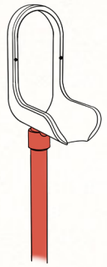
The mouthpiece is designed with a motorized rotating brush for better dust pick up. This brush is driven by a separate battery and motor cylinder with the same connection that allows the customer to repair and upgrade components.

The brush has two types of brush lines allowing the customer to vacuum on all surfaces and floor types.

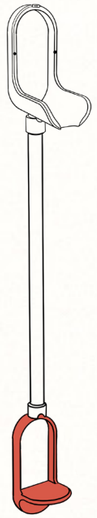




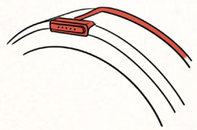
1. The top part is installed on the wall via two screws.



2. The vacuum tube is inserted into a socket on the top part.



3. The tube is used as a spacer to ensure the correct length.



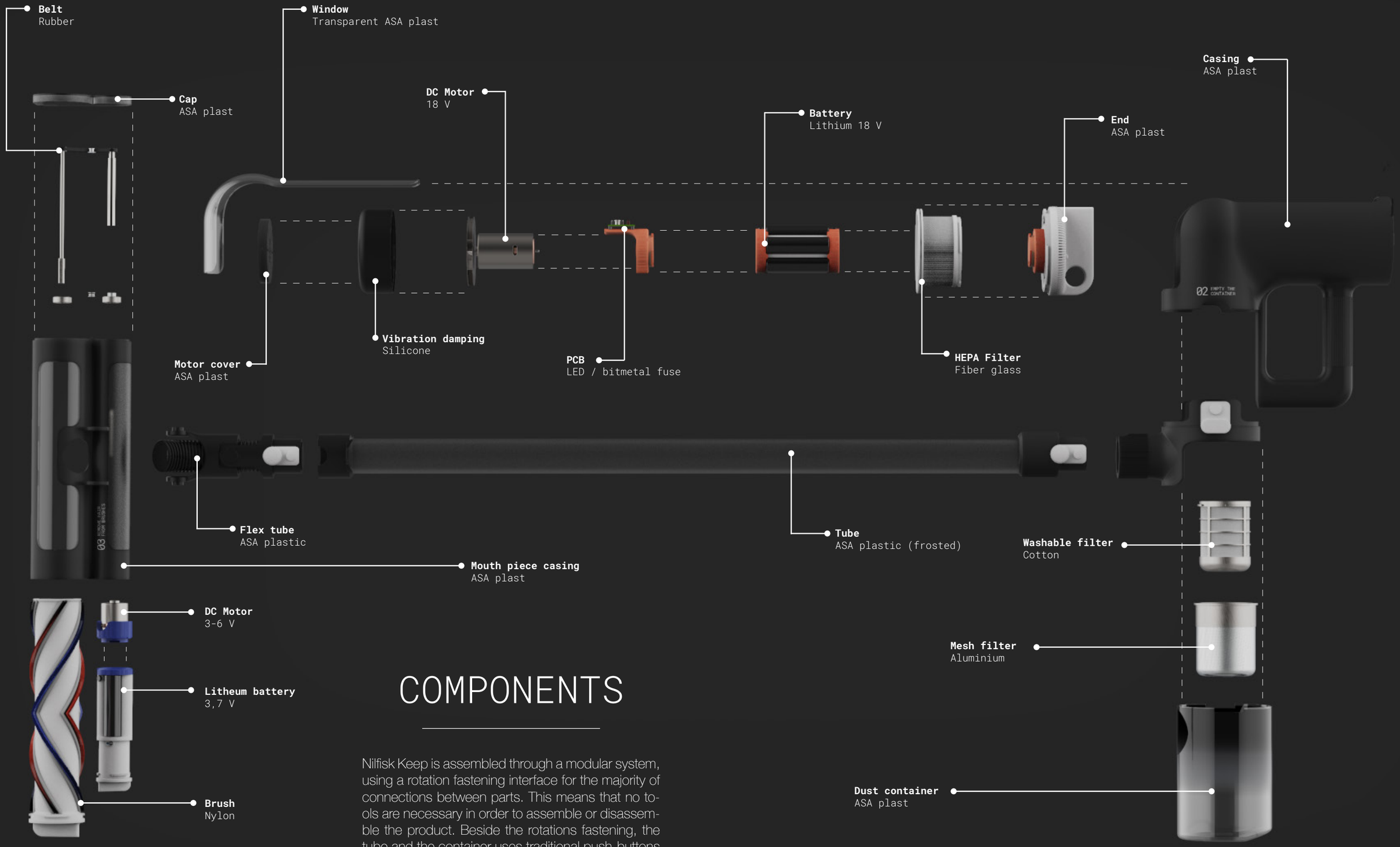
4. The charging cable is inserted into the grooves of the docking station.

DOCKING STATION

The docking station is designed in a simplistic design and looks elegant with or without the vacuum cleaner docked. The station makes sure the vacuum cleaner is charged in both charging points.

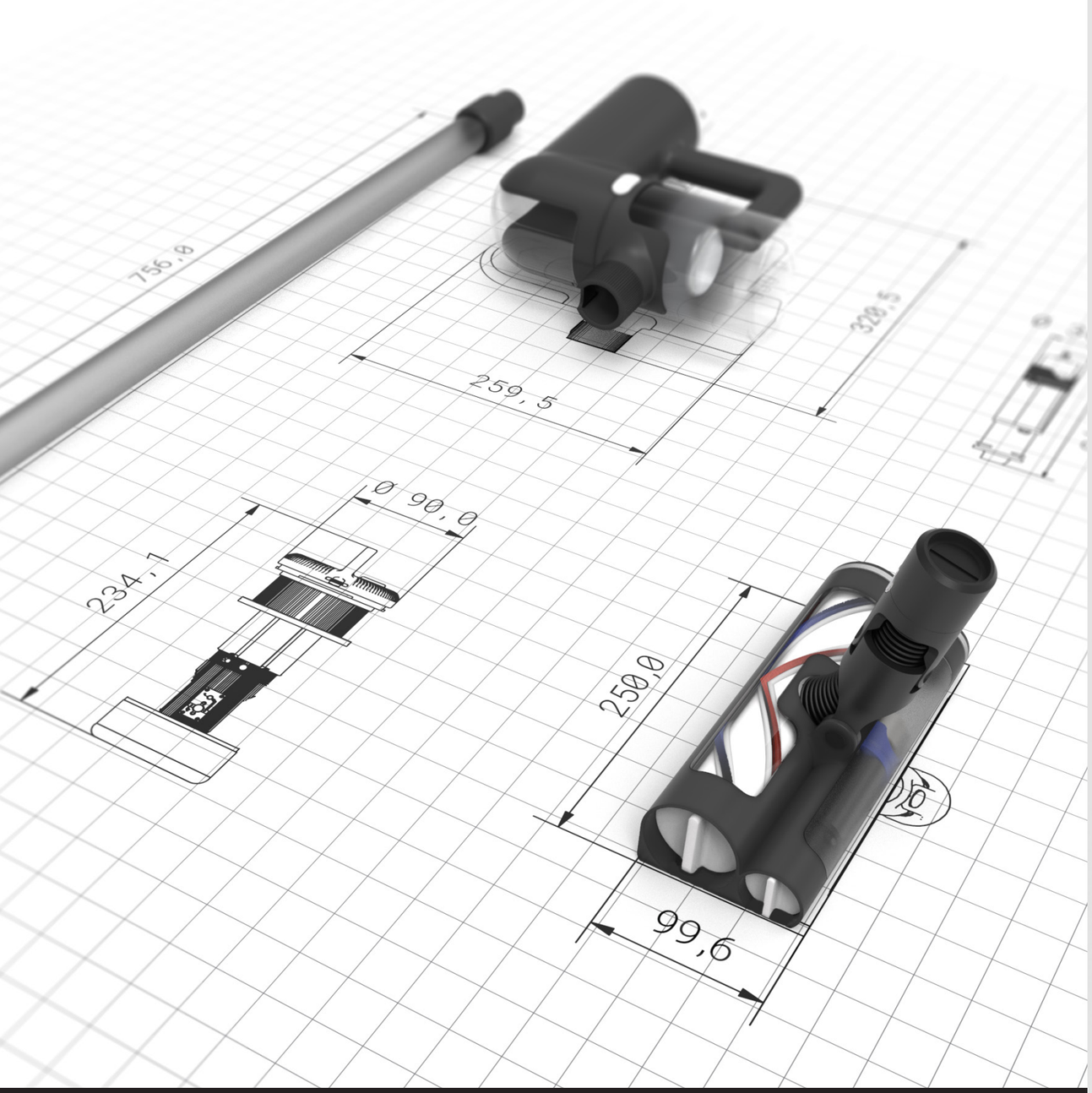
AIRFLOW

The vacuum cleaner is designed with a cyclonic air filtration which separates bigger particles from the airflow. A mesh filter along with a washable filter separates smaller particles from the airflow and lastly a HEPA filter filtrates 99,9% of all particles.



COMPONENTS

Nilfisk Keep is assembled through a modular system, using a rotation fastening interface for the majority of connections between parts. This means that no tools are necessary in order to assemble or disassemble the product. Beside the rotations fastening, the tube and the container uses traditional push-buttons that users already are familiar with from current stick vacuum cleaners, whilst the window into the belt driven system window is attached via snap-fixes.



SPECIFICATION

General specefication	
Weight	3 kg
Lenght	1225 mm
With	250 mm
Depth	260 mm

Battery span	
Max power	19 min
Medium power	25 min
Low power	38 min
Charging time	40 min

BUSINESS PLAN

Nilfisk Keep is the first product in the potential of a new repairable product line for Nilfisk. This new strategy can be expanded across the Nilfisk portfolio. Nilfisk Keep introduces 3 core design principles that can be included in the next generation of Nilfisk products.

The electronic cylinder

By combining the electronics in as few areas as possible with modular connection, it makes the product less complicated, and easier to disassemble and repair.

Visible access to the driving components

Allowing the user to see into the operational function and state of the driving components gives them knowledge for the product and affords maintenance.

Maintenance steps

Integrated steps give active communication regarding the necessary maintenance inorder to keep a well functioning and long lasting product.

AD NYE VEJE

AALBORG UNIVERSITET

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Nilfisk Keep

User Centered Repairable Vacuum Cleaner

THE DESIGN TEAM

Katrine Nielsen | **Erik Helleshøj** | **Christina Palsten Nielsen**

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Thanks to our main supervisor Linda Nhu Laursen, for pushing, and guiding us through out the process. Thanks to our technical supervisor Benny Endelt.

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Peter Noehr Larsen - Principal Engineer - Sound & Cleaning Technology

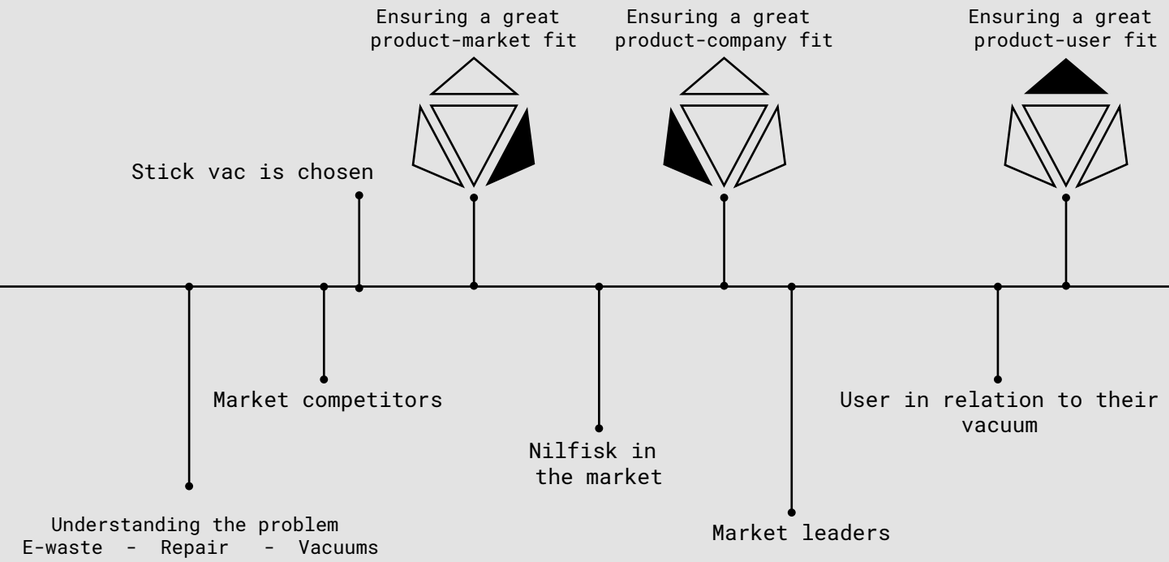
Thanks the Cj Hvidevareservice In particular to Steen for knowlegde regarding repair of vacuum cleaners.

CONTENTS

ABSTRACT

The purpose of this master thesis project is to describe the design process behind the final product proposal: Nilfisk Keep, a stick vacuum cleaner with maintainable and repairable design features that are consumer oriented. The main focus areas of the project is uncovering the complexity of vacuum cleaner obsolescence and vacuum cleaner anatomy, and combining it with understanding of user oriented repair and user vacuum cleaning behavior. Additionally, the approach to enter the market with a product of this type is considered, and Nilfisk is chosen as the case company. The overarching goal is to develop design principles that can be implemented into consumer products that help with the reduction of e-waste.

TIMELINE



READING GUIDE

The project is documented in four parts. A process report, product report, technical drawings and appendix.

The process report describes the various discoveries, reflections and decisions made during the span of the project. It is divided into focus areas resulting in 10 phases: understand, market, user relation, repair, mouthpiece, cleaning behaviour, design for longevity, construct, business and an epiloug.

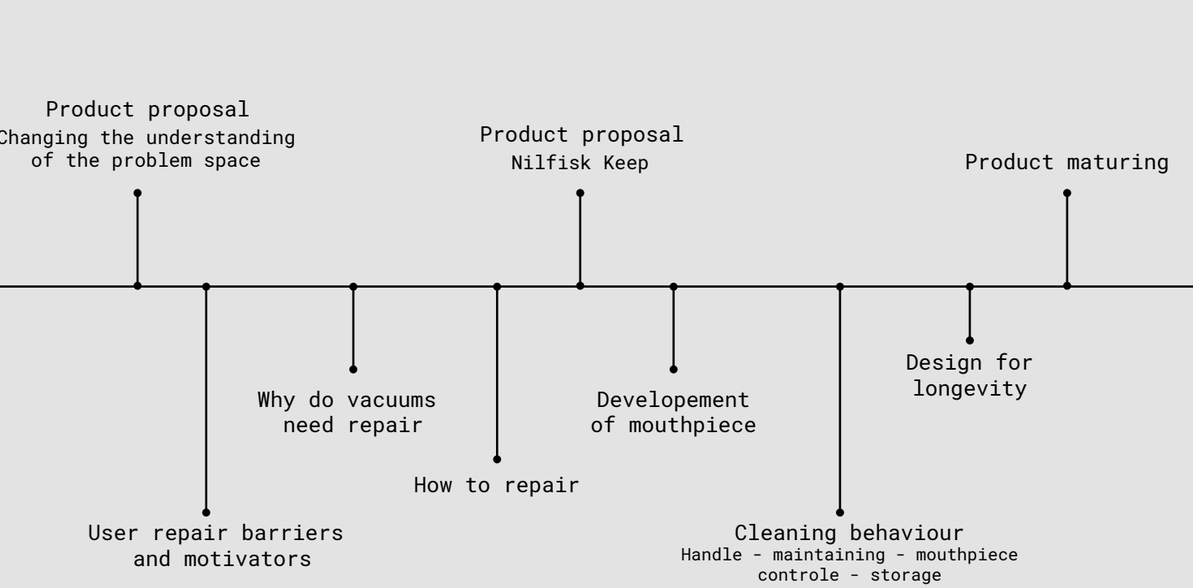
In the report the following icons and boxes will occur:

Insights

Design criterias

Requirements

Important choices



INTRODUCTION

E-waste is currently considered to be the fastest growing wastestream in the world and initiatives to reduce e-waste are in motion. Vacuum cleaners are a major source of e-waste and whilst many vacuum cleaner manufacturers have a sustainable focus, it's mainly in regards to energy efficiency and the use of renewable materials. Consumerism has caused a major focus on product production optimization, which in terms has left little focus on product life after assembly. As a result of this, product maintenance or repairability can often be difficult and not worthwhile. However, the first regulations that forces manufacturers to consider easier disassembly and replacement are coming, making it necessary to adapt the way that products are designed. This thesis aims to explore these adaptations and how they can be integrated into vacuum cleaners in order to make a user centered repairable vacuum cleaner.

This phase describes the initial scoping and research areas that creates a foundation for the design project. This is mainly based on desktop research, interviews and hands-on research. This culminates in initial design strategies, that based on the initial scopings seems to be relevant for solving the problem, as well as an initial design brief highlighting the learnings from the chapter.

UNDERSTAND

01

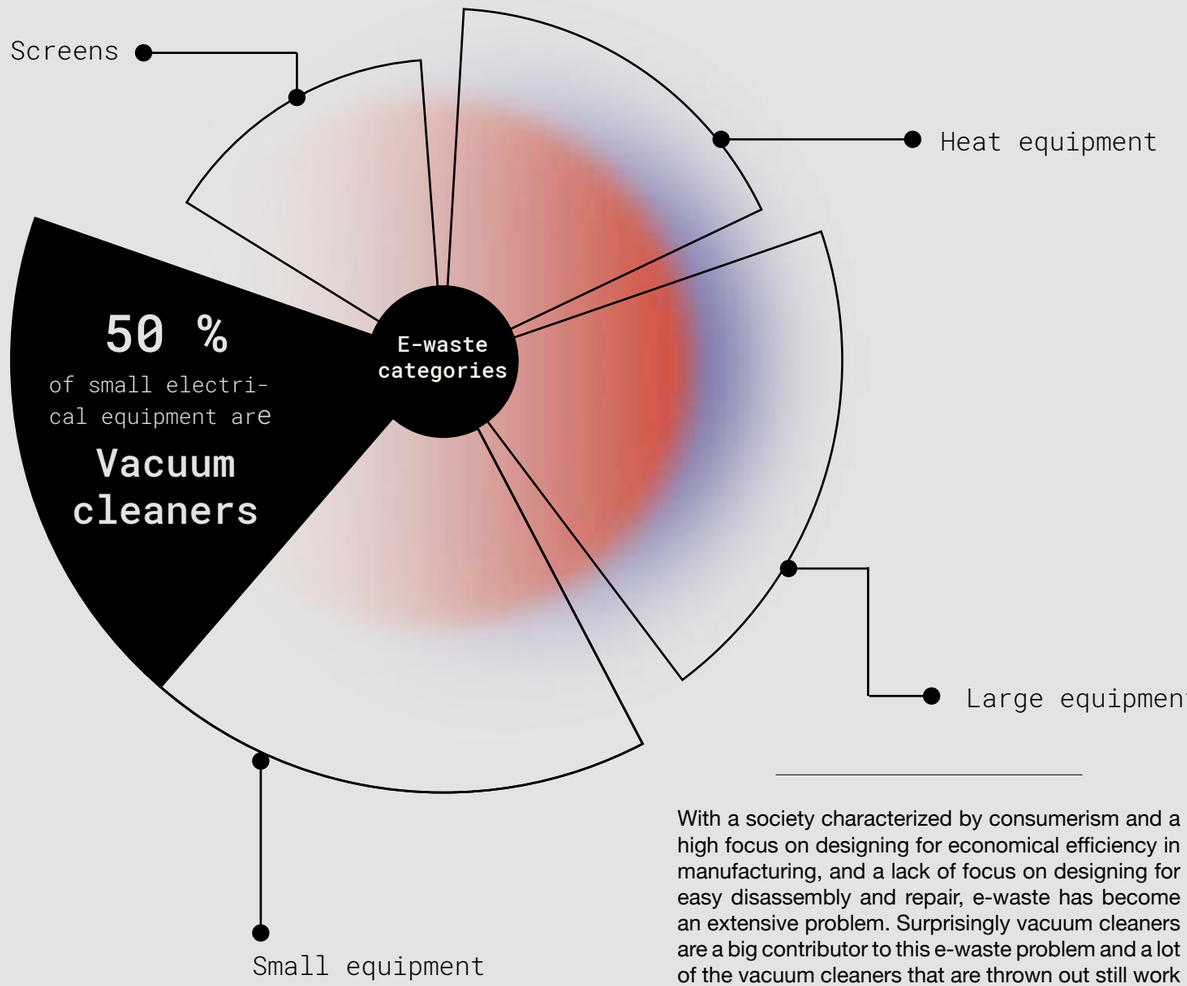
E-WASTE

To gain knowledge about the preliminary problem a desktop research was conducted by the team. This was done to understand the extent of the e-waste problem today and the factors that have led to the rising problem. The answer to these questions will be used as background knowledge throughout the entire project.

E-waste is electrical and electronic devices that have reached their end of life and are therefore discarded. This is devices such as electrical shavers, screens, washing machines or smartphones.(PACE, 2019) E-waste is considered to be the fastest-growing domestic waste stream in the world. (PACE, 2019) The Global E-waste monitor predicts that by 2030 the global e-waste amount will be almost doublet compared to e-waste generated 16 years ago. (Forti, 2020) In 2017 The Global E-waste Monitor reported that in just one year, enough e-waste was produced to be equivalent to the mass of 125.000 jumbo jets. That is about six-kilogram of e-waste for every person on the planet. (PACE, 2019) E-waste is categorized depending on the type of product, with the biggest category being "small equipment" such as kettles, toasters, vacuum cleaners, and mixers, responsible for 38% of the global E-waste. (PACE, 2019)

Rapid advancement in technology, increased affordability, and planned obsolescence are some of the main factors for the rapid increase of e-waste. Many electronics face the same turnover in style as fast fashion, centered around selling the latest model and increasing affordability. (PACE, 2019). Likewise research in regards to reducing cost of manufacturing and design for assembly has been very successful, allowing for reduction of price for mass manufactured products. In comparison, very little focus has been on design for disassembly and design for repair, leaving the consumers with few options for repair, further increasing the tendency for generation of e-waste. (Madsen, 2018

Only 25% of e-waste is recycled, while the rest goes into landfills and incinerators (U.S. Environmental protection agency, 2010) This can be problematic since e-waste can contain hazardous substances, which may affect the environment or cause health issues. Additionally, the reason so little e-waste is recycled is mainly due to the complexity of the products. These must be separated, requiring expertise and time in order to be safely and correctly recycled, which in the end may not be worth it economically, compared to the worth of the recycled material. (Tech Reset n.d.)



> 2/3 OF DISCARDED VACUUM CLEANERS STILL WORK OR CAN EASILY BE REPAIRED

With a society characterized by consumerism and a high focus on designing for economical efficiency in manufacturing, and a lack of focus on designing for easy disassembly and repair, e-waste has become an extensive problem. Surprisingly vacuum cleaners are a big contributor to this e-waste problem and a lot of the vacuum cleaners that are thrown out still work or can easily be repaired. Because vacuum cleaners are a huge contributor and have a complexity that the design team find very suitable for a master thesis project it was decided to tackle this e-waste problem with a focus on a repairable vacuum cleaner.

2/3 of discarded vacuum cleaners still work or can easily be repaired

Vacuum cleaner is chosen as case product

E-waste in Vacuum cleaners

Vacuum cleaners are a huge contributor to the E-waste problem. In the EU 50% of the e-waste generated in the category "small electrical equipment" is generated from vacuum cleaners (Lupe pure 2023). Surprisingly a lot of vacuum cleaners that are thrown out still work or can easily be fixed. This was discovered by a group of researchers at the University of Southern Denmark who did a study of 2251 kg of E-waste. In this pool of E-waste they found 233,52 kg of e-waste generated from vacuum cleaners. Unexpectedly they found that ⅔ of the vacuum cleaners still worked or could easily be fixed. (Madsen 2019)

WHY ARE SO MANY VACUUM CLEANERS THROWN OUT?

In order to understand why so many vacuum cleaners are thrown out even though they still work or can easily be repaired, it was investigated why products become obsolete. By getting knowledge about the product's lifetime and analyzing these in relation to vacuum cleaners it can be determined which parameters and which problems to tackle when designing a repairable vacuum cleaner.

The actual lifetime of a product spans from the purchase to when it is discarded. (Bracher et. al 2020)

The designed lifetime is the maximum time the manufacturer intends that the product to be functional. (Bracher et. al 2020)

The optimal lifetime is the amount of time when the product has achieved the optimal environmental, social, and economic impact. (Bracher et. al 2020)

Absolute

When a product fails to function it becomes absolute obsolete, and the actual lifetime is equal to the designed lifetime. This happens when the failure is caused by a lack of performance of materials or components or when the failure is caused by a lack of interoperability of software and/or hardware.(Bracher et. al 2020)

Example - The motor fails after five years and the entire vacuum cleaner is discarded.

Relative

Relative obsolescence is when a still functional product is disused. Here the actual lifetime is shorter than the designed lifetime. This happens when the product is replaced due to the desire of a new one, even though the old one still functions. It can also happen if an old product is replaced as the cost of product repair or product upgrade is too high compared to a whole new product or if a new product is offering better quality, functionality or effectiveness. (Bracher et. al 2020)

Example - A new vacuum cleaner model is bought because of improved battery life.

Premature

A premature obsolete product can both be absolute and relative obsolete. Premature obsolescence is when the product's useful lifetime is shorter than what is possible, the designed lifetime, or what is desirable, from the view of the consumer. In some cases the premature obsolescence is intentional from the manufacturer, this is called planned or programmed obsolescence. (Bracher et. al 2020)

Example - The vacuum cleaner fail after two years.

01 E-waste from vacuum cleaners

Both the design of the vacuum cleaner and consumer behavior drives people to toss their vacuum cleaner. They become absolute obsolete if just a single component in the vacuum cleaner fails. This is an important problem to tackle because the entire vacuum cleaner is thrown out if the motor fails, generating way more waste than necessary. Relative obsolescence is influenced by consumers behavior and their desire for newer products. The cost of the repair is too high compared to a new upgraded product resulting in obsolete and wasted products.

The product must be upgradeable

Vacuum cleaners are discarded if just a single component fails.

REPAIR

It is clear that vacuum cleaners become obsolete for various reasons. To understand why people do not repair their product when it becomes obsolete this is investigated.

Circular economy

Moving away from the traditional linear model of consuming and throwing away pattern, the circular model implies a way of reducing waste to its minimum by extending the life cycle of a product. (European Parliament 2015) The goal of a circular economy is to keep the value of the product most efficient. This is above all done by maintaining, repairing and reusing the products. The last option is then to recycle the materials if a product can not be repaired. (Ellen Macarthur Foundation 2019)

02 Circular economy

Currently, repair is often less likely than replacement in regards to electronic products, especially if the consumer has a low expectation regarding the product's lifetime. (Bacher et. al 2020). The biggest reason for avoiding repair turns out to be the cost (Šajn N, 2022). A quick investigation (app. 1) of repair prices in Denmark was made to understand the price difference between a new vacuum cleaner and repair cost.

Bosch Repair prices of small household electronics starts at a minimum of **1170 DKK**

Støvsugerbanden Repair prices of a vacuum cleaner is typically between **1000-1200 DKK**

Cj-service Repair prices of a vacuum cleaner is typically between **849-1149 DKK**

Tim from Støvsugerbanden mentioned that most people make the decision to buy a new vacuum cleaner instead of having their broken vacuum cleaner repaired, as the price of a new vacuum cleaner is so cheap compared to the repair price. A new vacuum cleaner from a decent brand like Hoover has a starting price at 499 DKK.

However, as product price goes up, it becomes more valuable to repair. Studies also show that striving towards repair instead of replacing electronic products, could reduce household spending by an average of 22%. (DeBellis, 2021) In recent years, repair initiatives such as repair cafes, have become more popular in many industrialized countries (Hielscher, 2019). Studies also show that products with repairability scores result in consumers willingness to pay more for the product. However, society is still based on consumerism, and a lot of consumers don't know where to get their products repaired, or indicate that it is too expensive or takes too much effort. These challenging conditions for repair of electronics push consumers towards cheap products, which often have a shorter lifespan. (Šajn, 2022)

The investigation of repair prices in Denmark shows that repair prices are high and people are not willing to pay for this service when a whole new vacuum cleaner can easily be bought for the same price. However in recent years, consumers have paid more attention to the repair of products. **This might indicate that there is a need for a vacuum cleaner that consumers are able to repair on their own in order to lower the repair price.**

People think that the repair cost of a vacuum cleaner is to high

Repair initiatives are becomming more trending

THE RIGHT TO REPAIR

To gain a base knowledge about rules and legislations for vacuum cleaners, EU regulations were investigated. These regulations will be guidelines or set requirements for the design of a user centered repairable vacuum cleaner.

Movements such as “The right to repair movement" have begun their fight against consumerism and pushes for a change around repair. They believe that products should be designed for repair when broken, in order to last longer. They ask for the right to repair. Their goal is legislation with set design requirements to make sure that products can easily be disassembled and key components can be replaced. They likewise think that consumers should be aware of whether they are buying a disposable product or if the product is built to be repaired (Right to repair).

Legislations

Some legislation has been set for electronic products by the European Union. An extended legislation for electronic products will also be implemented or considered in the nearest future. Legislations with importance will be explained in the following. (European parliament 2022)

Future intentions

From 2026 a battery regulation will become effective. This legislation will require manufacturers to design their products that allows the consumers to replace their batteries without any professional repair help. (Right to Repair 2023)

The commission has made a legal initiative proposal that will encourage manufacturers to design products that last longer and are easier for the consumer to repair. (European Commission 2022) These initiatives present levels of intervention, where lower interventions encourage businesses to commit to repairing their products voluntarily and higher interventions require an extended legal guarantee period for consumers who choose to repair their products instead of replacing them.

EU ecodesign legislation

Along with a handful of other household appliances, vacuum cleaners must meet the eco design requirements. (European Union, 2022) However this has mostly focused on energy efficiency so far. (European Commission, 2019) New eco design acts have been implemented for larger household appliances such as washing machines, dishwashers and refrigerators. This addition enhances repairability and recyclability for these products as it requires manufacturers to have spare parts available for professional repairers for a certain number of years (10 years for washing machines). This does not apply to vacuum cleaners yet. The ecodesign detective will be revised and is set to be widened for the broadest possible product range. (European parliament, 2022)

Ensure that vacuum cleaners comply with the following limits:

* Annual energy consumption: less than 43 kWh/year
* Rated input power: less than 900 W
* Minimum dust pick up on carpet (dpu_c): 0.75
* Minimum dust pickup on hard floor (dpu_{hf}): 0.98
* Maximum dust re-emission: 1,00 %
* Minimum operational motor lifetime: 500 hours

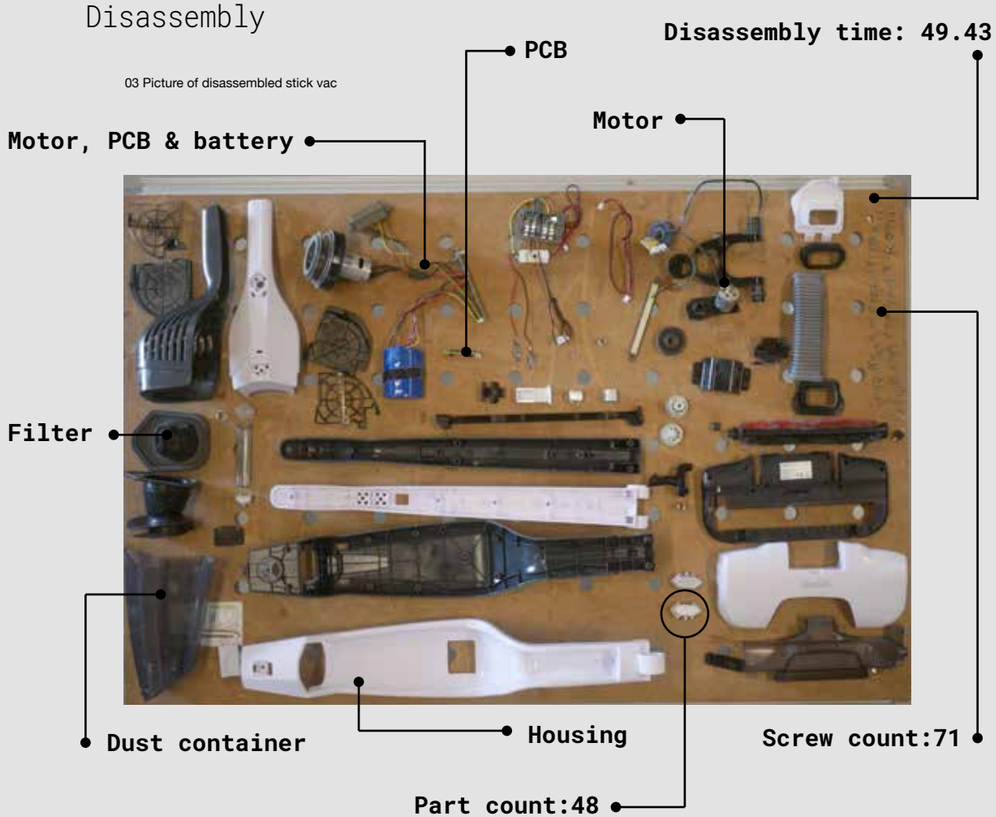
Future legislation will force companies to consider the repair process in the near future. Both consumers and the companies will profit from an easily repairable vacuum cleaner when stricter legislations are applied. This supports the importance of the identified problem area where the design team will focus on easy repairability. A set of requirements have been identified. These will however be considered in the detailing face of the design process.

- [x] Minimum dust pick up on carpet (dpu_c): 0.75
- [x] Minimum dust pick up on hard floor (dpu_{hf}) : 0.98
- [x] Minimum operational motor lifetime: 500 hours
- [ ] Future EU legislations for repair is set for the near future

UNDERSTANDING THE VACUUM CLEANER

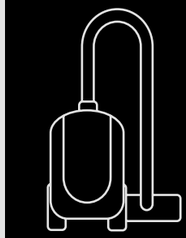
Through the initial investigation of the problem it was made clear that vacuum cleaners are not initially designed to be repaired by consumers. To experience this problem first hand and to obtain a deeper knowledge, a disassembly (app. 2) of two vacuum cleaners was conducted.

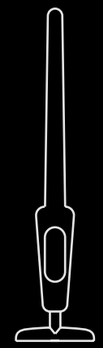
Disassembly



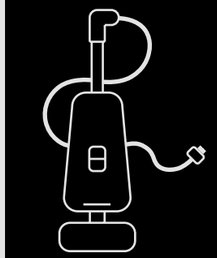
Stick model

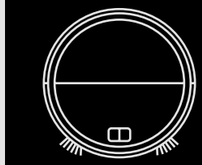
The stick vac model was very complex to disassemble because of the many parts it consisted of. Just to unscrew all the screw was a hassle as some was hidden behind wheels and finishing covers and required different kinds of tools. The architecture inside was opposite the canister model, very complex and the product had multiple motors and pcb’s. These electronic components were not collected in one area, but placed around the shell of the product. The driving motor, pcb and battery were soldered together which made it impossible to replace one of these components without advanced tools and associated knowledge and skills. This product was not broken before the team had started the disassembly but after the reassembly the vacuum cleaner did not work properly. Four parts were left behind, as no one could remember where these parts were placed.

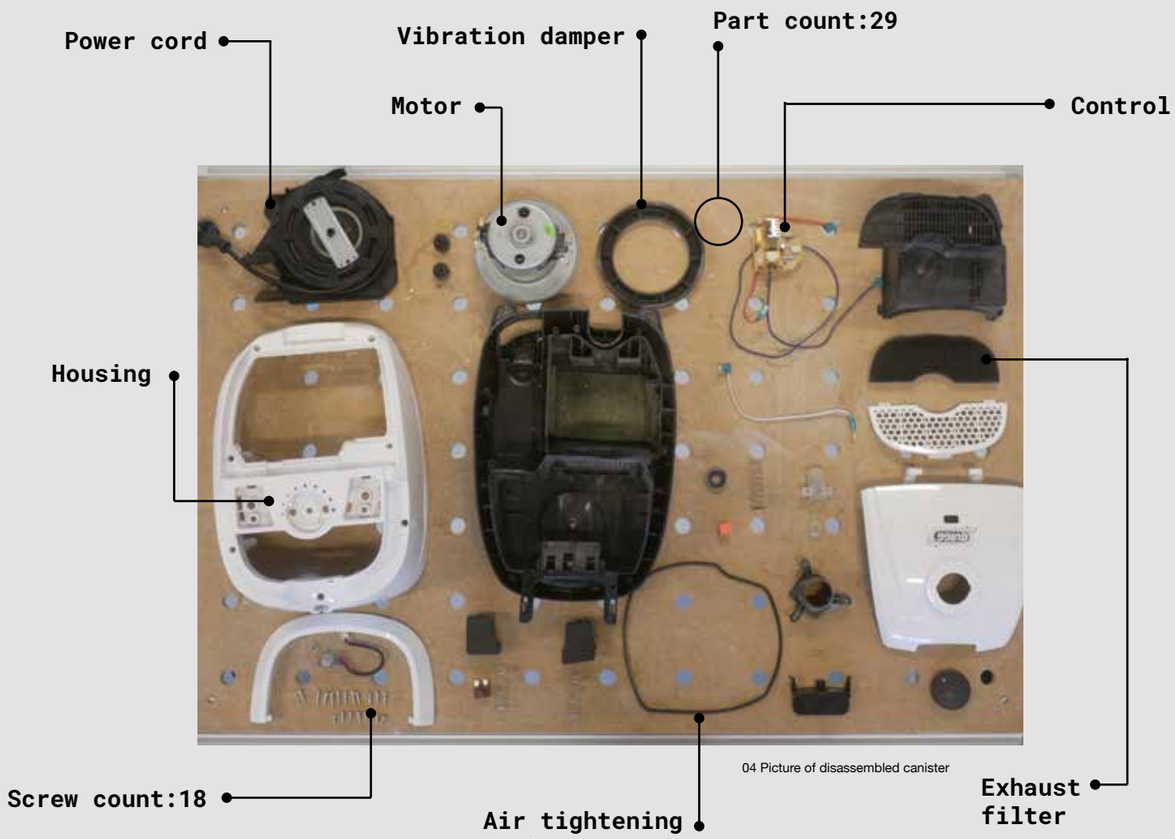

CANISTER


STICK


HANDHELD


UPRIGHT


ROBOT



04 Picture of disassembled canister

Canister model

Straight from the beginning it was very clear for the design team that this vacuum cleaner was not designed for disassembling. The product had a lot of attachment points that needed different kinds of tools, which made it a hassle to disassemble. The snap fasteners made the team unsure whether or not you would break the points when pulling the fasteners apart. Despite the complex disassembling process the architecture inside was very simple, consisting of only a few components, however the components seemed very advanced and fragile. This vacuum cleaner was broken but it was not possible for the team to detect the fault. Putting the product back together was another problem. As no identification showed where the components or wires had to be put back, it made the team unsure that the product was correctly reassembled in the end.

This activity showed the importance of designing for disassembling and reassembling when making a repairable vacuum cleaner. Many parts, a complex architecture and attached components makes it a hassle and almost impossible to repair a vacuum cleaner. Likewise it was noticed that diagnosing failed components might be difficult for “ordinary” consumers.

The vacuum cleaner must be airtight from the in-port to the exhaust-port

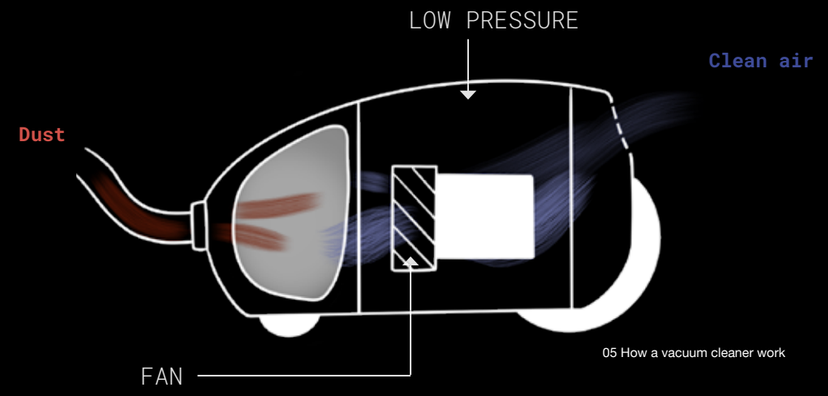
It is difficult to diagnose the failure

The required time and effort of disassembly and reassembly are too demanding

How does a vacuum cleaner work?

A conventional vacuum cleaner consists of six essential parts; an intake port, exhaust port, electric motor, fan, dust bag and a housing containing all the parts.

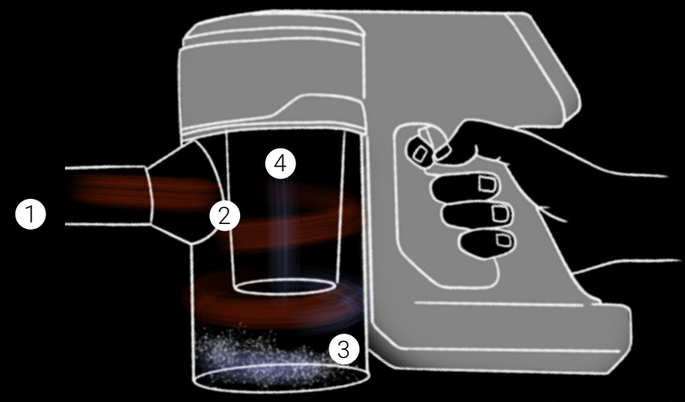
The electric motor is attached to the fan and as the fan blades turn they force air forward, towards the exhaust port. The air pressure increases in front of the fan and decreases behind the fan. Air (and dust) is pushed through the intake because the air pressure inside is lower than the pressure outside the vacuum cleaner. (Harris n.d.) Dust is captured in a dust bag whilst air flows through.



05 How a vacuum cleaner work

Cyclonic air filtration

Cyclonic air filtration is commonly used in many vacuum cleaners today. This technology allows for bagless vacuum cleaners which offers more consistent suction power. Cyclonic air filtration works by pulling air and dust apart at high speed by pushing dust particles to the sides, where they will fall to the bottom of the dust container. The air will spin around creating a cyclone and be drawn up through the middle. (Hoover 2021)



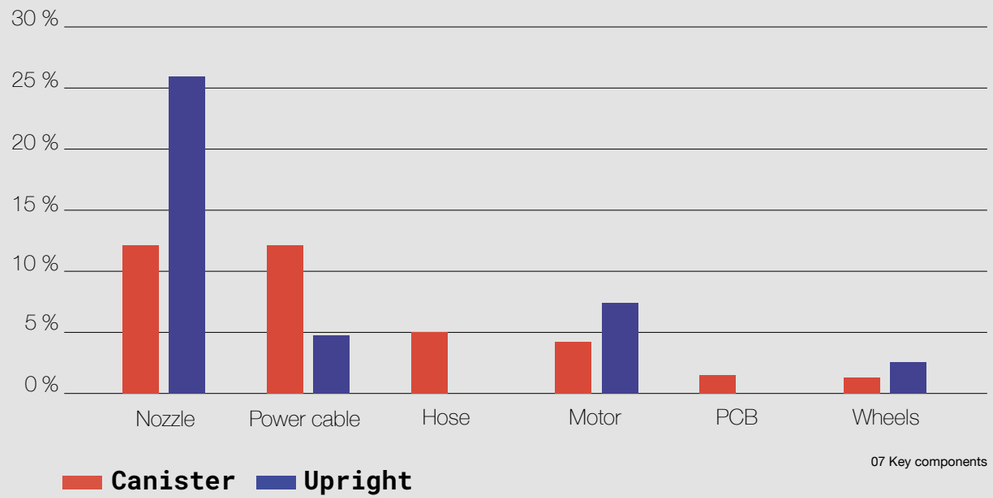
06 How cyclonic air filtration work

1. The air and dust is forced in to the vacuum cleaner.
2. The air enters the container perpendicular to the dust container and spins around
3. Dust and dirt is pushed to the edge and will fall downward
4. The air will be forced up through the middle

KEY COMPONENTS

Disassembling a vacuum cleaner showed the complexity of a vacuum cleaner, and in order to design a repairable one it was clear that a priority within the components had to be made. Because of this it was investigated which components in a vacuum cleaner most often fail. The team will be focusing on these key components in future design proposals.

Research, comparing different surveys reporting main failures, shows that the following parts are considered to be the key components that most often fail in a canister and upright vacuum cleaner.



07 Key components

It is expected that electronic boards will play a bigger part in failures as vacuum cleaners will be designed with more electronics. The vacuum cleaners included in the survey all included motors with carbon brushes that eventually will wear and fail. An alternative to these motors is electric motors without brushes. (Bracquené, 2018)

Investigating the key components showed that the type of the vacuum cleaner has great influence on the considered key components. As an example, an upright vacuum cleaner does not have a hose that is otherwise considered to be a key component in a canister model. This research indicates that the design team will have to choose and focus on a vacuum cleaner model in the near future in order to identify the specific key components. However common key components for all the vacuum cleaners are electronic boards and motors, because of this these are picked as key components for now.

Key components can be replaced

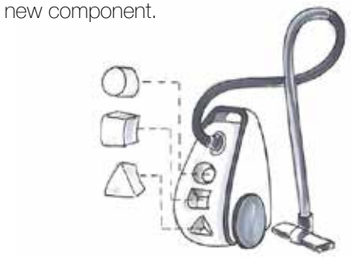
FIRST SKETCHES

With the initial understanding of the problem a sketching round was conducted (app 3) . This sketching round was focused on incorporating design strategies observed from different product categories. This was done to target problem areas separately and work with them parallel to each other. The problem areas have been identified as, disassembling the vacuum cleaner, diagnosing the repair, obtaining knowledge about the components and future proofing the vacuum cleaner.

The basis of these four concepts is developed upon strategies seen in products from Tesla, Nilfisk, Ikea and Fairphone (app. 4). The concepts can either be developed separately or together and implemented into the design of a repairable vacuum cleaner.

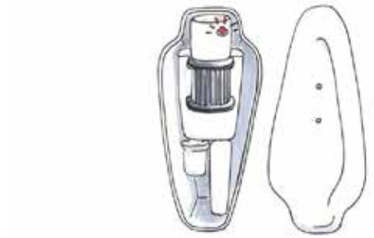
Modular vac

Nilfisk intuitive cord change of their VP 600. This design strategy is implemented in order to make the level of repairability suitable for the user by implementing modules of key components that can be replaced by a new component.



Self diagnose vac

Tesla's Self diagnose system that alert user. This design strategy is implemented in order to take the guessing game out of the equation and give the user the ability to detect the specific part that needs to be changed.

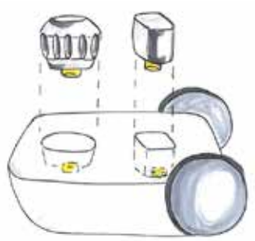


Build it yourself vac

The Ikea assembling your own product. This design strategy is implemented in order to give the user a "first impression" relationship to the individual parts, making them familiar with the system before they have to open it up again.

Platform design

Fairphones platform that allows for upgradeability and repairability of their phone. This design strategy is implemented in order to create a universal interface, so parts can be interchanged in the future.



The initial sketching round emphasized that the design team had to focus on one type of vacuum cleaner. The sketching round also made it apparent that the team had to verify that there was a market for a user centered repairable vacuum cleaner. Likewise it made it clear that business knowledge was needed to tackle the challenges of implementing repairability in a supply chain.

DESIGN BRIEF

Problem area

E-waste is one of the fastest growing waste streams in the world, and vacuum cleaners make up 50 % of small electrical products generated in Europe. This problem has grown enormously parallel with the focus on reducing manufacturing price, ease of assembly, and the constant consumer need for the newest technology. But both legislation and requests from the consumers calls for a new way of designing household products with a longer life. Prolonging the life of a product by repairing is the best way of keeping valuable resources in the loop. But consumers are not able to repair current vacuum cleaners on their own and are not willing to pay the prices of a professional repair or know that this is even a possibility.

As an attempt to solve a small part of this extensive problem the design team believes that there is a need for a vacuum cleaner where the consumers have the possibility to prolong the life of their vacuum cleaner by repairing and upgrading on their own.

Problem statement

“How can a future proof vacuum cleaner with user centered repairability and upgradeability be designed”

Requirments

- The product must be upgradeable
- Minimum operational motor lifetime: 500 hours
- Minimum dust pick up on carpet (dpuc): 0.75
- Minimum dust pick up on hard floor (dpuhf) : 0.98
- Key components can be replaced
- The vacuum cleaner must be airtight from the in port to the exhaust port

Insights

- 2/3 of discarded vacuum cleaners still work or can easily be repaired
- People think that the repair cost of a vacuum cleaner is to high
- Vacuum cleaners are discarded if just a single component fails.
- Future EU legislations for repair is set for the near future
- The required time and effort of disassembly and reassembly are too demanding
- It is difficult to diagnose the failure
- Repair initiatives are becomming more trending

02

MARKET

This phase describes the research that has been done in order to understand the current vacuum cleaner and repair market, to determine whether there is a gap in the market. Additionally the phase introduces the case company, and researches the positioning that gives the company the best prerequisites for a product launch of a vacuum cleaner with repairability as the main focus. The phase ends by narrowing down the design strategies, as well as updating the design brief.

MARKET INVESTIGATION

Prior research and investigations done by the design team has framed the problem area and made it clear that there is a need for a vacuum cleaner that consumers can repair on their own. The market of vacuum cleaners was investigated to understand the potential and anticipated gap for vacuum cleaners that are “easy to repair”.

A quick market investigation in the sustainable vacuum cleaner market was made to understand the sustainable market and identify a potential gap. This market analysis shows that most vacuum cleaners are sustainable because they either use recycled material or are energy efficient. A few vacuum cleaners that promoted themselves as being easy to fix were also found. The Lupe Pure vacuum cleaner especially seemed promising in this category. However the team does question if “normal” consumers are actually able to repair this vacuum cleaner on their own.

09 Market investigation

Lupe pure

Besides excellent suction efficiency, the Lupe Pure is also branded as an unfashionably long lasting vacuum cleaner with easy replaceable parts. Their mission is to make technology stand the test of time and make upgrades available for the battery and motor when new technology comes along

Are “normal” consumers able to repair the Lupe pure?

Since the Lupe Pure is promoted to be easy to repair, it is investigated if “normal” consumers are able to repair this vacuum cleaner on their own or if this “easy to repair” only applies to professionals. A repair video of the Lupe Pure was shown to five people (app 5). They were asked to state their opinion on whether or not they would repair this vacuum cleaner if they had to go through the same steps as shown in the video or if they would buy a new vacuum cleaner.

“ I AM NOT GON-NA FIDDLE WITH THE ELECTRONICS THERE, I DONT HAVE THE KNOWLEDGE ”

- Christian

“ I AM NOT SURE I WOULD BE ABLE TO IDENTIFY THE ERROR, I WOULD NOT KNOW WHAT TO REPLACE ”

- Mads

All participants stated that they would have a very hard time identifying the error. They didn't have the required knowledge, and were not comfortable fiddling with the electronics, especially the cords and the board. Though some stated that they would be confident in changing bigger parts. The process of repairing the vacuum cleaner also seemed like a big hassle to the participants. Some even stated that the thought of repairing the vacuum cleaner would not occur to them. The result of this led to all participants opting for a new vacuum cleaner instead of a repair.

“ I DONT HAVE THE TOOLS SO THAT WOULDN’T BE ANYTHING I WOULD BE DOING AT HOME ”

- Johanne

10 User repair investigation

French repairability index

It was brought to the design team's attention that a repair index (rating how easy a product is repaired) is set for all products sold in France. This index and the top ranking vacuum cleaners were investigated to determine any market competitors (app. 6).

In 2021 the French government implemented a mandatory repair index on electrical products. This measure was implemented in order to reduce the amount of e-waste and increase the amount of products that are repaired. This index score has to be visible to the consumers at the time when they buy the product. The index score is mandatory on nine types of electrical products including vacuum cleaners. With this measure they are making the consumers aware of the repairability of the products upon purchase.

The rating is based on 5 different criterias:

1. Availability of documentation
2. Dismantling, access and tools
3. Availability of spare parts
4. Spare parts prices
5. Criterion specific to the category of equipment concerned

The five criterias take both consumers and professional repairers into account except for the second criteria (Dismantling, access and tools)

Each score of the criteria is defined by the Ministry of Ecological Transition and is applied to the products by the manufacturer.

For one of the top ranking vacuum cleaners the scores has been defined as 8,6 (app 6):

BOSCH BCH3K2851 CORDLESS VACUUM CLEANER

Brand	**Bosch**
Model reference	**BCH3K2851**
Calculation date	**09/13/2022**

8,6 /10
INDICE DE RÉPARABILITÉ

11 French repairability score on Bosch vac

Investigating top product on the repairability index

12 Youtube video of a repair process of Bosch BCH3K2851

Investigating the Bosch BCH3K2851 cordless vacuum cleaner made it clear that the top rated vacuum cleaners doesn't mean that they are easily repaired by the consumer. A repair video of this model showed that you both need professional knowledge and professional equipment like a soldering kit to repair the vacuum cleaner. Additionally the products also had visible cords and electrical components which the team know that consumers do not dare to fiddle with (app. 5). Because of this the team finds the index insufficient even though some criterias also include consumers.

This market investigation and competing product analysis showed that there is a gap in the vacuum cleaner market and a need for a vacuum cleaner that can easily be repaired by the consumers themselves. Consumers do neither have the knowledge to identify the error nor to repair any vacuum cleaners on the market as of right now.

- Must be able to repair the product without the use of tools
- The electrical components must not be perceived as dangerous
- People are afraid of unknown electrical components
- People do not have the knowledge to identify the error
- People don't have standard tools

MARKET TRANSFORMATION

To understand the vacuum cleaner market and how it has transformed, a desktop research was done. This was initially done to choose a type of vacuum cleaner.

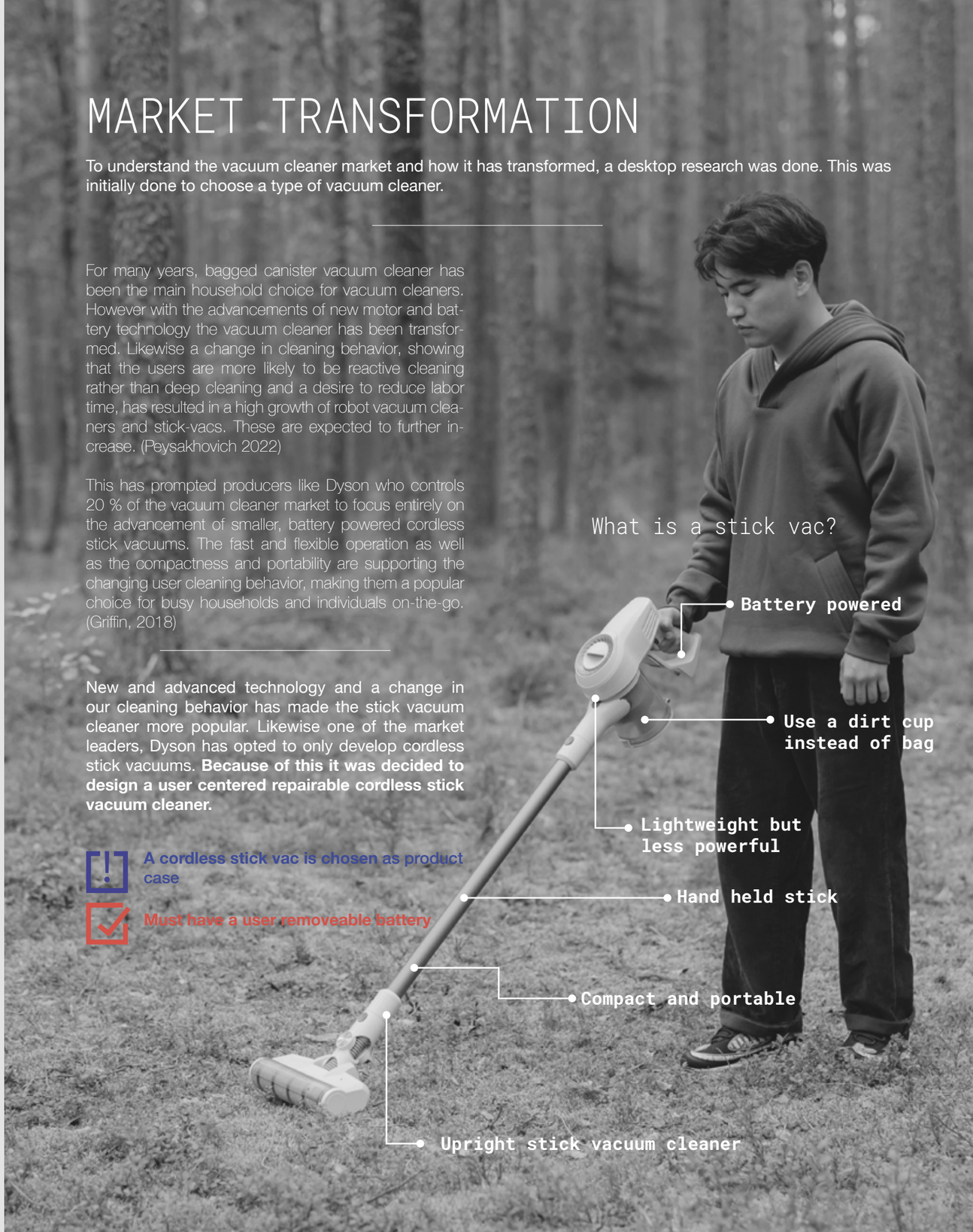
For many years, bagged canister vacuum cleaner has been the main household choice for vacuum cleaners. However with the advancements of new motor and battery technology the vacuum cleaner has been transformed. Likewise a change in cleaning behavior, showing that the users are more likely to be reactive cleaning rather than deep cleaning and a desire to reduce labor time, has resulted in a high growth of robot vacuum cleaners and stick-vacs. These are expected to further increase. (Peysakhovich 2022)

This has prompted producers like Dyson who controls 20 % of the vacuum cleaner market to focus entirely on the advancement of smaller, battery powered cordless stick vacuums. The fast and flexible operation as well as the compactness and portability are supporting the changing user cleaning behavior, making them a popular choice for busy households and individuals on-the-go. (Griffin, 2018)

New and advanced technology and a change in our cleaning behavior has made the stick vacuum cleaner more popular. Likewise one of the market leaders, Dyson has opted to only develop cordless stick vacuums. **Because of this it was decided to design a user centered repairable cordless stick vacuum cleaner.**

A cordless stick vac is chosen as product case

Must have a user removeable battery



13 Man with stick vac

NILFISK

A collaboration between Nilfisk and the design team was established to design for a more realistic design case and gain inside knowledge. This section investigates Nilfisk as a company, their design strategies and their position in the market.

Who is Nilfisk?

Nilfisk was founded in 1906 with a vision of producing products in the highest quality. Nilfisk are best known for their cleaning equipment and have through the years proven to be innovative in this category. In 1910 they developed and patented the first electrical vacuum cleaner in Europe and revolutionized the way we clean. Today the company is a global leader in professional cleaning equipment. They have always been and still are today, committed to develop and deliver innovative cleaning solutions to the market. Today they promise to make cleaning easy.

Nilfisk are determined to work towards a sustainable business but for now they have mainly focused on reducing water, energy, and the need for cleaning agents.

NILFISK BRAND PROMISE

CLEANING MADE SIMPLE

Visit at Nilfisk

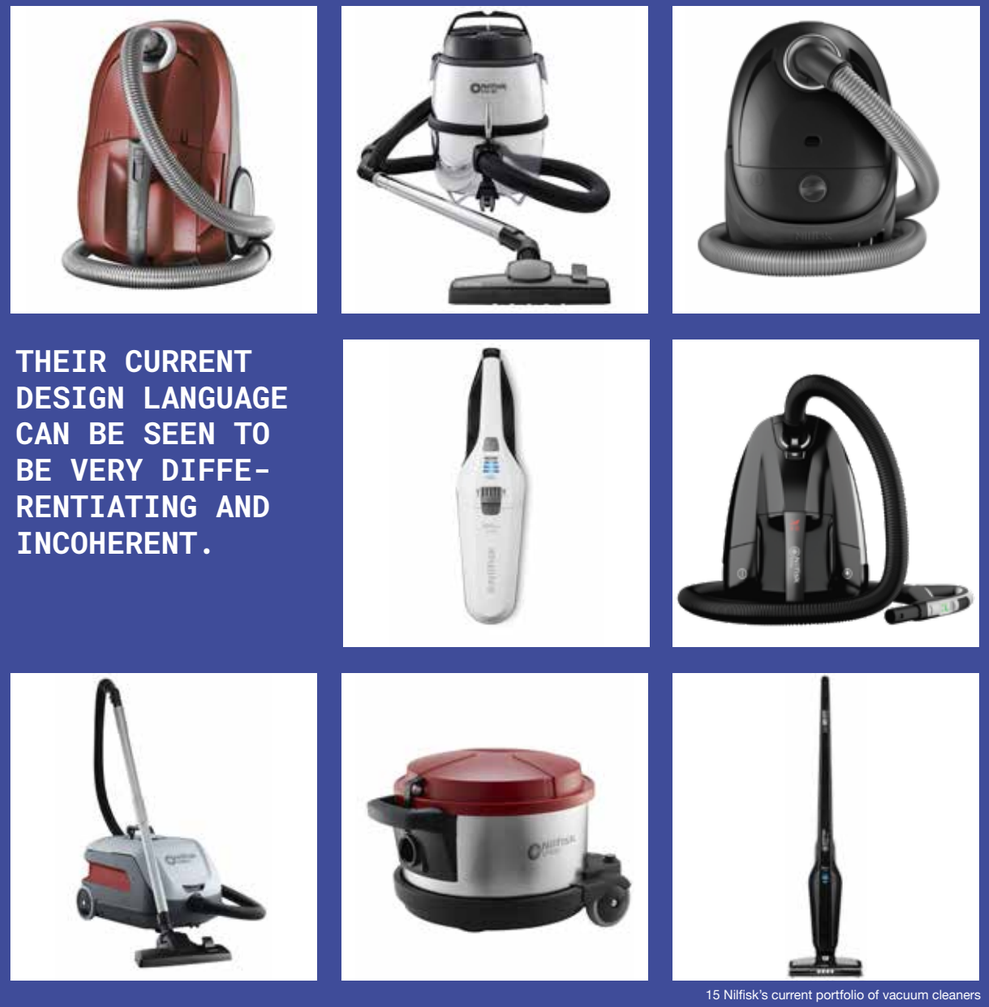
In order to get a first hand understanding of Nilfisk's inner workings, a field trip to Nilfisk headquarters was organized, where a meeting with Kristian, product manager for consumer vacs and Cleas, product manager for commercial vacs was set up.

Kristian and Cleas helped shed some light on internal processes that might indicate the future direction for Nilfisk. They said that stick vacs are on the rise. For a long time robotic vacuum cleaners have been hyped, but a shift in our cleaning behavior and the need for a quick and convenient cleaning option has caused the demand for stick vacs to rise. People keep clean, they don't deep clean. Their primary target group for stick vacs are families with young children. The current Nilfisk stick vac model will be discontinued due to the new battery regulations that will become effective in 2026. Because of this, a new stick vac is under development. This model will include cyclone technology to separate dust, they state that this is the future.

In regards to the repairable agenda, they are highly aware of its importance and its inevitability in their products, but questioned how it should be handled. They indicated that they could either be dictated by the political pushes that would eventually come, or become market leaders and push the agenda forward. They stated that design for repairability will require a culture change and developing a product that can be easily repaired wouldn't necessarily change the consumers behavior.

14 Visit at Nilfisk headquarter in Hadsund

Additionally, with their new product launch, they are also working on a new design language across their product portfolio. A lot of their current products have been developed by companies bought by Nilfisk, because of this they do not have a coherent design language across their product portfolio. However a new task force has been assigned to create a coherent design language across their new products. Their future design will focus on simplicity and minimalism combined with quality and durability. New products will be based on the consumers needs and have a homey, less tool-like design. They stated that their coming products would stand out from their previous products.



THEIR CURRENT DESIGN LANGUAGE CAN BE SEEN TO BE VERY DIFFERENTIATING AND INCOHERENT.

15 Nilfisk's current portfolio of vacuum cleaners

After the visit at Nilfisk the team decided to comply with the new design strategy that Nilfisk has created for future products, incorporating simplicity, quality and durability.

- Must use cyclone dust filtration
- The design will be driven by simplicity, quality and durability

MARKET LEADER MAPPING

Different brands have focused on different areas of innovation in order to stand apart in the market of stick vacuum cleaners. A market mapping (app. 7) of all the market leaders in the stick vac market was made, to understand how to position Nilfisk and market competitors.

Dyson

Dysons core is built upon engineered new technologies. They show scientific ways to obtain a deeper cleaning with patented new technologies like their dual cyclone filtering, digital high speed motor and laser mouthpiece incorporated in their smart stick vacs.

Miele

Miele targets the consumer's cleaning behavior. Their triflex stick vac is a multifunctional 3 in 1 patented design that suits all cleaning requirements. Miele has likewise been focusing on having spare parts available for a minimum of 10 years.

Electrolux

Electrolux uses recycled plastic in a lot of their vacuum cleaners. They promote efficiency both when cleaning and in regards to energy due to their built in auto mode.

Bosch

Bosch state that their stick vacs are as efficient as a canister vacuum cleaner because of their new and improved battery, motor and mouthpiece. Likewise they promote cleaning efficiency because of their various accessories choices that offer cleaning on different surfaces.

Hoover

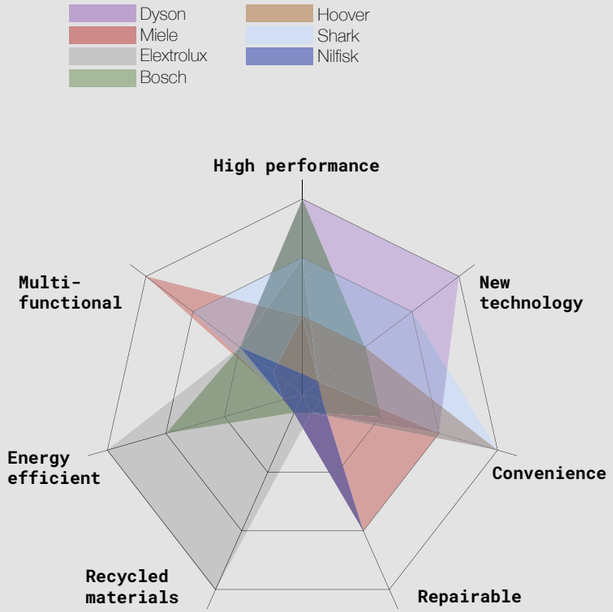
Hoover offers optimal user convenience with a 120 minute battery capacity and an innovative extra maneuverable mouthpiece.

Shark

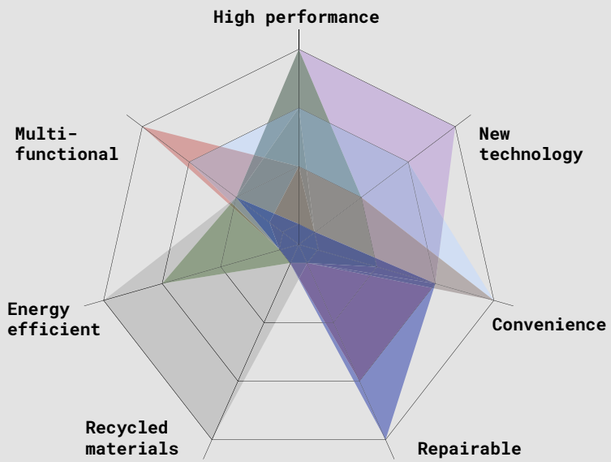
Shark also promotes a smart stick vac detecting small dust particles for a deeper cleaning. They offer flexible stick vacs for easy access underneath furniture making it a more convenient experience.

Nilfisk

Nilfisk Has taken innovative steps into repeatability with their VP600 which is the first vacuum cleaner that has user oriented interchangeable components. Their stick vacs features user convenience with their 2 in 1 design.



16 Current market position of Nilfisk

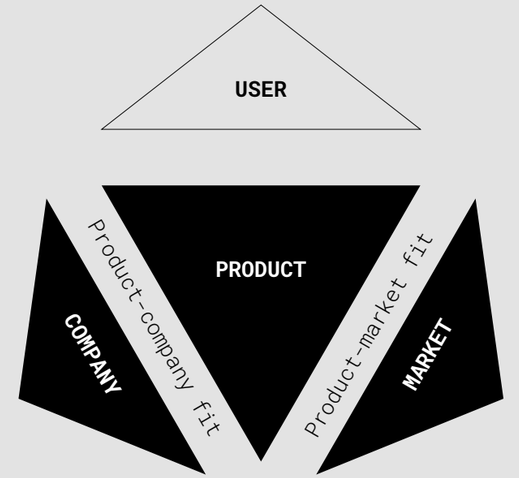


17 Suggested future market position of Nilfisk

Currently Nilfisk only has one stickvac on the market scoring very low on innovation and price compared to market competitors. Multiple areas of the stick vacuum market are occupied by several competitors, however user repairability leaves a major gap in the market. Even products with the highest repairability scores aren't designed for user centered repair. This leaves an opportunity for Nilfisk to fill this gap in the market. Nilfisk could have the necessary ability, knowledge, and experience to enter this market successfully, based on the market mapping.

Strategic fit

An innovative stick vac with user centered repairability is a great fit for Nilfisk as they have proven to be an innovative company with a focus on sustainability. The team believes that this could be a great way to differentiate from market competitors and create a long-term market advantage if they become market leaders of repairable stick vacs. Likewise it would also enhance the strengths of the company because it aligns with their company values and core competencies.



18 Strategic fit of a repairable stick vac

Product-company fit

Nilfisk have already made repair initiatives with the VP600

They are determined to work towards a sustainable business

They have a history of market leading innovations

Product-market fit

A possibility to become market leaders on repair

Differentiate from market competitors

Create market advantage as no other company offers this

Based on the analysis of market leader vacuum cleaner companies and the strategic fit model it is clear that Nilfisk is a great fit for the desirable user centered repairable vacuum cleaner.

Nilfisk is chosen as a business partner

CONCEPT

Based on the gathered insights and set criterias for the user centered repairable stick vac new approaches were considered and investigated. These approaches had a focus on a product architecture that allowed for easy access to key components and hiding “dangerous” electrical components.

Clustering the pool of drawings showed 3 different ways a product architecture would allow for easy access to key components:

Internal modular components

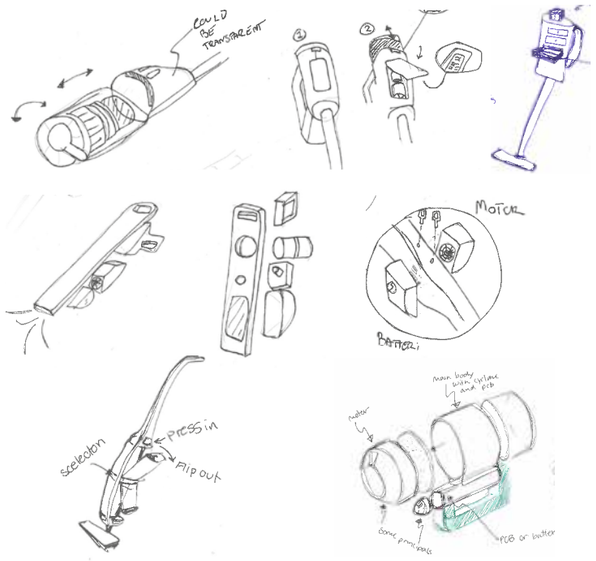
The core components are integrated into a modular casing that are placed inside the vacuum cleaner, that can easily be opened for.

External module components

The core components are integrated in modular casing that can then be attached to a core frame which will activate their function.

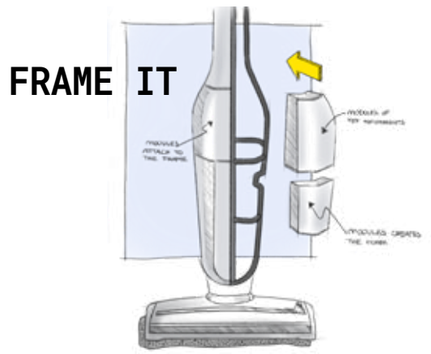
Internal external modular components

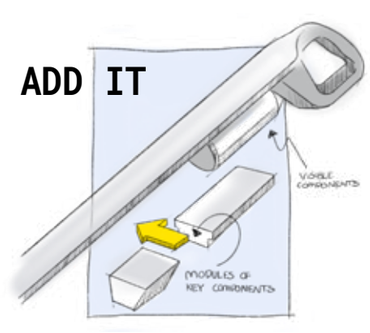
The core components are integrated into modular casing that can then be attached to a frame element. Once all the components are integrated into the frame, the vacuum cleaner will take form.



With the main purpose of creating less waste, the idea of creating components that could be packaged into modular cases, just to be integrated into another case seemed redundant, creating more material than necessary.

Based on this assumption, two design strategies were chosen, one where the modules would be inserted into a frame inorder to create the form of the vacuum, and one where the modules would be inserted into a main platform.





In order to focus on a single product solution it was clear that the design team needed more knowledge about what the user would hook on in a repairable vacuum cleaner design.

DESIGN BRIEF

Problem statement

“How can a future proof vacuum cleaner with user centered repairability and upgradeability be designed”

Requirments

The product must be upgradeable

Minimum operational motor lifetime: 500 hours

Minimum dust pick up on carpet (dpuc): 0.75

Minimum dust pick up on hard floor (dpuhf) : 0.98

Key components can be replaced

The vacuum cleaner must be airtight from the in port to the exhaust port

Must be able to repair the product without the use of tools

Must have a user removable battery

Must use cyclone dust filtration

Insights

2/3 of discarded vacuum cleaners still work or can easily be repaired

People think that the repair cost of a vacuum cleaner is to high

Vacuum cleaners are discarded if just a single component fails.

Future EU legislations for repair is set for the near future

The required time and effort of disassembly and reassembly are too demanding

It is difficult to diagnose the failure

People are afraid of unknown electrical components

People do not have the knowledge to identify the error

People don’t have standard tools

Design criterias

The electrical components must not be perceived as dangerous

The design will be driven by simplicity, quality and durability

03

USER RELATION

This phase defines the target demographic as well as describs the research that has been done in order to understand the users relation and needs. This is compared with product opportunities in regards to users and stick vacuum cleaners and their repairability. The phase ends with the first concrete product proposal and an updated design brief. I

USER INVESTIGATION

To secure a great product-user fit, and make sure the vacuum cleaner will fulfill their needs, wishes and aspirations, knowledge about the specific target group was evident.

Specifying the target group

The target group is “People on the go” as they are the primary customer of the stick vacs. The stick vac compliments the spot cleaning behavior and the fast paced lifestyle of people on the go. A large number of people on the go are represented by families with small children. However they can be found across different age groups and genders. People on the go are characterized by wanting to do a lot of stuff at the same time and they never feel like they have enough time. For that reason they prioritize convenience and products that don't require much effort.

The needs, wants and aspirations that fit the specific target group were investigated with user interviews. The purpose of the interviews was to gain knowledge about the users relation to their vacuum cleaner and what they value. This knowledge is essential in order to design for a user centered vacuum cleaner. Seven people were interviewed (app 7).

People are attached to the function of the vacuum cleaner

The design team did put forward a hypothesis that with the current hype of Dyson stick vacs, vacuum cleaners have become a high engagement product such as Smeg refrigerators and Kitchenaid mixers. However the interviews showed that this is not evident and people are mainly attached to the function and the practicality of their vacuum cleaner. Likewise a lack of function would cause them to buy a new vacuum cleaner.

“I THINK I MIGHT HAVE TO REPLACE IT IF WE MOVE IN TO SOMETHING BIGGER, AFTER THREE YEARS THE BATTERY DO NOT LAST FOR 45 MINUTES ANYMORE” - Lasse

People do not want to showcase their vacuum cleaners and even Dyson stick vacs are stored in closets or utility rooms.

19 Storage of Dyson stick vac

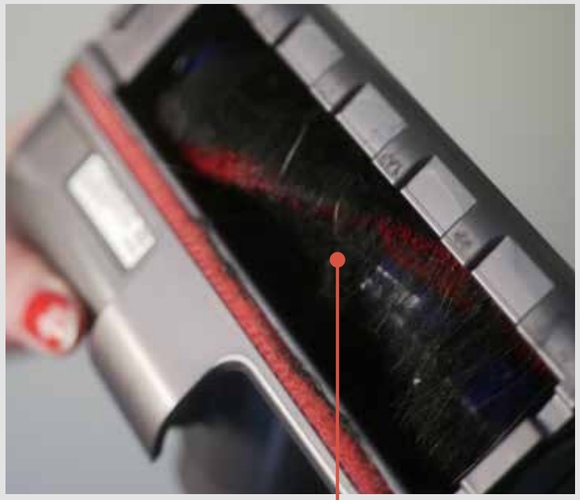
“I WOULD HIDE IT, NO MATTER HOW PRETTY IT IS, AND THEN APPRECIATE THE DESIGN WHEN CLEANING” - Lene

and they prefer cleaning that is quick easy and effortless

However it became clear that even though they prefer that the vacuum cleaner is hidden away they still want it to be easily accessible. Most participants vacuum their home once or twice a week, but problem areas are vacuumed more often. The cleaning time is kept to a minimum and they do not prioritize using time on swapping out different attachments and accessories for their vacuum cleaner.

"I VACUUM THE ENTIRE HOME ONCE A WEEK, BUT IF THERE IS A PROBLEM AREA SOMEWHERE I QUICKLY HOOVER THE SPOT" - Lasse

20 Dyson acessories



21 Hair caught in brush

They maintain when necessary but do not repair

None of the participants stated that they have done a repair on the vacuum cleaner. They do not repair their vacuum cleaner as they are discouraged because repair success isn't guaranteed due to a lack of knowledge. However the investigation also showed that all participants actually do repair their vacuum cleaner, but they categorize it as maintenance and not as a repair.

"IT HAS SMALL WHEELS UNDERNEATH THAT ACTUALLY GETS CAUGHT IN LONG HAIRS WHICH CAUSES THE WHEELS TO GET STUCK AND THEN I HAVE TO CUT IT WITH A SCISSOR" - Rasmus

---

The user interviews provided great insights in to the users relationship and use of a vacuum cleaner. Vacuum cleaners are not a high engagement product but the aesthetics are still important. However the functionality is most essential. Repair of the vacuum cleaner has to be as easy as maintenance of the vacuum cleaner.

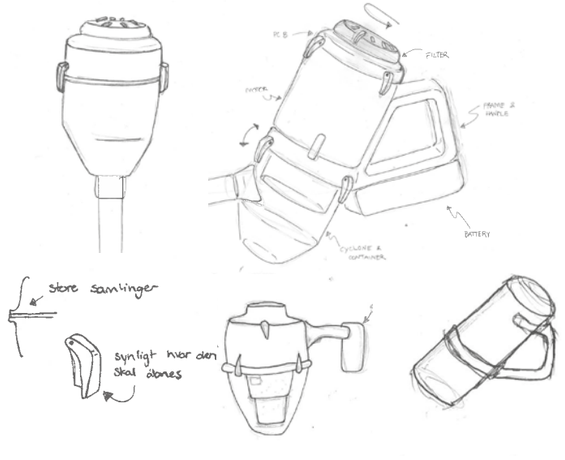
- Must be grab and go
- A lack of function will cause people to discard their vacuum cleaner
- People spot clean
- People do not use all their accessories
- People maintain their vacuum cleaner but they do not "repair" them

PRODUCT PROPOSAL

With the knowledge gathered from the user investigation a product proposal that fits both the users, market and company were developed.

The principles of the prior product proposal that is built of key components were further investigated. Key components and other core components that would make up the vacuum cleaner were considered in order to match these up and connect them to each other.

Based on an analysis of the vintage Nilfisk vacuum cleaner, it was clear that a lot of the aesthetics and functional values from the old vacuum cleaner could be utilized in a modular stick vac that would be as easy to repair as maintaining your vacuum cleaner. These principles were then developed into a stick vac setup.



22 Nilfisk G70

The product is centered around the handle component that acts as a frame. The remaining components will be attached to the frame via hinges. Based on the feedback from Nilfisk, they wanted their future products to look less tool-like. Because of this the battery is attached to the back of the "cylinder" instead of the bottom of the handle, which makes products look very tool-like.

The vacuum cleaner was designed to fit Nilfisk by bringing back values and old heritage with attachment principles that are very easy for the user to understand. However feedback on the vacuum cleaner made the team question if the product was looking backwards instead of presenting a new set of design principles that fits the future way of designing products made for repair.

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People don’t have standard tools

People spot clean

People do not use all their accessories

People maintain their vacuum cleaner but they do not ”repair” them

A lack of function will cause people to discard their vacuum cleaner

Design criterias

The electrical components must not be perceived as dangerous

The design will be driven by simplicity, quality and durability

Must be grab and go

This phase explores the important perspective of repair. The phase shows the scenario of going through a repair from start to end by shadowing repair experts and development of target specific repair behavior and expert knowledge. The phase ends by culminating the gathered knowledge into a new product proposal and a finalized design brief.

REPAIR

04

REPAIR STEPS

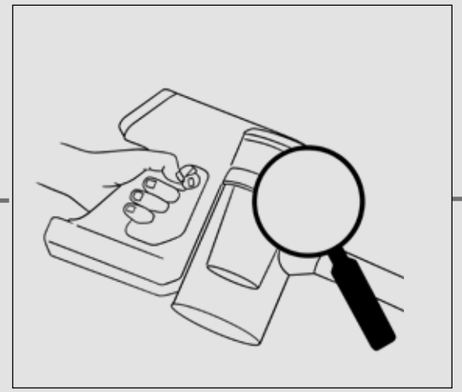
To understand the repair process and the situations where the consumer decides to buy a new vacuum cleaner instead of repairing their current failed product the five repair steps were analyzed.

The repair process of a vacuum cleaner will differ from situation to situation, however Bracquené et. Al (2018) has described the repair process in 5 steps that the user must go through from failed product to repaired product.

Step 01

Product identification

The first step is to identify the product model, this is done in order to retrieve the needed information, such as disassembly instructions, failure diagnostic guides and if available, spareparts.



Step 02

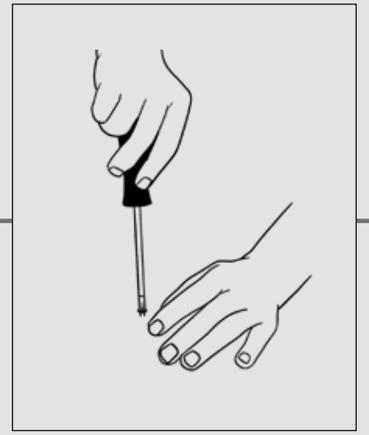
Failure diagnosis

The next step is to diagnose the failure and to consider the repair action needed. Is it necessary to replace a part?

Step 03

Diasassembly/ reassembly

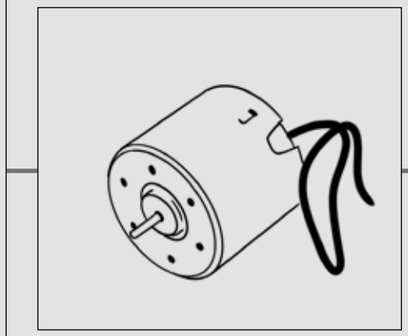
To acquire the broken components it is often necessary to disassemble the product, and, after the product has been fixed, to reassemble it again.



Step 04

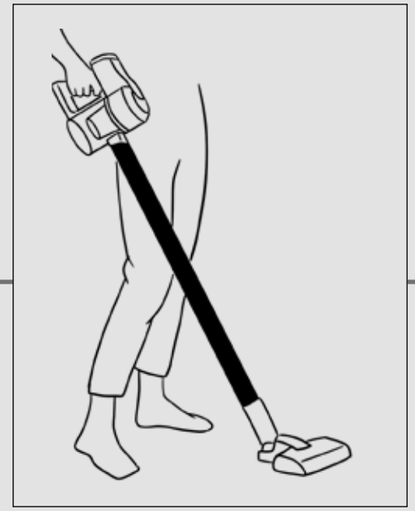
Replace spare part

The fourth step is to replace the broken part.



Step 05

The last step is to restore the product to working condition. In many cases this requires testing or resetting of the product.



In order to repair a product all of these steps must be performed. If any of the steps are not performed by the consumer the team believes the vacuum cleaner will be declared obsolete and swapped with a new vacuum cleaner.

Nielsen et. Al (2023) has been investigating critical repair steps for electro mechanical products such as vacuum cleaners. This research is conducted in repair cafe's in Denmark and investigates fixers. Repair of electromechanical products are particularly difficult because of the complexity of the products and often need a collaborative repair between more fixers. The most critical step for electromechanical products was found to be diagnostic (step 2). This is critical because it is often difficult to know what part is broken as motor exhaustion often causes other components to fail. Faults often occur due to a lack of maintenance. Electromechanic products faced one of the lowest percentages of repair, however static products faced a much higher rate. This is due to a lower complexity that is easier to decode by consumers and fixers having the sufficient skills to conduct the repair.

Repair cafe

"Repair Café Denmark" is a voluntary organization that accommodates common consumers who don't have the knowledge or tools to repair their own devices. For this very reason, Repair Café Denmark has created repair cafés across Denmark. At the repair café citizens bring their broken devices and receive help by voluntary 'fixers'.
A visit to the repair café in Aalborg was conducted in order to gain knowledge from the fixers' experiences first hand and to gain knowledge about the visitors' challenges.

Visitors seek help at repair cafes as they gain confidence in the repair when they have support from fixers.

Fixers experience that people do more harm than good when they try to repair products at home with no guidance.

23 Visit at repair cafe

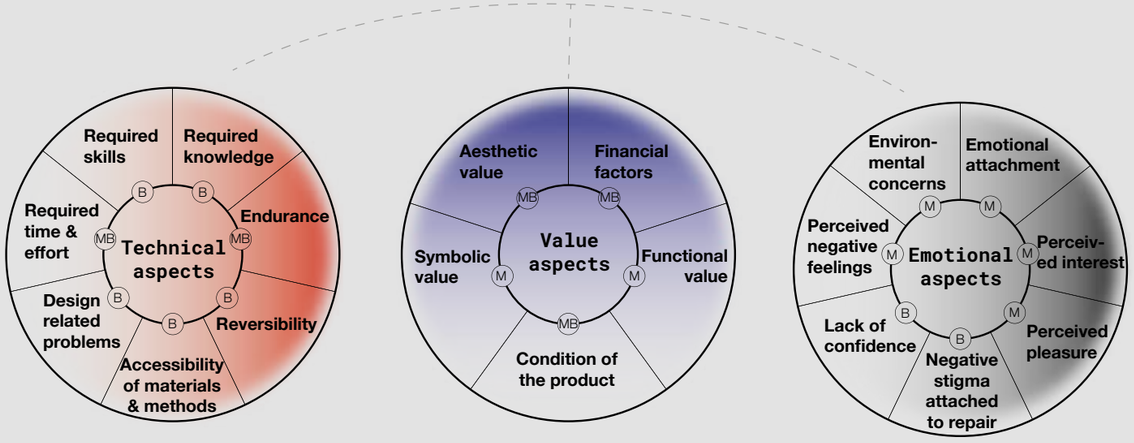
This investigation and research shows that diagnostic of failed components in a vacuum cleaner is the most critical step of the repair process. Likewise static products that are easier to decode and have lower complexity face higher repair rates.

- The design of the product must elevate the users skills and knowledge required for repair
- The most critical repair step for electro mechanical products is diagnostic
- Repair without sufficient knowledge and skills can cause additional damage to the product

REPAIR BARRIERS AND MOTIVATORS

Multiple barriers can be identified across the repair steps but how are users motivated towards a repair? These motivators and associated barriers are identified in order to narrow the problem space.

Nazli Terzioglu (2021) has been exploring the user's perspective on product repair and gathered these in a repair motivation and barriers model. 19 categories were identified, all having an impact on the users decision to repair a product. Some categories were identified as both a motivator and a barrier.



24 Repair Motivation & Barriers model

Investigating the repair motivation & barriers model showed repair barriers and motivators for the generic consumer however it became apparent that the design team needed to investigate what barriers and motivators are most apparent for our specific target group in order to prioritize.

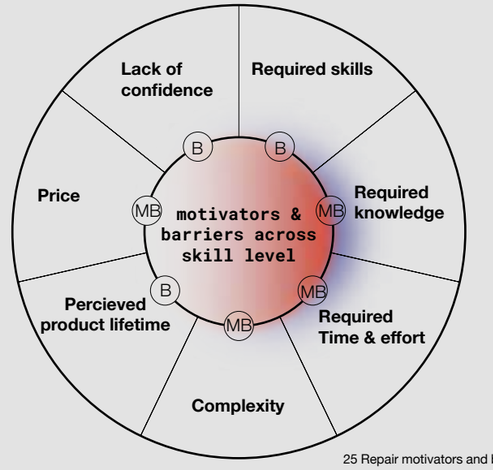
Investigating repair barriers and motivators

An investigation of repaired products across 10 participants was conducted (app 9.) The participants were clustered in three groups based on the required skills needed for making the repair of their products. Motivators and barriers were retrieved from the three clusters

Products that the participants had repaired on their own had several similarities but their skill level also showed to play a role. All participants had repaired a low complex static product such as clothes and furniture however high skilled participants threw themselves into more complex repairs such as computers and playstation controllers. Across all skill levels participants told that they wanted to use the minimum time and effort possible, as they live a busy life with small kids. They appreciate products that are easy to decode and they use their senses, hear, see or smell, to diagnose failures. Likewise even skilled people appreciated a low complex repair that was easy to conduct. All participants also expressed that they have a conviction that products do not last for many years. Skills and knowledge was a major barrier for low to middle skilled people but was not that apparent for highly skilled people.

Low skilled	Middel skilled	High skilled
Barriers		
Confidence	Knowledge & skills	Time
Knowledge & skills	Complexity	Effort
Complexity	Time	Break of warranty
Time	Price	Conviction that products do not last for many years
Price	Conviction that products do not last for many years	
Conviction that products do not last for many years		
Motivators		
Price	Easy to conduct	Easy to conduct
Easy to conduct	Easy to decode	Easy to decode
Easy to decode	Environmental concerns	Preserve the function
Fit their skill level		

Across all skill levels the motivators and barriers can be gathered in the following model. Two new categories were found to play a part. The level of complexity was both a motivator and barrier as products that was easy to conduct and easy to decode was seen as low complexity and high complexity was a barrier (see illu. 25-29).

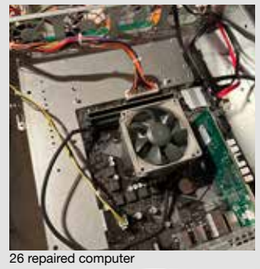


25 Repair motivators and barriers for our user

A product of low complexity, that is easy to decode and where the users are able to use their senses to diagnose failure seemed to have a higher likelihood of being repaired when broken.

- The user must be able to use their senses to diagnose failure
- The product should have low complexity
- People use their senses to diagnose failure in a product
- People's perceived product life time is very low

High complexity



26 repaired computer

27 Repaired coffe machine

28 Replaced wheels

29 Hole sewn

30 Glued on hand

Low complexity

WHY DO VACUUM CLEANERS NEED REPAIR?

An interview with head repairer at CJ Service Steen was interviewed to gain knowledge about the repair of vacuum cleaners and why they even break.

The main cause of failure in a vacuum cleaner is due to overload of the motor. This simply happens when consumers do not maintain or they misuse their vacuum cleaner. A lack of maintenance and misuse is the cause of the majority of failed vacuum cleaners that are handed in.

"MOST OFTEN WE SEND THEM AN OFFER ON A CLEANING OF THEIR VACUUM CLEANER" - Steen

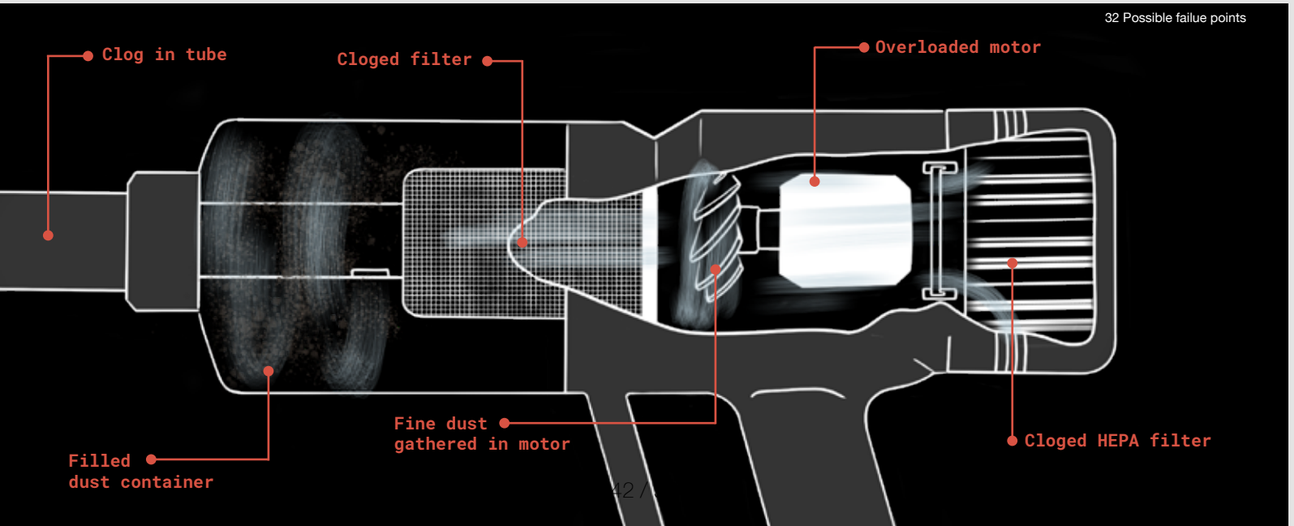
If a vacuum cleaner is not maintained such as emptying the dust container, cleaning the mouthpiece from hair, checking for clogs in the tube or changing the filter, this will stress the motor. The same is applied if a vacuum cleaner is used to clean up construction dust. Because of the small dust particles the dust will pass right through the filters and accumulate in the motor and this will stress the motor.

31 Clog in dyson stick vac

The design team got the opportunity to borrow a dyson stick vac. The owners thought it was broken and was going to send it to a repairer. However, the design team quickly diagnosed the error. It was detected that the air intake was completely clogged. Once the clog was cleared, the vacuum worked again.

The team asked Steen if it was possible to implement a HEPA filter in front of the motor, as this will filter out 99,9 percent of particles. But because of the density of the filter this will cause the air stream to heat up creating a very hot environment for the motor and causing it to fail.

The motor can handle the stress for a while, but over a period of time this will cause the motor to get hot and eventually fail. Overload of the motor can also cause the PCB to fail. Motor overload will discharge the battery faster but the battery does not fail suddenly. Diagnosing a failed motor and PCB can be difficult. An overloaded motor can sometimes be spotted before complete failure if dust or debris has been caught in the motor. The failure in the PCB can often not be diagnosed visually, only in rare cases a burned area can be spotted.



32 Possible failue points

How do professionals repair stick vacs?

Henrik from CJ service showed how he would normally tackle a repair of a vacuum cleaner. This vacuum cleaner had a mechanical failure in the casing, caused by a broken snap fix. Because the casing was not available as a spare part Henrik was not able to fix the vacuum cleaner. Because it was a warranty case the vacuum cleaner would most likely be discarded and replaced with a new one. However Henrik showed how he would tackle the repair if the vacuum cleaner wouldn't turn on. From the disassembly some trouble areas were found.

Even though Henrik is a professional, he still struggled with the disassembly where snap fixes, hidden screws and different screw heads made it a troublesome disassembly. Likewise the electrical cords made it difficult to reassemble as they had a hard time staying in the case.

33 Steen doing a stick vac repair

34 Steen doing a stick vac repair

The visit and interview with professional repairs at CJ service made it apparent that maintenance is a very important part of "repairing" your vacuum cleaner and making it last longer. The main cause of the failure is overload of the motor which has the potential to be visually diagnosed if the motor was visible. PCB is however not visually diagnosable.

Instead of only focusing on replacing and restoring parts of the vacuum cleaner the team also need to focus on maintenance of the vacuum cleaner.

Definition of levels of repair
1. Maintenance by removing unwanted debris from components
2. Replacing broken or worn part with new part
3. Restoring to working condition with or without visual change

- Motor overload must not cause any damage
- The user needs to be reminded when maintenance is required
- People do not maintain their vacuum cleaner properly
- Motor overload is the main cause of failure in a vacuum cleaner

PRODUCT PROPOSAL

Based on the interview with CJ service and investigations of repair barriers and motivators the design process developed drastically. It was now evident that the product should not only allow for repair, but also prevent the product from failure. Additionally, it needed a low complexity that is easy to decode in order for every consumer to repair despite skill level. Lastly the product should also provide the required skills and knowledge that the consumers need in order to repair.

Mouthpiece

To further reduce the complexity, the mouthpiece has a mechanical system that rotates a brush instead of a motor that is otherwise standard in stick vacs.

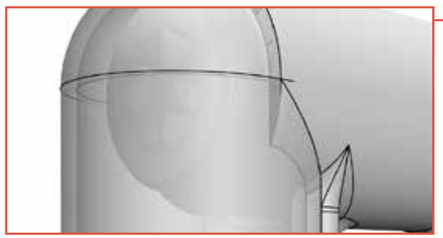
Connections

It is necessary to separate the electronic components from each other if one needs replacement. For this reason it was decided that the electronic components should be standard components with an attached modular interface that could connect together. This meant that every component could be separated, repaired and maintained but in a low complex way that “hides” the perceived dangerous electrical components, because they are covered by the modular interfaces. These connections would also allow for upgrade.

Maintenance

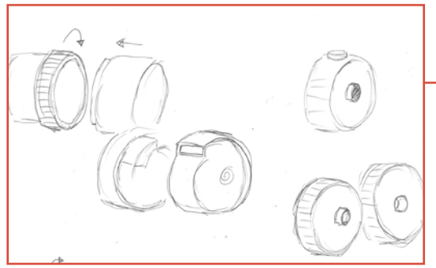
To give users the amount of maintenance knowledge necessary to avoid common failures, maintenance step guides were integrated directly onto the vacuum cleaner.

Window



As it was learned that the motor is the root of the majority of the failures, the architecture of the vacuum cleaner was bent in a 90 degree angle, making a gap between the motor and the container. In this gap, a window was implemented, so that the user had the possibility to visually see if anything would be clogging the motor and causing damage.

Connections



The connection principle that would connect the different components inside the cylinder were chosen to be a rotation fastening, due to the cylindrical form factor, taking inspiration from the way that camera lenses are connected. 3D printed models were created in order to test the fit and interaction with the retractable electronic cylinder.

Cylider

Additionally, in order to reduce the complexity of the product, it was decided to gather the different electronic components in one spot, isolating all the complexity to one area. This would in term convert all the remaining components to static components with very low complexity. In order to physically separate the electronic from the static components, the electronic components were then integrated into a retractable cylinder. This would allow the user to take out all the electronic components, separating the product into two, one of complex electronic components and one of simple static components that can simply be rinsed with water, since no electronics are present, as these would be damaged by water.

Active and passive communication

The current product proposal attempts to nudge the user into maintaining, by having the labels as an active motivator, and the window into the maintainable components as an passive maintenance motivator. If the product was still not maintained a safety system was decided to be implemented in the motor, causing it to shut off at too high temperatures. This feature was implemented as a final yell towards extra lazy users, indicating that the maintenance can no longer be postponed. Through research it was seen that this could be achieved with a bi-metal fuse, or through a motor controller of an electric brushless motor.

Knowledge

In order to provide knowledge to the userabout how a vacuum cleaner works, further increasing the likelihood of repair, the window was also extended, making it possible for the user to see all the electronics from the outside.

All these design iterations were collected in a new concept, called Nilfisk Keep, removing the emphasis of repair that “Frame it had”, and now focused on a product that would be long-lasting due to avoiding misuse, easy maintenance and in worst case easy repair.

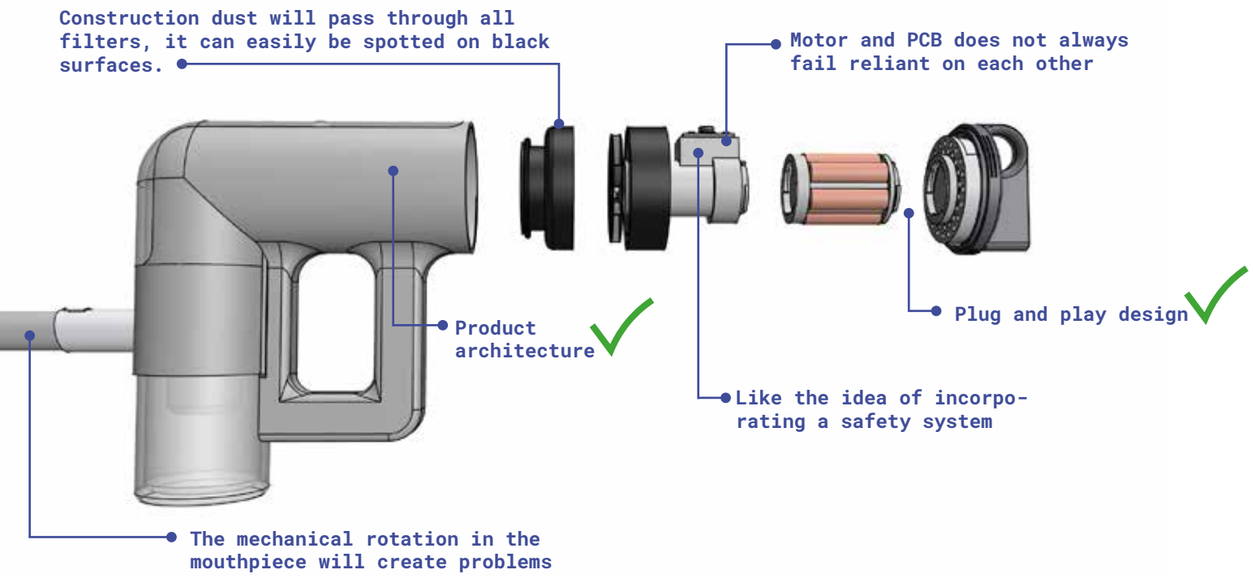
FEEDBACK ON THE PRODUCT PROPOSAL

To discover any technical critical areas of the product proposal Steen from CJ service was asked to give feedback on the proposal.

Steen saw great potential in the simple architecture and really liked the plug and play design. This structure would even make it easier for them to repair vacuum cleaners. Sten confirmed that the motor window would make it possible to immediately observe if dust has passed the filter and accumulated in the motor. However Steen mentioned that it would only be possible to blow this dust away.

Steen was very critical of the mechanical mouthpiece as vacuum cleaners have to comply with certain EU legislations for suction power. Sten mentioned that the mechanical brush driven by the wheel would require a very high gearing for it to be efficient enough.

35 Feedback from Sten



Until now the mouthpiece has not received much attention, as the design team were convinced that the most critical areas of a repairable vacuum cleaner were within the actual vacuum cleaner. However it was clear that critical areas could also be found within the mouthpiece and therefore required more attention.

DESIGN BRIEF

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Requirments

- The product must be upgradeable
- Minimum operational motor lifetime: 500 hours
- Minimum dust pick up on carpet (dpuc): 0.75
- Minimum dust pick up on hard floor (dpuhf) : 0.98
- Key components can be replaced
- The vacuum cleaner must be airtight from the in port to the exhaust port
- Must be able to repair the product without the use of tools
- Must have a user removable battery
- Must use cyclone dust filtration
- The user must be able to use their senses to diagnose failure
- Motor overload must not cause any damage

Design criterias

- The electrical components must not be perceived as dangerous
- The design will be driven by simplicity, quality and durability
- Must be grab and go
- The design of the product must elevate the users skills and knowledge required for repair
- The product should have low complexity
- The user needs to be reminded when maintenance is required

Insights

- 2/3 of discarded vacuum cleaners still work or can easily be repaired
- People think that the repair cost of a vacuum cleaner is to high
- Vacuum cleaners are discarded if just a single component fails.
- Future EU legislations for repair is set for the near future
- The required time and effort of disassembly and reassembly are too demanding
- It is difficult to diagnose the failure
- People are afraid of unknown electrical components
- People do not have the knowledge to identify the error
- People don’t have standard tools
- People spot clean
- People do not use all their accessories
- People maintain their vacuum cleaner but they do not ”repair” them
- A lack of function will cause people to discard their vacuum cleaner
- The most critical repair step for electro mechanical products is diagnostic
- Repair without sufficient knowledge and skills can cause additional damage to the product
- People use their senses to diagnose failure in a product
- People’s perceived product life time is very low
- People do not maintain their vacuum cleaner properly
- Motor overload is the main cause of failure in a vacuum cleaner

05

MOUTHPIECE

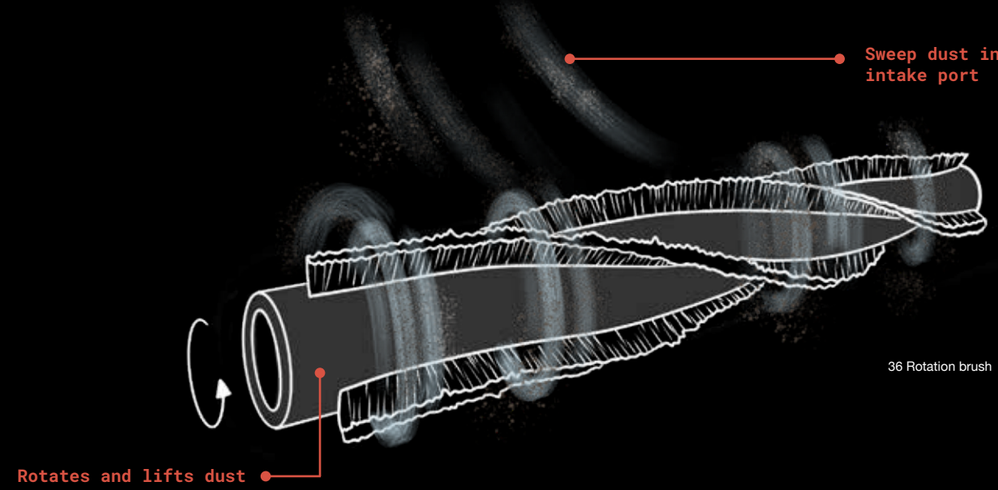
This phase describes the design process of the mouthpiece component of the stick vac. This component has shown to play a major role in the performance of a stick vac, and therefore an in depth design process has been dedicated to it.

WHY DO STICK VACS NEED A MOTOR IN THE MOUTHPIECE?

The mechanical rotation feature in the mouthpiece design faced critical feedback. However the team questioned why stick vacs have rotational brushes driven by motors.

Stick vacs are equipped with a motorized rotating brush in the mouthpiece. This is implemented to lift dust particles and enhance suction power because the motor power inside stick vacs is not that powerful compared to canister models. The rotation brush is driven by an additional motor that is connected to the main battery. This feature is essential for an optimal dust pick up.

Most stick vacs have a measured RPM (rounds per minute) between 2000-5000 in the motorized brush.



Meeting the requirements of EU legislations

According to the EU legislations the requirements for minimum dust pick up is as followed:

* Minimum dust pick up on carpet (dpuc): 0.75
* Minimum dust pickup on hard floor (dpuhf): 0.98

This is measured with a very comprehensive test where an electromechanical arm will control speed and motion of the vacuum cleaner as it passes and sucks up artificial dust. This test is performed on both hard floors and Wllton carpets. (European Commissoin 2013)

The comprehensive test will not be prioritized to be performed, however some criterias can be drawn from this investigation. If the stick vac can achieve an average RPM at 3100 on both hard floors and carpets the design team believes that the stick vac will pass the test.

- [x] Minimum of 3100 RPM on hard floors
- [x] Minimum of 3100 RPM on carpets

MAPPING OF OPPORTUNITIES

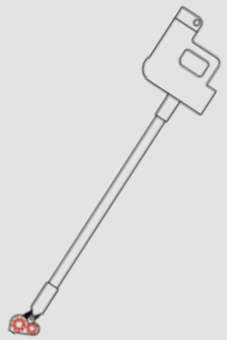
Because of the critical feedback on the mouthpiece design, different opportunities and principles of a mouthpieces design were investigated. These were afterwards confirmed or denied through testing, explorations and calculations as a result of choosing the best possible mouthpiece design.

In the early stages of the design process, the design team decided to reduce the complexity of the product as much as possible, in order to reduce the amount of components that would potentially need repair. As a result of this the mouthpiece was reduced to a purely static component by removing the motorized brush. This was done without the knowledge that this motorized brush is an essential component and a removal of this could impact the vacuum cleaners function. This creates a dilemma between a design for repairability and a design for functionality.

Complexity vs. functionality

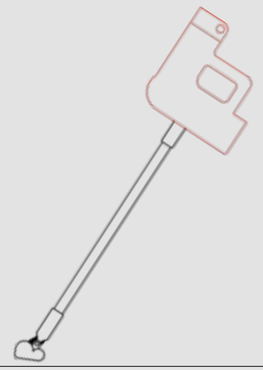
Increased complexity makes it more likely that the product will be more difficult to understand, repair and maintain, while reduced functionality and user experience makes it more likely that the user will not use the product.

As an attempt to solve this problem, several ideas and principles were drafted, in order to create a solution to the sweeping function that would not compromise either repair or functionality.



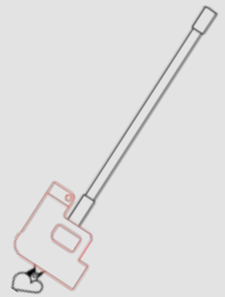
Redesigning the mouthpiece with mechanical rotation.

+ Reduces the amount of electronic components, and maintains the amount of static components.
÷ Requires high gearing to achieve high rpm.
÷ Rpm depends on the user's vacuum sweeping speed.
÷ No sweeping function when the mouthpiece stands still.



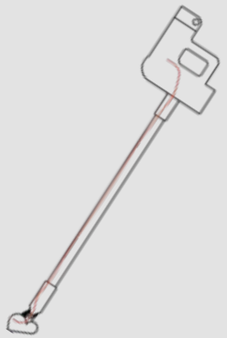
Implementing a bigger motor and battery to increase suction power, removing the need for a rotating brush.

+ Reduces the amount of electronic components, and maintains the amount of static components.
÷ Bigger motor makes more noise and requires more battery power.
÷ Bigger motor and battery increases the weight of the product, reducing ergonomics.



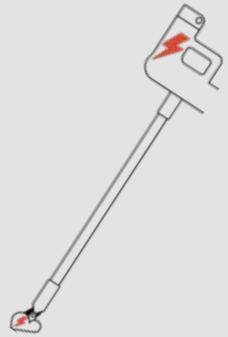
Implementing a motor in the mouthpiece and moving all other electronic components down to the mouthpiece, collecting all electronics in one place.

+ Increases the amount of electronic components, but collects them together
÷ Makes the product heavier to lift.
÷ Makes it more difficult to maneuver the product near or under objects.



Adding wiring and electronic connections all the way from the motor in the mouthpiece to the battery in the chassis.

+ State of the art suction functionality.
÷ Increases the amount of electronic components drastically.
÷ Makes it difficult to rinse parts with water, as all components will have wiring.

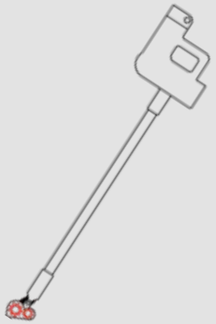


Implementing a secondary electronic cylinder in the mouthpiece, with isolated motor, battery, and charging

+ State of the art suction functionality.
+ Utilizes the same collection of electronic components principle.
+ Several of the static components remain static.
÷ Increases the amount of electronic components.
÷ Requires extra interactions to use.

These opportunities are investigated further in order to confirm or deny their likelihood to work in the design

DEVELOPMENT OF THE MOUTHPIECE



Redesigning the mouthpiece with mechanical rotation.

It was decided to take inspiration from mechanical carpet sweepers in the development of the mechanical rotation. This works by rotating the brushes by a mechanical connection to the rotation of the drive wheels. This was chosen as a solution since it didn't require electronics, but also as it seemed fitting with the idea of low and simple complexity.

Test

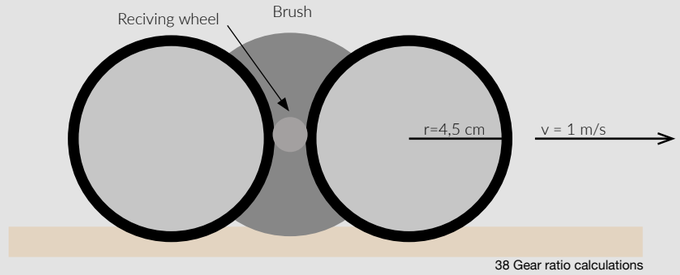
A test (app. 10) showed that the device was able to pick up the dust, but that it was required to do several passes before everything was picked up. The passes were conducted with long and fast swipes, which can't always be assured of being possible in some cleaning scenarios.

37 Carpet sweeper test

Nilfisk's technical department

A contact to Peter from Nilfisk's technical department was established to discuss the idea of a mechanical rotating mouthpiece. Nilfisk has been testing this principle and could conclude that a brush driven by the wheels was efficient on hard floors, however it was not efficient enough on carpets with long hairs.

Gearing calculations



38 Gear ratio calculations

Analyzing other vacuum cleaner designs, it was apparent that the RPM of the motor driven brushes were way higher compared to the mechanical sweeper. In order to increase the RPM, a large gearing ratio would need to be implemented. For in depth calculation see appendix 11

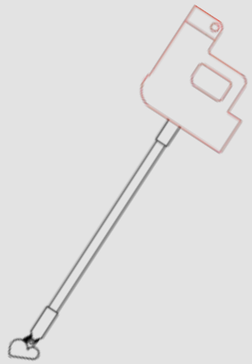
The average RPM in brushes in current vacuum cleaners is 3100. The RPM in the wheels of the sweeper is calculated to 213. The gear ratio will therefore become

$$m = \frac{3100\ RPM}{213\ RPM} = 14{,}5$$

A gear ratio of this size would mean that the receiving wheel must be 3 mm in radius in order to create the necessary RPM's in the brush. If the drive wheels are 4.5 cm:

$$\frac{45\ mm}{14{,}5} = 3\ mm$$

This calculation is dependent on the speed that the user vacuum at. If a user vacuums slower than estimated (1m/s) the output of the RPM's would decrease drastically due to the high gear ratio.

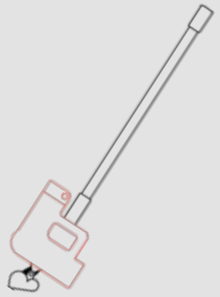


Implementing a bigger motor and battery, removing the need for a rotating brush.

For this suggestion to be realistic, the weight of the internal components must be at a range that is plausible to carry. The motor in canister models are sufficent enough to pick up dust without a rotating brush. The weight of a motor from a canister is compared to the weight of a motor and battery from a stick vac, in order to investigate if it is plausible to implement a motor that size.

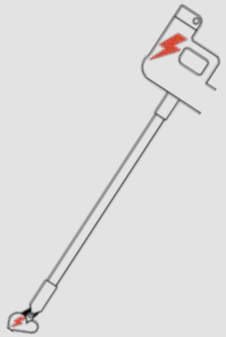
Investigation of weight

A canister motor weighs about 1300 g, while the battery and motor from a stick vac weighs about 450 g meaning that the canister motor weighs 3 times as much as the components from the stick vac. Likewise a motor with this capacity will require a very big battery adding additional weight. The design team concludes based on this that it will not be plausible to implement a bigger motor.



Moving all other electronic components down to the mouthpiece, collecting all electronics in one place.

Flipping the design on its head and transferring all the components down to the mouthpiece has the advantage of simplifying the electronic setup by collecting them together, and simply implementing a handle on the top. However, it comes with a surplus of disadvantages in regards to the grab and go mentality of the stick vac, as it becomes heavier to lift due to the weight being further away. Likewise the increased size of the bottom part makes it more difficult to maneuver the product near or under objects. The design team concludes based on this that it's not the best direction for the design.



Implementing a secondary electronic cylinder in the mouthpiece, with isolated motor, battery and charging

In order to find out if this princible was feasible a simple battery calculation was made to conclude if it would be realistic to implement an additional set of batteries or if the weight and size would make it unlikely.

Battery calculations

For in depth calculation see appendix 12. The capacity of the battery is calculated based on a motor implemented in a current stick vac. It is chosen that the capacity of the battery must allow for the motor to run for 1,5 hours. This is twice the runtime based on the average stick vac.

The motor uses 1,3 A at maximum efficiency. Meaning that the needed mAh for the battery is:

$$1{,}3\ A \cdot\ 1{,}5\ hours = \ 1{,}95\ Ah \longrightarrow 1950\ mAh$$

The motor is operational in the range of 3-6 v. An investigation of standard batteries shows a battery with 3.7 v with a range from 80-3000 mAh. This means that a single battery with 3.7 v and 2000 mAh would have enough capacity for the mouthpiece to run in 1.5 hour.

It was obvious that every solution would have some kind of compromise however it was decided that to make the decision for the design direction of the mouthpiece, more knowledge was required. Additionally, a deeper understanding of the vacuum cleaning scenario was required, as several compromises were based on user interactions.

06

CLEANING BEHAVIOR

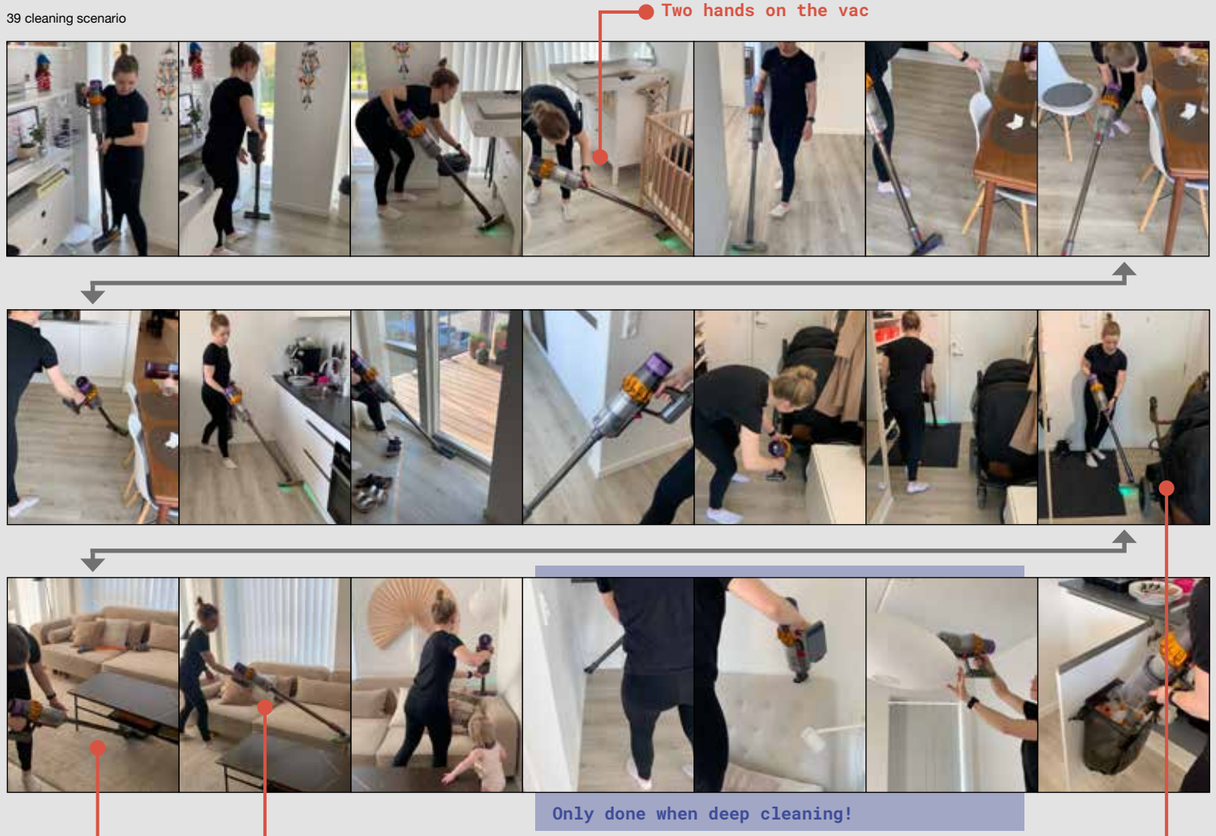
This phase introduces in depth analyses of users cleaning behavior with a stick vac, in order to get specific insight that can further develop the current product proposal.

CLEANING OBSERVATION

A lot of resources have been applied to make the vacuum cleaner easy to maintain, diagnose and repair for the user. However the team knows that consumers only keep vacuum cleaners where the functionality is great. Because of this a user observation was made, to understand and obtain insights about the user's cleaning behavior and their interaction with their vacuum cleaner, to make sure that the vacuum cleaner fit their needs.

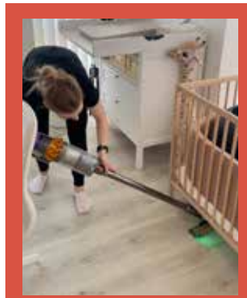
Two people in the category "people on the go" were observed vacuuming their apartment (app. 13). They were told to go through their normal routine.

39 cleaning scenario



Many important insights were observed during the user observations and a lot of them did have a big impact in the design process. The observed interaction areas will be developed separately in the following.

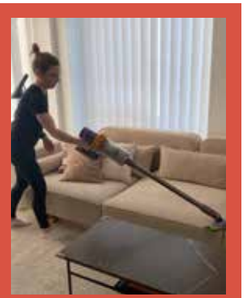
Mouthpiece



Low speed close to objects

Holding the vacuum cleaner still in corners

Using the same mouthpiece on carpets



Using the same mouthpiece on the sofa

40 Mouthpiece investigation

The user observations made it clear for the design team that having a mechanical rotation would bring challenges in the daily cleaning scenario. Close to edges and objects on the floor the participants rolled over the floor with a very slow speed. Because of this the rotation of the brush will not be efficient enough even with high gearing and therfore the mechanical brush was ruled out as an option.

The options for the mouthpiece are revisited again. The suitable options left was to add wiring or to implement a secondary electric system in the mouthpiece. Both of the solutions would bring challenges to the design however most advantages are seen with the implementation of a secondary electric system. This system adheres to the design principles of collecting the electrical components in as few areas as possible and keeping the rest as static components. It was decided to use the cylinder principle in the mouthpiece as well to gain access to the brushes and the electrical parts.

One of the challenges with the system is the required extra interactions, since users need to turn on both the electrical system in the mouthpiece and in the casing. This is solved by implementing a short range bluetooth chip in both the casing and in the mouthpiece. This will transfer information regarding if the electric system in the casing is turned on, and thus turn on the electric system in the mouthpiece as well.

The next challenge is that the vacuum cleaner now needs to be charged in two places and these two separate systems needs to be communicated to the user. This challenge will be addressed on page 61.

Furthermore, It was also confirmed that people are too lazy to switch out the mouthpiece when cleaning and they use a single mouthpiece for both hard floors, carpets and their sofa. Thus making it necessary that the mouthpiece is workable on all surfaces. Different types of brushes were investigated in order to create a versatile mouthpiece that can be used on multiple surfaces.

The brush consists of 4 brush strips, 2 with hard brushes accommodating for soft surfaces and 2 with soft brushes for hard flooring.

The brushes are angled in order to transfer the dirt to the middle of the mouthpiece where the suction is placed

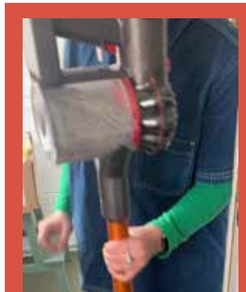
Small wheels reduces the friction on the floor making it easier to glide over.

A silicone strip will scrape the floor and capture the remaining dirt

The windows in the mouthpiece allows the user to use their visual sense to detect if any hair is stuck in the mechanism causing the brush to stop rotating.

The straight surface allows for the user to get as close to the edges as possible

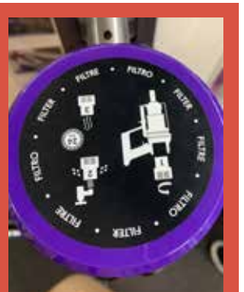
Maintaining



Very full dust container

Cloged filter

Max line on dust container



Sticker showing how to rinse filter

41 maintaining areas

It was clear that both participants did not maintain their vacuum cleaner properly.

One participant had a clogged nozzle, a dust container filled way over the capacity and had never rinsed or changed the filter. The other participant told that they had returned their vacuum cleaner because it would not turn on. The problem showed to be a clogged filter that had to be washed, and this fixed the problem.

Both participants had a Dyson vacuum cleaner with labels or screens with instructions to some of the maintenance areas. But the participants did not understand these or had never noticed the labels. This made the team question if the maintenance labels on our vacuum cleaner would be noticed properly. Because of this the labels were tested.

Labeltest

In order to test the maintenance guide, labels were glued onto the physical prototype (app 14). The intention was to have users perform an act-out of vacuum cleaning, and then informing them that the vacuum cleaner suddenly stopped working, thus prompting them to figure out what is wrong and hopefully use the guide to get it back to working conditions.

42 Participant from usertest

The test concluded that the users didn't look for the labels when needed. However, it showed that the labels worked as intended, once the users noticed the labels.

Based on the test feedback, the design team discussed two possible directions to accommodate this problem. The maintenance steps could be made bigger and more eye-catching, making the user more likely to see them, or something could indicate the user to look for them once they are needed.(app 15).

The design team chose to go with the ladder. An internal LED was integrated, that would light up a "Start maintain steps" label, incase the bi-metal fuse would activate. This would create an eye-catching nudge to find the labels once needed.

The labels have been moved to be more visible from the field of view when vacuuming. The labels have been integrated on both sides of the vacuum cleaner in order to accommodate both left handed and right handed people.

Emptying

It was observed that the participants do not empty the dust container when dust has reached the MAX line but fill it to way over its capacity. The team believes that this might be because the container visually looks like it can handle more dust than where the MAX line is indicated. However, the space above the MAX line needs to be free for the the cyclonic dust filtration to work properly. In an attempt to accommodate for this, it was decided to obstruct the view into the cyclonic chamber with a grading color, making it look smaller than it actually is.

43 Gradiant dust container

Control

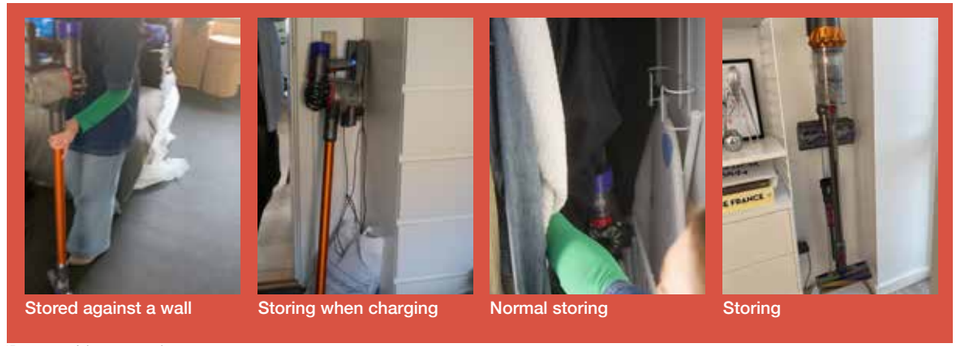
Control button in the handle

43 Dyson control button

One of the participants turned the stick vac on and off multiple times when vacuuming in order to save battery power. This was easily done since the control button is placed in the handle. The team believes that this is a workaround to compensate for a bad battery capacity and not a necessity for the user. It was therefore decided to stick with the initial idea of keeping all electronic components gathered in the cylinder and place a button in the cap of this. This way it was avoided to place wires in the handle, keeping the frame a static component.

44 Cap of cylinder

Storage



45 storage of the vacuum cleaner

Observing the participants it was noticed that the vacuum cleaner was placed against walls when both hands were acquired for moving furniture etc. However it would often slide and fall in this position. In order to accommodate this insight into the design, the cylindrical dust container got a bevel integrated in the bottom, making the surface parallel to the wall in case of wall leaning storage.

Observing the participant it was also noticed how the vacuum cleaner was stored and charged. In one of the cases the vacuum cleaner was stored in a closet but temporarily stored in the bedroom when charging. This was due to the lack of storage space in the bedroom and the lack of electricity output in the closet. In order to accommodate the issue of not having the possibility to charge the same place as storing, design iterations were made on movable and closet-friendly docking stations.

However when testing this docking station it became clear that people that keep their vacuum cleaner in a closet because of a lack of space do not have the required space for a moveable docking station either. A quick user investigation showed that most people prefer to hang their stick vac and told that the grab and go mentality of the vacuum cleaner and docking station was the most important for them. This parameter was chosen to be the main factor to accommodate for in the development of a new docking station.

45 Movabale charging stand

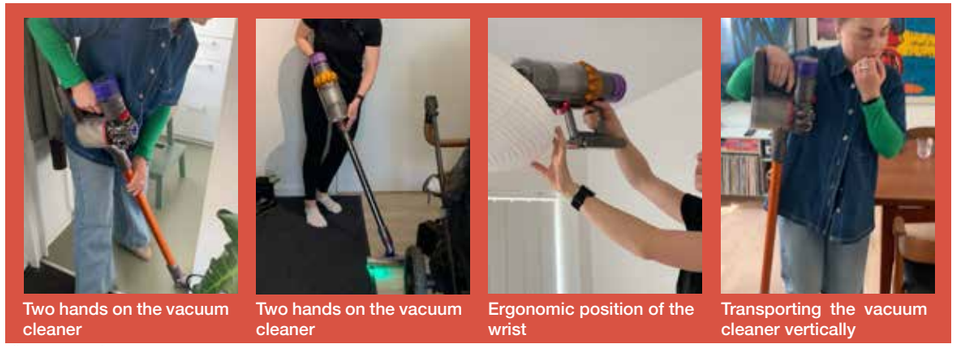
As the design of Nilfisk Keep required two charging ports, which would potentially influence the user experience of charging the product, it was important to not compromise the grab and go mentality. In the development of the charger it was important to stick to the design principles of an honest and educational design.

With a wall mounted design, the docking becomes more sturdy, allowing for easier grab and go. In order to reduce material, the middle part was cut, separating the docking station into two. A workaround for the precise installation procedure was designed, using the tube as a guide for the space between the chargers. The charging cable from the outlet separates into two, highlighting the two electrical cylinders that need charging. The cables will be able to be separated from the docking station, in order to accommodate for charging separately from the docking station.

46 Mock up of hanging charging stand

47 Hanging charging stander

Handle

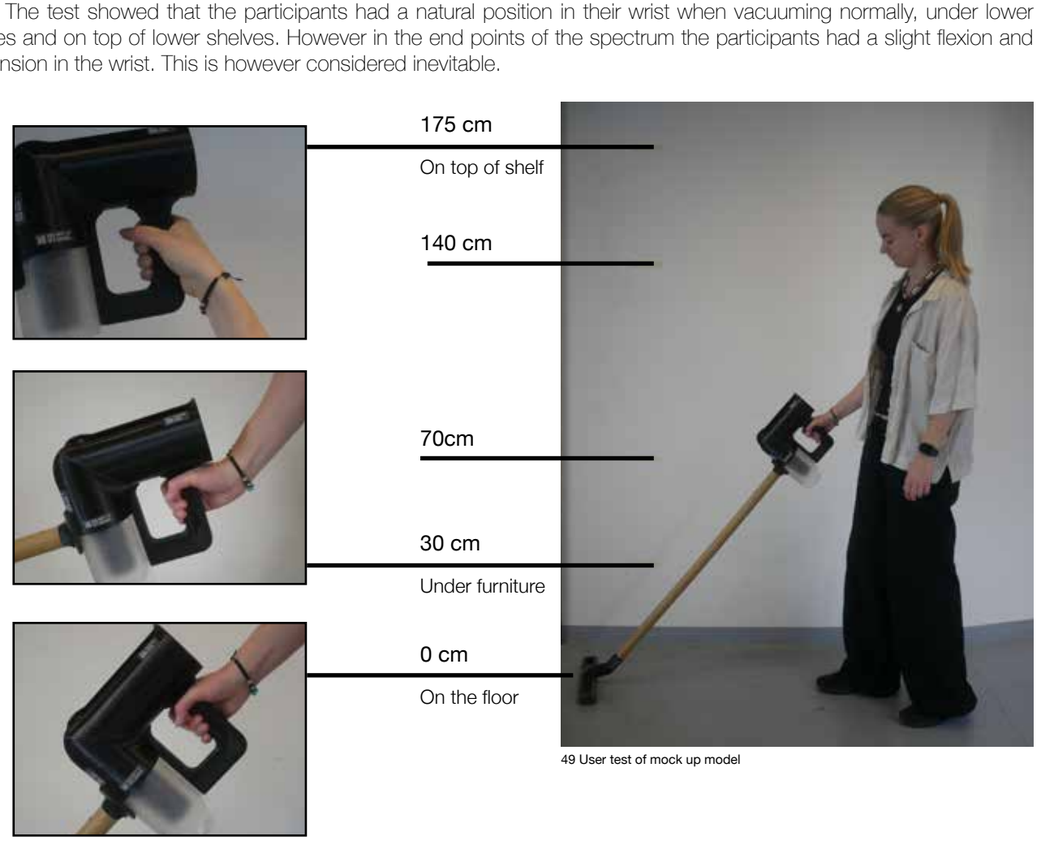


48 handeling a stick vac

Horizontal handle

The ergonomic position of the participants was observed and this left the team wondering what ergonomic position was provided with our design especially considering the wrist position.

The ergonomic position of the wrist when vacuuming with the stick vac was tested in five different height positions (App. 16). The test showed that the participants had a natural position in their wrist when vacuuming normally, under lower tables and on top of lower shelves. However in the end points of the spectrum the participants had a slight flexion and extension in the wrist. This is however considered inevitable.



49 User test of mock up model

The participants did mention that the handle was too square. Because of this the handles were rounded off and a line pattern was applied to ensure a good grip.

Vertical handle

Bringing the vacuum cleaner from one room to another the vacuum cleaner was often carried vertically resulting in an awkward position for the participants.

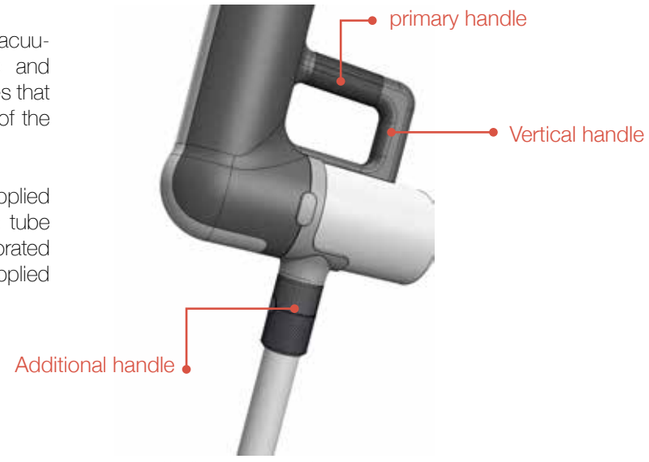
The closed-off handle on the stick vac was not initially thought of as an extra handle but instead as a strengthening spacer. However the user observation showed that this spacer could in fact be very useful as an extra handle, positioning the wrist in a better orientation when moving the vacuum cleaner.

49 Participant with vertical handle

Additional handle

Both participants used two hands when vacuuming, especially when close to objects and vacuuming under furniture. The team believes that the extra hand is used to get extra control of the vacuum cleaner.

Because of this an additional handle was applied to the tube. The connection between the tube and the actual vacuum cleaner was incorporated in this handle. The same line pattern were applied to amplify that this is in fact a handle.



50 Handles on the vacuum cleaner

With an initial strong design focus on repairability and maintenance, a concept of a vacuum cleaner had been developed. However, in-depth exploration of users' interaction with the prototype and current stick vacuum, gave important insights into how this repairability aspect could live side-by-side with the functionally requirements of stick vacuum cleaners. This helped mature the concept tremendously, and added several details and new helpful implementations to the design.

- The vacuum must accommodate for a second handle
- The mouthpiece have to be sufficient on several surfaces
- Users do not change mouthpieces
- The user easily ignores text on products
- The users vacuum slowly along edges
- People often vacuums with two hands

DESIGN BRIEF

Problem statement

“How can a future proof vacuum cleaner with user centered repairability and upgradeability be designed”

Requirments

- The product must be upgradeable
- Minimum operational motor lifetime: 500 hours
- Minimum dust pick up on carpet (dpuc): 0.75
- Minimum dust pick up on hard floor (dpuhf) : 0.98
- Key components can be replaced
- The vacuum cleaner must be airtight from the in port to the exhaust port
- Must be able to repair the product without the use of tools
- Must have a user removable battery
- Must use cyclone dust filtration
- The user must be able to use their senses to diagnose failure
- Motor overload must not cause any damage
- Minimum of 3100 RPM on hard floors
- Minimum of 3100 RPM on carpets

Design criterias

- The electrical components must not be perceived as dangerous
- The design will be driven by simplicity, quality and durability
- Must be grab and go
- The design of the product must elevate the users skills and knowledge required for repair
- The product should have low complexity
- The user needs to be reminded when maintenance is required
- The mouthpiece have to be sufficient on several surfaces
- The vacuum must accommodate for a second handle

Insights

- 2/3 of discarded vacuum cleaners still work or can easily be repaired
- People think that the repair cost of a vacuum cleaner is to high
- Vacuum cleaners are discarded if just a single component fails.
- Future EU legislations for repair is set for the near future
- The required time and effort of disassembly and reassembly are too demanding
- It is difficult to diagnose the failure
- People are afraid of unknown electrical components
- People do not have the knowledge to identify the error
- People don’t have standard tools
- People spot clean
- People do not use all their accessories
- People maintain their vacuum cleaner but they do not ”repair” them
- A lack of function will cause people to discard their vacuum cleaner
- The most critical repair step for electro mechanical products is diagnostic
- Repair without sufficient knowledge and skills can cause additional damage to the product
- People use their senses to diagnose failure in a product
- People’s perceived product life time is very low
- People do not maintain their vacuum cleaner properly
- Motor overload is the main cause of failure in a vacuum cleaner
- Users do not change mouthpieces
- The user easily ignores text on products
- The users vacuum slowly along edges
- People often vacuum with two hands

TIMELESS DESIGN

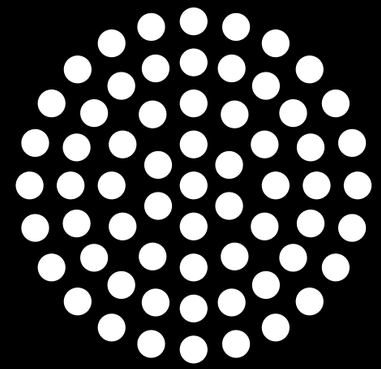
Since the design team strives to design a vacuum cleaner that can last for many years it requires a design that people are comfortable with for years to come, without looking old or “last year” as this is very important in regards to aesthetics obsolescence.

Wallner et. al. (2020) has been examining design styles that have been proposed as timeless. Their findings supported that specific design styles were considered timeless and can improve consumers evaluations of refurbished products. Our vacuum cleaner will, with time, face the same challenge as refurbished products that do not follow the latest trends and will lack a desired new look. A strategy to enhance the appearance and be attractive for a longer time is by giving them a timeless design.

Simplistic design is one strategy of timeless design. Characteristics of these products are simplicity in correspondence to essential parts, balance in proportions, symmetrical, ordered, little contrast in color and use of pure and cold materials. The designs have as few ornaments as possible and do not follow the fast trend cycles. Because this design strategy complied with the aspired design language of Nilifsk, this simplistic design strategy was investigated further.

Dieter Rams

Dieter Rams products can be considered as having a simplistic design. Dieter Rams's 10 principles of good design where investigated along with an analysis of five of his designs.



01
Good design is innovative

02
Good design makes a product useful

03
Good design is aesthetic

04
Good design makes a product understandable

05
Good design is unobtrusive

06
Good design is honest

07
Good design is long-lasting

08
Good design is thorough down to the last detail

09
Good design is environmentally-friendly

10
Good design is as little design as possible

51 Analysis of Dieter Rams designs

Implementation

After analysing Dieters designs and design principles, it is evident that many aspects are already present in the current design; the simple geometric forms, the instructions and the honest design. However, some of the additional design principles could benefit the user in the understanding of the product.

Key aspects in Dieters design is to highlight important elements of the design with a color of contrast. One of the most important aspects of Nilfisk Keep is the possibility of replacing components, made possible through the connections. Therefore, it is chosen that the connections will be produced in an orange contrast color.

Dieter works with hierarchy in his products. It is chosen to implement hierarchy in the passive communication of the product. This is done by frosting areas of the window that have lower priority of visibility, while still maintaining full visabilty in the high priority areas.

This investigation could imply that the Nilfisk Keep has a timeless design. The simplistic design in the Nilfisk Keep consisting of only essential parts and with as little ornaments as possible corresponds with the simplistic design strategy.

The product will have a simplistic design strategy

MATERIAL AGING

Material aging is also apparent in aesthetic obsolescence. A long product lifetime will affect the material and with time it will lose its pristine look. It is investigated how materials age and how the users perceive this aging.

Lilley et. al. (2019) has investigated how different materials age and how these changes in the material are perceived, from a users perspective. Their study found that sudden changes in a pristine surface are cause for a negative reaction, while gradual changes are more acceptable, as it allows time for acclimatisation and can even be perceived as something positive. It also states that it might be why natural materials are perceived as aging more gracefully as the surface of these is textured and complex, making changes in the surface less apparent.

With this knowledge in mind, it's not only ideal to pick a durable and scratch resistant material, but also make sure that areas that are exposed to abrasion will include a less pristine surface. ASA plastic is chosen as it is durable, resistant to scratches, uv-resistant and can be transparent (Prospector n.d). The casing is produced with a black textured surface, causing the first scratches to be less evident than if the surface was glossy. Sand will scratch the inside of the tube and dust the container. Therefore the tube is made with a matte transparent surface. However it is important that the user can see when the container is full, therefore it is necessary that this part is made with a glossy transparent surface, with the acceptance that it will become scratched over time.

The maintaining labels will be debossed to make sure that these will not wear as fast and be scratched off.

UPGRADE CHALLENGES

The rapid development of technologies causes relative obsolescence in products. It is necessary to tackle this in order to create a long lasting product. The design team has chosen to do so by allowing for upgradability.

Upgradeability is achieved through the connections. It will be possible for the consumer to change and upgrade a component, as long as the connections and interfaces between the components are kept the same.

However, upgradeability doesn't come without challenges. The future and the development of new technologies are uncertain, and it can be difficult to account for all of these uncertainties. Possible challenges that could emerge when new technologies are developed and how these could be tackled will be described in the following.

Different size components

Future components might differ in size from current ones. The casing can accommodate for upgrade, as long as the components fit inside the cylinder. But the casing will become obsolete if the components increase in diameter. However, If the length of the components increases, it would be possible to elongate the casing with an extra part.

Active communication becoming obsolete

The active communication in terms of the stickers might become obsolete with new technologies. f.ex. if a new self cleaning filter is developed, the "sticker" *clean filter* would be obsolete. However the team believes that the value of the "stickers" compensate for the possibility of the "stickers" becoming obsolete.

Limitations in the connection principle

The allowance for upgradeability relies on the connection principle. It is possible that the connections will meet its limitations if they are not compatible with future technologies. In that case it will be necessary to reevaluate the connection principles and develop and launch a new connection system, that can be integrated into the static frame.

DESIGN BRIEF

Problem statement

"How can a future proof vacuum cleaner with user centered repairability and upgradeability be designed"

Requirments

- The product must be upgradeable
- Minimum operational motor lifetime: 500 hours
- Minimum dust pick up on carpet (dpuc): 0.75
- Minimum dust pick up on hard floor (dpuhf) : 0.98
- Key components can be replaced
- The vacuum cleaner must be airtight from the in port to the exhaust port
- Must be able to repair the product without the use of tools
- Must have a user removable battery
- Must use cyclone dust filtration
- The user must be able to use their senses to diagnose failure
- Motor overload must not cause any damage
- Minimum of 3100 RPM on hard floors
- Minimum of 3100 RPM on carpets

Design criterias

- The electrical components must not be perceived as dangerous
- The design will be driven by simplicity, quality and durability
- Must be grab and go
- The design of the product must elevate the users skills and knowledge required for repair
- The product should have low complexity
- The user needs to be reminded when maintenance is required
- The mouthpiece have to be sufficient on several surfaces
- The vacuum must accommodate for a second handle
- The product will have a simplistic design strategy

08

CONSTRUCT

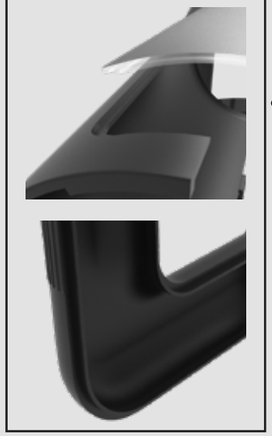
This phase describes the technical aspects, detailing and the realization of the product proposal. This is in regards to production, assembly and electronic functioning.

CASING

Detailing, material and production methods of the components in the casing

Glue surfaces

Glue surfaces allow for bigger adhesive area



Window

The fade from clear to matt plastic is created in the surface of the mold from smooth to textured

Sides

The textured surface on the side is created in the surface of the mold, The knock out pins are placed on the inside, to ensure a smooth finish on the outside.

52 Exploded casing

Maintainance steps

The surface of the letters are debossed in the plastic injection mold. A pad printing process stamps into the debossing, transfers ink. with a custom-shaped pad to match the contour of the writing,

INTERNAL COMPONENTS

Detailing, material and production methods of the internal components

Dilemma of internal components

With the choice of which electrical internal components the vacuum cleaner should use, the design team faced a dilemma of how long a vacuum cleaner should last (app. 17).

High

With high quality components that has a higher price, and are more complex, it would be possible to create a vacuum cleaner that potentially can last for centuries. This will require a brushless motor with a motor controller that ensure that the motor don't fail

53 DC brushless motor

vs.

Low

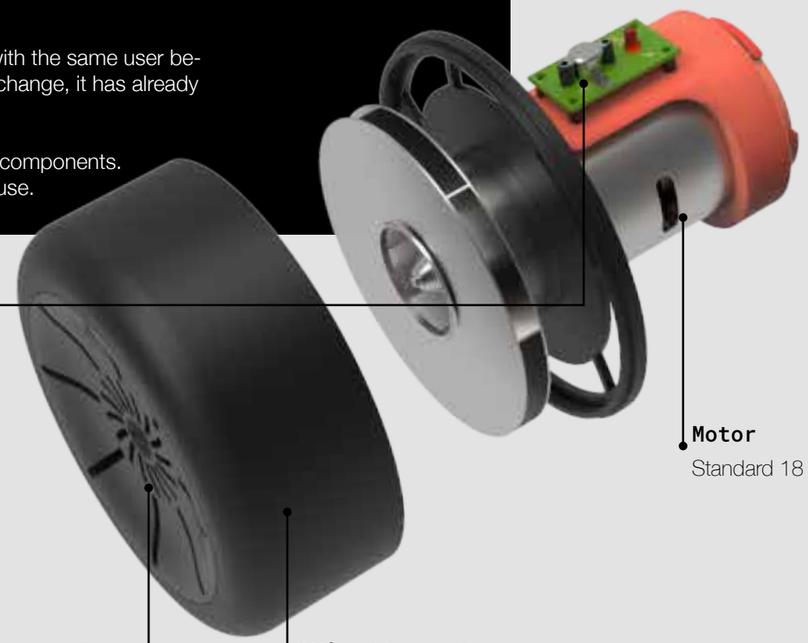
On the other hand it can be chosen to use lower quality components that will be worn down in 10-30 years. Additionally, these components has a lower price and are less complex. This would be a brushed motor and a bi-metal fuse to prevent overheating.

54 DC brush motor

The team questions if it is even realistic to implement components that will last for centuries when taking the following parameters into account that; cleaning behavior will change, technology will evolve, users appreciate low complexity when repairing

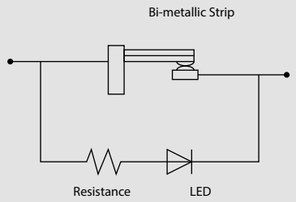
Kristian from Nilfisk also stats that "Using the same product with the same user behavior in 60 years, I don't believe that. The user behavior will change, it has already changed within a few years"

For these reasons it is chosen to implement the lower quality components.
Thus implementing a 18 v dc brushed motor and a bi-metal fuse.



Bi-metal fuse

A bimetal fuse is implemented to prevent overheating of the motor. When the temperature in the motor rises, the bimetal strip in the thermostat will start bending, cutting off the motor temporarily and light a LED.



Motor cover

Injection molded ASA plast

Vibration motor cover

Absorbs some of the vibrations from the motor

Motor

Standard 18 v motor

Battery

The size and capacity of the battery has great impact on the size of the casing. The battery capacity is calculated based on the chosen motor (App 18.). It is chosen to use the same 3.7 v battery from the mouthpiece. Connecting five of these batteries in series will give the necessary 18 voltage required in the motor. With 3000 mAh it would be possible to have

19 minuts runtime on 100 % efficiency
25 minuts runtime on 75% efficiency
38 minuts runtime on 50 % efficiency

Connections

The connections fastens the components to each other and transfers the current. Dents in the surface indicate that there is a grib and that the parts can be rotated.

A locking button ensures that the connection stay together. Where as the notches indicates where the modules must meet before being secured to each other.

55 Exploded internal components

Post motor HEPA filter

Battery control

It is a legal requirement that batteries has a control unit to ensure that it don't overheat and flames occur. This control unit is integrated into the connection in the battery.

Bluetooth

The bluetooth modem that connects the cylinder to the mouthpiece is integrated in the battery control unit. The bluetooth sensor should be a short range sensor, but must at least have a range of 1 meter. It is suggested to use an ERD 3M with the lowest possible transmit power, transmitter and receiver antenna gain, which has a range of 5-7 meters (Bluetooth® Technology n.d).

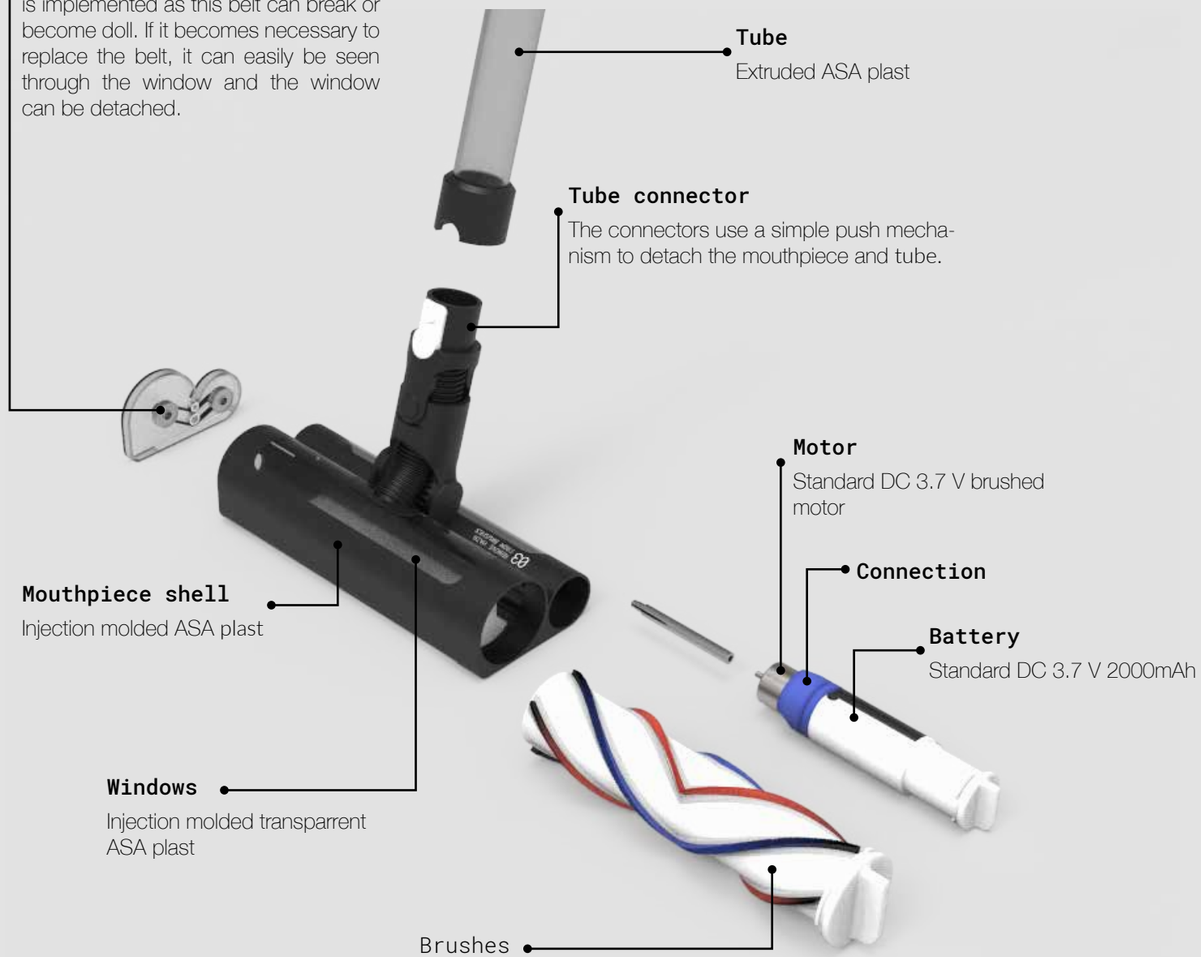
To connect the two systems to each other the connection button is pushed down on both the mouthpiece and the cylinder. When the two parts are connected, feedback to the user is given in form of a LED that will light up.

MOUTHPIECE

Detailing, material and production methods of the components in the mouthpiece

Conversion belt

A conversion belt transfers the rotation from the motor to the brush. A window is implemented as this belt can break or become doll. If it becomes necessary to replace the belt, it can easily be seen through the window and the window can be detached.



Tube

Extruded ASA plast

Tube connector

The connectors use a simple push mechanism to detach the mouthpiece and tube.

Motor

Standard DC 3.7 V brushed motor

Connection

Battery

Standard DC 3.7 V 2000mAh

Mouthpiece shell

Injection molded ASA plast

Windows

Injection molded transparrent ASA plast

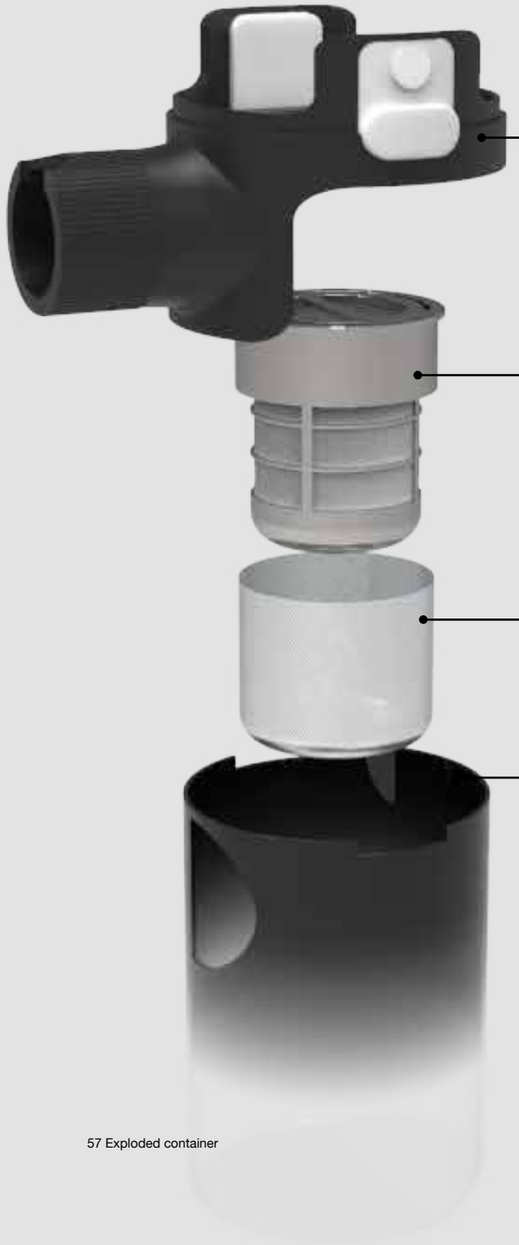
Brushes

Two types of brush hardness to accomdate for all flooring

56 Exploded mouthpiece

CONTAINER

Detailing, material and production methods of the components in the container



Container connector

The container connector fastens the container to the upper casing and to the tube. Grooves in the connection to the tube indicates that there is a interaction surface, accommodating for the second grib when more control is needed when vacuuming.

Pre motor filter

Metallic mesh filter

Container

Injection molded transparrent ASA plast

57 Exploded container

Filtration

The air and the dirt needs to be separated. This is done through a 4 step filtration system. Firstly, the dirt and air enters the cyclone where the larges debris are seperated from the air. Before the air reaches the motor it passes through the metallic mesh filter and the pre motor washable filter. Here are most of the dust particles are separated from the air. Lastly, the air passes through the post motor HEPA filter. This filter separates up to 99.99% of the dust particles from the air.

DETAILING THE END OF THE CY-LINDER

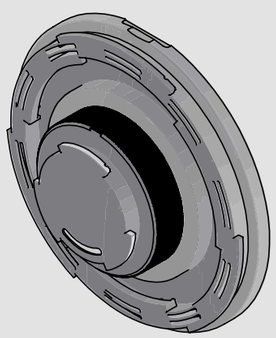
The end of the cylinder contains air outflow, control of the vacuum, communication of the battery level, charging port and safety pin. Making it one of the most complex components of the vacuum cleaner. Because of this it is chosen to detail this part further.

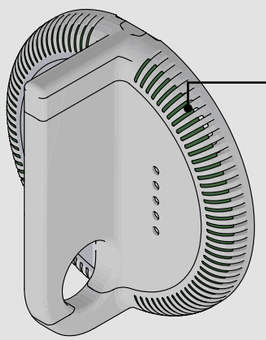
Because of the complexity of the component, the design team wonders if a second layer of repairability should be included in this component, allowing for professional repair. Adding a level for a deeper repair process, inside the component would reduce the amount of e-waste, as it would make it possible to only discard a single part instead of the entire component. Therefore, It is chosen that the end of the cylinder should allow for profesionel repair.

The requirements for the professional repair isn't that different from the requirements for consumer repair, however the required skills and tools change. The component must have easy access to the internal parts, without the risk of damaging the casing, and the electrical parts must be easy to replace. These are included in the detailing of the component.

59 Cylinder end

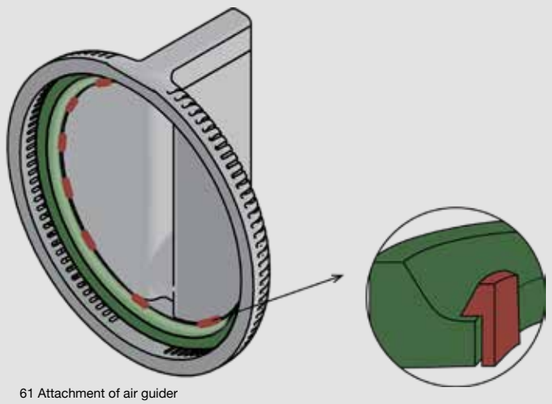
The end of the cylinder is injection molded in 3 parts. The outer shell, the air guider(The green area) and the connection to the rest af the cylinder.





The air guider blocks the air, making sure that it is transferred out the sides instead of backwards, in to the face of the person which is cleaning.

60 Controllers in cylinder end

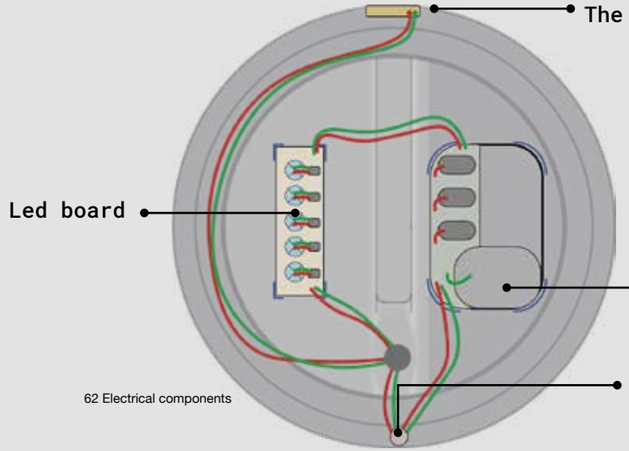


In the assembly process the air guider is pressed into the outershell and held in place with small snap fixers.

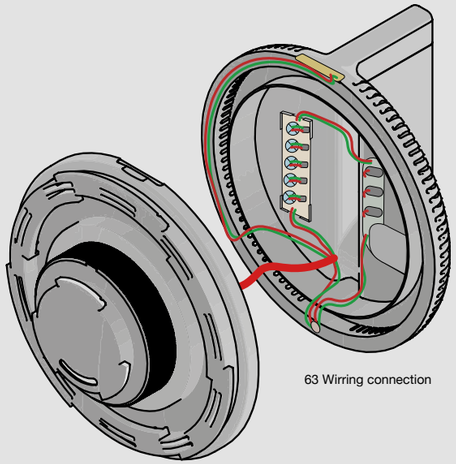
61 Attachment of air guider

The electrical parts

Compartments to fit the electrical parts are molded in the outer shell.

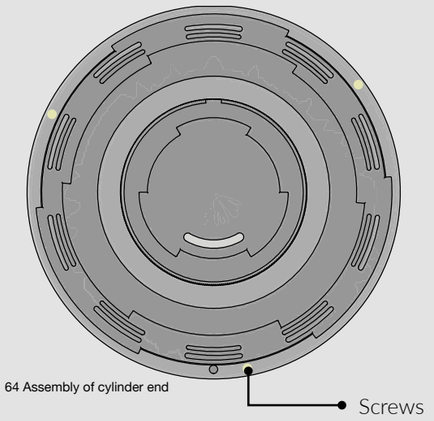


62 Electrical components



The electrical components are connected through wiring. The wires meet in one point where they are gathered and combined with the connecter.

63 Wirring connection

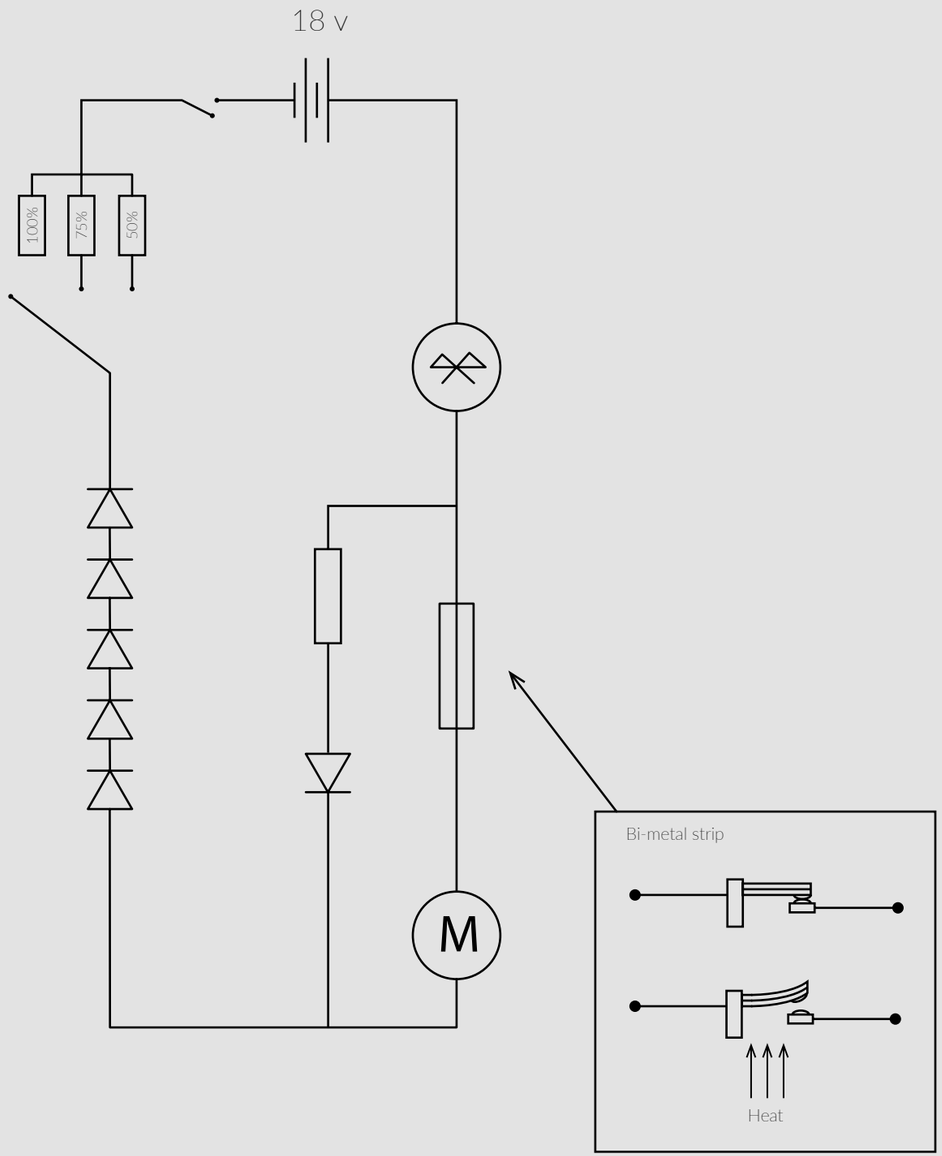


Lastly, the connecter is screwed onto the outershell, allowing for the professional repairer to gain accesses to the interior, without the risk of damage.

64 Assembly of cylinder end

The electrical circut

The following will create an overview of how the electric circuit in the cylinder is connected.



65 Electric circuit

09

BUSINESS

This phase describes the implementation of the product proposal to the case company, in regards of integration into their spare part system, sales prices and road map for the product launch.

PRODUCT SERVICE SYSTEM

Creating a repairable vacuum cleaner features a product service system as well. It is very important that spare parts are easily available for the customers as well as being easy for the Nilfisk. Buying spare parts has to be as easy as buying a new vacuum cleaner.

The design team sees three possible product service systems for Nilfisk. These are presented for Nilfisk in order to gain a business perspective, this way creating a system that fits both the user and the company (App 19.).

01

ELGIGANTEN

The user are able to buy spare parts at stores like Elgiganten.

"ELGIGANTEN DOES WHATEVER THE CUSTOMER DEMANDS, AND THEY WANT THE CUSTOMERS DEMANDS BEFORE THEY DO ANYTHING RADICAL" - Kristian Nilfisk

02

WWW.Nilfisk.com/spare-parts

The user can buy spare parts at Nilfisk's webshop.

"I THINK THIS COULD BE A GOOD BUSINESS, IT COULD BE A WAY OF DIFFERENTIATING FROM MARKET COMPETITORS, BUT ALSO BE AN ADVANTAGE FOR OUR OWN WEBSHOP" - Kristian Nilfisk

03

WWW.Nilfisk.com/spare-parts

The user can buy spare parts at Nilfisk's webshop, and send the broken parts back for refurbishment.

"THIS WILL REQUIRE RESOURCES TO HANDLE AND TO BE A PROFITABLE BUSINESS CASE WE MIGHT HAVE TO CHARGE A HIGHER PRICE AT THE BEGINNING" - Kristian Nilfisk

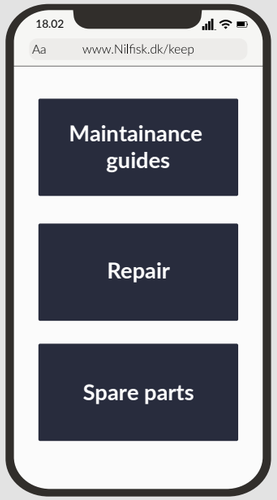
Nilfisk sees a great potential in having the spare parts available at their webshop as it could be a good business, and a way of differentiating from market competitors as well as an advantage for their webshop. While having the spare parts available in stores like Elgiganten would be a decision they would make. The refurbishment strategi would require a lot of resources that the users have to pay for, however this would be a way of reducing E-waste and utilizing resources even more.

Based on this the spare parts will be available in Nilfisk's webshop. However the design team does see a possibility to create a refurbishing business in the future.

IMPLEMENTING A PRODUCT SERVICE SYSTEM

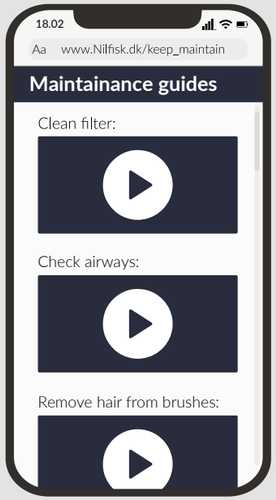
Based on the feedback from Nilfisk, it was clear that a webshop solution would be the most realistic system. This solution, however has to be very easy for the user to access.

A QR code is implemented on the vacuum cleaner next to the maintenance steps. The QR code creates an opportunity to elevate the user's knowledge and skills even further.



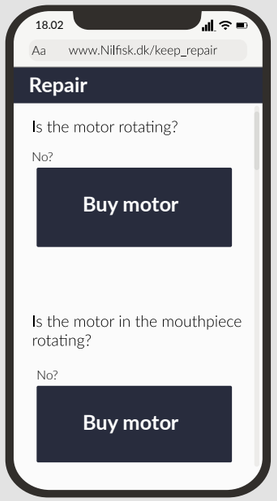
1.

When the user scans the QR code they are transferred to the homepage of Nilfisk Keep. Here they can choose between 3 topics: maintenance, repair or spare parts.



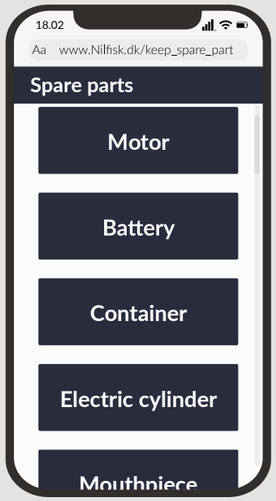
2.

The maintenance page will provide videos guiding the user on how to maintain the vacuum cleaner. These videos elevate the user's knowledge regarding how to take care of the vacuum cleaner.



3.

The repair page will help the user to understand which part is broken and needs to be replaced. Even though the vacuum cleaner is designed for easy diagnosis, this single step helps to make sure that consumers buy the right sparepart. When the user knows which part that needs replacement, they will be directly transferred to a page where they can buy the needed spare part.



4.

The sparepart page will have all the suitable spare parts available for the model. This includes parts such as casing, filter, container etc.

66 Maintainance steps

PRICE ESTIMATION

A price estimation is conducted, in order to understand where in the market, Nilfisk Keep can be positioned by looking at the price isolated.

The product is designed as a long lasting product. The aim is for the product to be at least within the mid-premium market area. An investigation of the price point of stick vac from current market leaders are created to be able to compare the price point with the existing market. This shows that prices span from 950 DKK to 8800 DKK

67 Average pricepoints from market leaders

A positioning in the mid-premium market area seems plausible as the product enters the market with new innovative features. However, as it is something that hasn't been seen before within the product category, it's difficult to compare Nilfisk Keep's value to other Stick vac products. Even though consumers are becoming more conscious, it isn't completely certain that the consumers are ready for repairability and maintainability as a feature.

In regards to the production price of the product, the design both accommodates several cheap production methods and some expensive production methods. The costs for the electrical components of Nilfisk Keep are kept at a minimum as the product uses standard motors and batteries. The most complex and expensive process of the product is estimated to be the modular connections between the electronic components, as they require a lot of assembly steps and is not something that has been seen in vacuum cleaners before.

An additional expense that could influence cost could be the requirement to store the extra spare parts. However, as regulations continue to develop, the requirements of keeping spare parts in stock will be relevant for other manufactures as well.

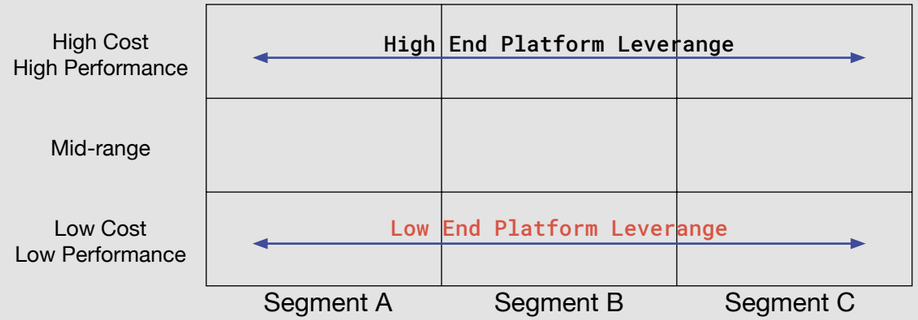
Based on this, it is estimated that the production cost could be within the current mid-premium price range. Because of this, the sales price is more dependent on a discussion of which additional values the product brings and whether the market is ready for it. Nilfisk has indicated that they do see brand value in being market leaders, being the first to adapt to changes. As Nilfisk Keep is innovative in regards to reliability and maintainability, there would be value in being first in this area.

Based on these considerations and a comparison with existing stick vacs it is estimated that Nilfisk Keep would have an initial sales price at 4000-5000 DKK. However, the design team does see the possibilities for an increase in price point, once the consumers grow accustomed to a product of this type.

IMPLEMENTATION

Nilfisk Keep introduces the first product in the new repair direction for Nilfisk. This new direction should be expanded across the Nilfisk portfolio. The implementation of the new direction will happen in several phases, until the entire Nilfisk portfolio has been covered. This section will present a suggestion as to how the design principles from Nilfisk Keep can be implemented in the other products and which platform strategy would be suitable for this.

The design team suggests that a horizontal platform leveraging (Meyer, 1997) is used to branch out the design principles of Nilfisk Keep to different segments within the portfolio of Nilfisk. This way it will not be necessary to invent entirely new principles to create easy repairable and maintainable products across the portfolio.



68 Horizontal platform leveraging

The following design principles from Nilfisk Keep will be expanded to other products:

1. The electronic cylinder
Combine the electronics in as few areas as possible with modular connection.

2. Visible access to the driving components
Allowing for the user to see the function and state of the driving components affording knowledge and maintenance.

3. Maintenance steps
Active communication regarding maintaining and repair

Phase 0 - Launch Nilfisk Keep

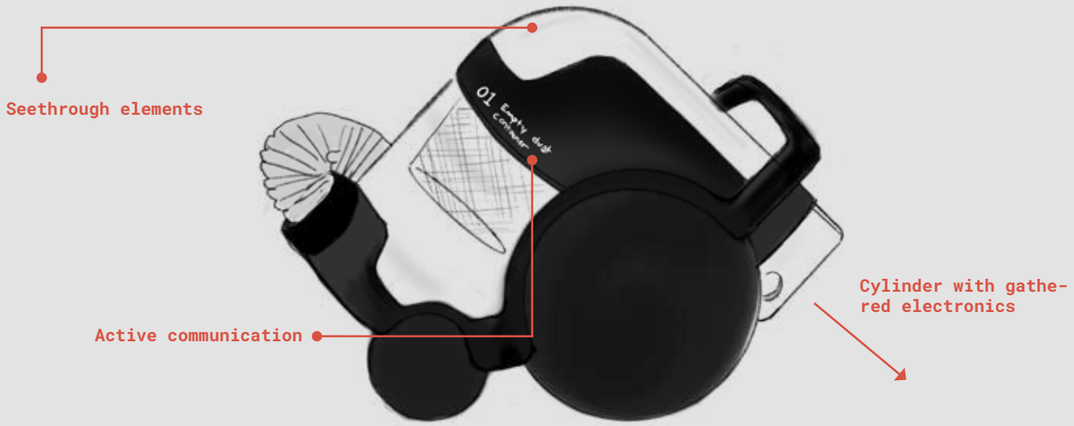
Phase 0 will launch Nilfisk Keep in Scandinavia and Germany. This is the market that Nilfisk are most present in. A calculation on how many vacuum cleaners sold in 2023 and 2028 (App. 20) are made to visualize the potential market.

It is estimated that Nilfisk Keep could take 1 % of the stick vacuum cleaner market in Scandinavia and Germany. Nilfisk Keep introduces a new aspect to stick vacs and a change of consumerism, and it will take time for the market to adapt to these new aspects. This means that the revenue in the first year will be 36.4 m $ with a prediction of 62.700 units sold.

After a five year period the benefits of being "first mover" will be visual. The demand from the consumers for repairable products has risen alongside additional regulations from the European commission. It is estimated that Nilfisk Keep's market share will rise to 5 % resulting in a revenue of 265.5 m $ and a prediction of 457.000 units sold.

Phase 1 - Expanding to other consumer vacuum cleaners

The first phase of the implementation plan will expand the principles to other types of consumer vacuum cleaners, such as a canister and handheld vacuum cleaner. In this stage the principles can be implemented fairly easily as all vacuum cleaners are based on the same composition. A first draft on the new direction for a canister vacuum cleaner could look like this:



69 Repairable canister vacuum cleaner

69 Repairable canister vacuum cleaner

Phase 2 - Expanding to the rest of the consumer portfolio

The next phase would be to expand to pressure washers and wet and dry vacuum cleaners. The expansion to these segments will require development regarding the challenges of implementing our system when the product has diffent functional needs.

Phase 3 - Expanding to the professional marked (Platform 2.0)

Once Nilfisk has gained knowledge and expertise regarding the system in their consumer market, it will be possible for them to develop and launch a new platform that will be suitable for their professional market.

10

EPILOGUE

This phase gathers the final contemplations from the design team in regards to the final product proposal its intended goal, and the full design process and key learning from it.

CONCLUSION

The main goal with the project was to reduce e-waste within the stick vacuum category. In order to achieve this goal, it was first necessary to understand what the underlying problem were, that caused the high amount of e-waste. What was achieved was the following.

- Product complexity showed to be one of the main factors for avoiding repair. Even though Nilfisk Keep still contains all the complex components of a conventional stick vac, it has focused on reducing the perceived complexity, by separating electronic mechanical and static components, and gathering all the electronics in collected areas.

- Lack of maintenance showed to be the main cause for the need of repair. Nilfisk Keep makes user maintenance more plausible, by highlighting and exposing the areas that need attendance, making the user able to see and sense when need for maintenance is required. Nilfisk Keep's integrated bi-metal fuse helps avoid motor failure, adding additional levels of indication for the user to perform maintenance, as well navigating them how to maintain, through the maintenance guide.

- A lack of understanding of how products work showed to be a main factor for the possibility of repair. Nilfisk Keep's design focuses on giving back knowledge to the user. This is done by avoiding hiding away any functional operation, as well as allowing them to get an accessible hands on experience with user friendly internal components.

In the end, the design team concludes the overarching agenda of e-waste reduction will inevitably become a necessary topic that forces manufacturers to rethink how products are designed, and that the design Nilfisk Keep proposes how to accommodate and optimize for these important future processes.

REFLECTION

At the end of the process, the design team reflected on which key learnings the project had resulted in, and which take-aways could be able to be used moving forward.

Constraints

The majority of the initial process was spent opening up the scope, giving a great number of options and possibilities. However, some of our work could have benefited from more constraints. Examples of this were conducting user interviews without any knowledge of our target demographic, or doing test models of vacuum cleaners without a chosen vacuum cleaner type. This occurred early in the project, and once these problems showed themselves, they were reflected upon and attempted to act on. This resulted in less fear of setting constraints, as it was seen that setting wrong constraints could also increased our knowledge. An example of this was the decision to force ourselves to stop analyzing and dive into creating a product proposal that became Nilfisk FrameIt, whose design faults ended up showing more solutions than deadends.

Iterative steps backwards, once new knowledge is acquired

For a majority of the process, the work was in a duality: making a repairable product and making a vacuum cleaner. The former was prioritized, but what was realized is that the two perspectives can't be fully separated, as our repairable design principles and users' vacuum cleaning behavior often caused design clashes, and individually had tremendous impact on the comprehensive design. An example of this was the clash between the implementation of the single electric cylinder for easier repair, and the user's cleaning needs of the motorized brush in the mouthpiece. The realization of this problem of workflow made us more likely to go back and forth between the two areas, using different tools and approaches necessary for the two domains, in order to gather insights and combine it into a comprehensive solution.

Product

Design of a product with radical changes takes many iterations to mature and doesn't come without challenges. The most radical and challenging change in this project is the implementation of the electronic cylinders.

- The integration of the electronic cylinder in the vacuum cleaner casing introduces a lot of technicality, as the fastening needs to reduce air leakage as well as guiding the air out through the exhaust areas. Simultaneously, the design needs to allow for the electronic cylinder to be pulled in and out without collison and without the use of tools. This can be difficult to achieve.

- Because the two electronic cylinders has been designed with a wireless system in mind, challenges arise in regards to the user interaction of connection between the two systems. Additionally, because of the connectivity, independent use of the two parts, when they are detached from each other, can cause unintentional activation of the mouthpiece.

- In the quest of designing for a less complex product to afford user repair, the cost has been an increase in complexity in regards to the user experiences of the product. This is mainly due to the user having to connect their product, as well as charing two separate places, something that has never been necessary in traditional stick vacs.

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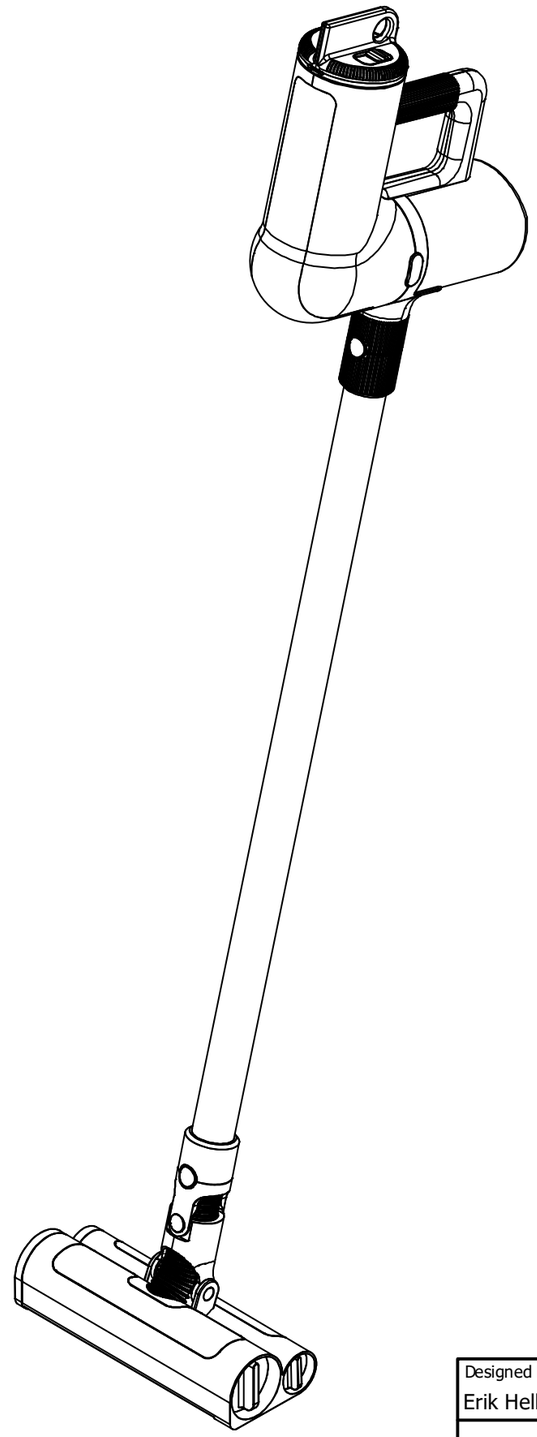
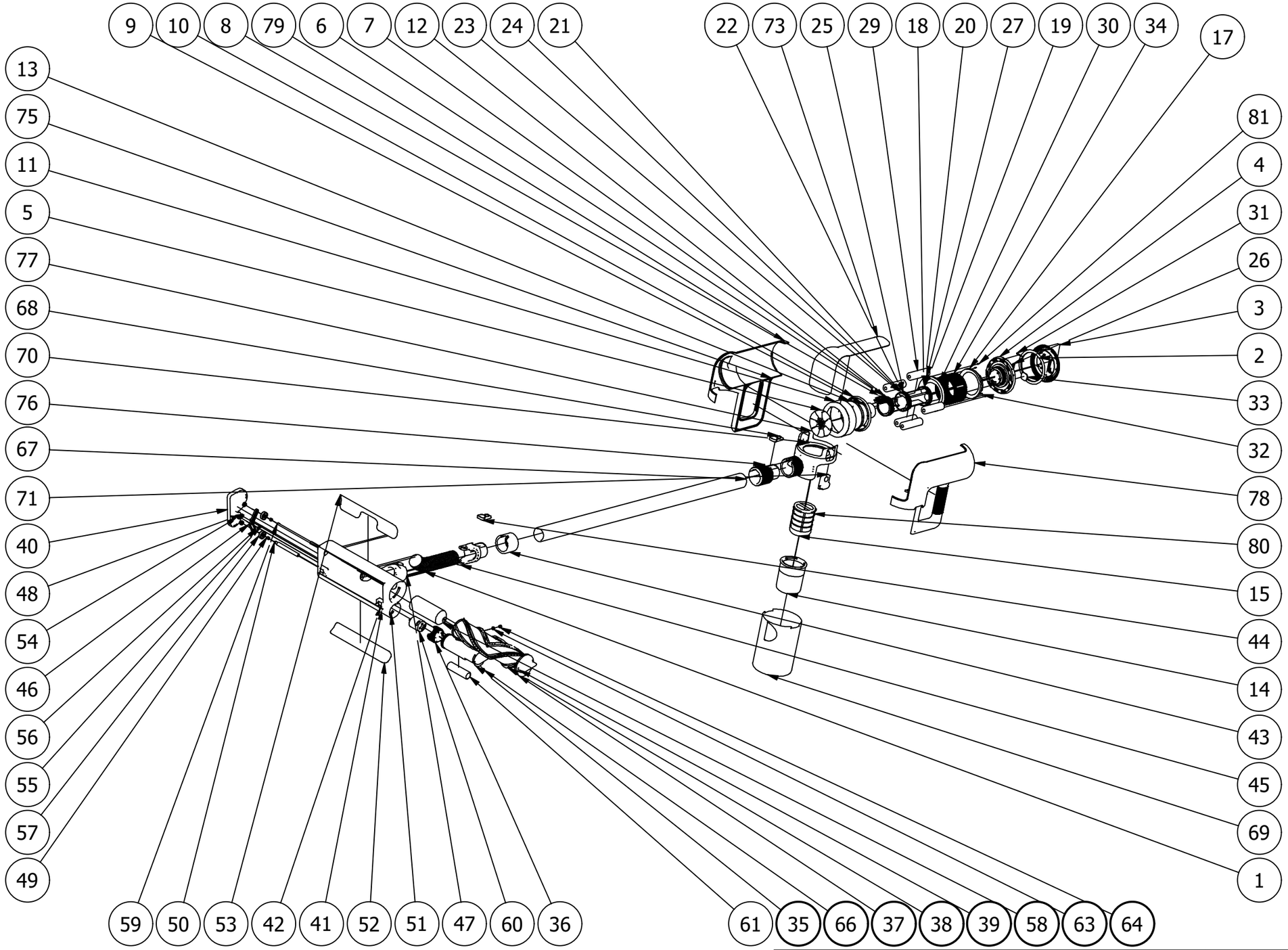


Designed by	Checked by	Approved by	Date	Date	
Erik Helleshøj	Katrine Nielsen	Christina Palsten		5/26/2023	

Nilfisk	Nilfisk Keep	Scale 1 : 5	Sheet 1 / 7



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Erik Helleshøj	Katrine Nielsen	Christina Palsten		5/26/2023	

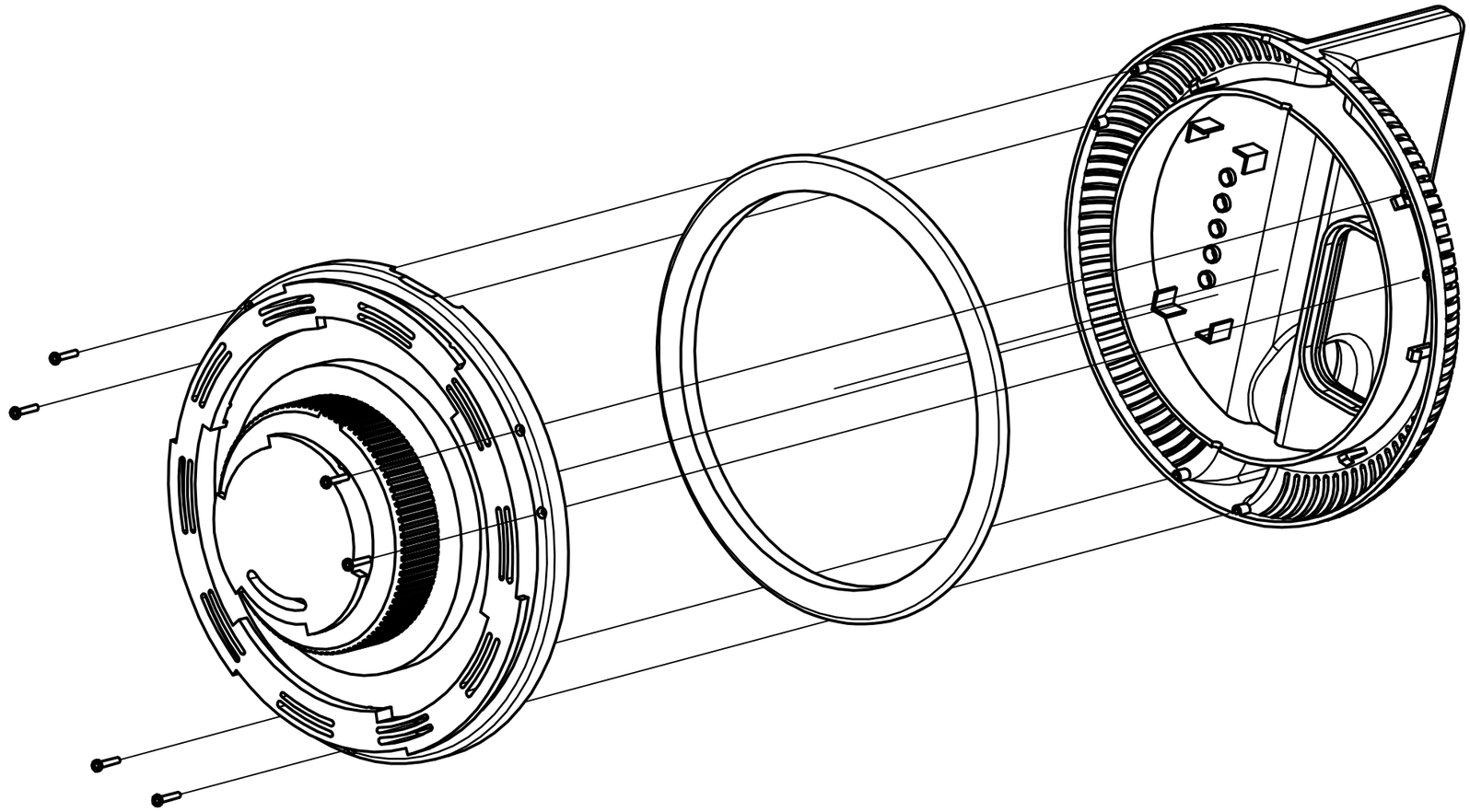
Nilfisk

Nilfisk Keep Exloded view

Scale 1 : 10

Sheet 2 / 7

PARTS LIST				PARTS LIST			
ITEM	QTY	PART NUMBER	DESCRIPTION	ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	Bending Tube	Rubber	41	1	Rubber Profile	Standard Part
2	1	Air Guide	ASA	42	2	Wheel	Standard Part
3	1	Cylinder1 End Piece	ASA	43	1	Lower Tube Connector	ASA
4	1	Cylinder1 Connector Module	ASA	44	1	Lower Tube Release Button	ASA
5	1	Motor Cover	ASA	45	1	Mouthpiece Rotation Joint	ASA
6	1	Motor PCB	Standard Part	46	1	Mouthpiece COnnector	ASA
7	1	Motor LED	Standard Part	47	1	Belt	Standard Part
8	1	Bi-Metal Fuse	Standart Part	48	1	Idler Wheel 6mm	Standard Part
9	1	Cylinder1 Motor	Standard Part	49	2	Rod Connector	Steel
10	1	Motor Dampening Connector	ASA	50	1	Motor Rod	Steel
11	1	Motor Vibration Dempener	Rubber	51	1	Mouthpiece Casing	ASA
12	1	Cylinder1 Motor Connector Module	ASA	52	1	Mouthpiece Window 2	ASA
13	1	Motor Fan	Aluminum	53	1	Mouthpiece Window 1	ASA
14	1	Motor Filter	Aluminum	54	3	Belt Drive Pulley	Standard Part
15	1	Filter Frame	ASA	55	1	Ball Bearing 4mm	Standard Part
16	1	End piece Wireconnector	Stardard Part	56	1	Ball Bearing 6mm	Standard Part
17	1	Filter Connector Module	ASA	57	2	Ball Bearing 19mm	Standard Part
18	1	Cylinder1 Battery Connector Module	ASA	58	1	Brush Cylinder Connector	ASA
19	1	End Piece Release Button	ASA	59	1	Brush Rod	Steel
20	1	End Piece Button Case	ASA	60	1	Cylinder2 Motor	Standard Part
21	1	Cylinder1 BT Case	ASA	61	1	Cylinder2 Battery	Standard Part
22	1	Cylinder1 Battery Button Cover	ASA	62	1	Cylinder2 Wireconnector	Standard Part
23	1	Cylinder1 BT LED	Standard Part	63	1	Cylinder2 Button Case	ASA
24	1	Cylinder1 BT Button	ASA	64	1	Cylinder2 Release Button	ASA
25	1	Cylinder1 Battery Release Button	ASA	65	1	Cylinder2 BT LED	Standard Part
26	5	Battery LED	Standard Part	66	1	Cylinder2 BT Button	ASA
27	1	Filter Front Connector	ASA	67	1	Tube	ASA
28	1	Battery Wireconnector	Standard Part	68	1	Front Tube Release Button	ASA
29	5	Cylinder1 Battery	Standard Part	69	1	Container	ASA
30	1	Filter O-Ring	Standard Part	70	1	Container Top Ring	ASA
31	1	Cylinder1 Charing Interface	Standard Part	71	1	Container Release Button Left	ASA
32	1	Electricity Safety Pin	ASA	72	1	Container Release Button Right	ASA
33	1	On-Off Slider Button	ASA	73	1	Casing Window	ASA
34	1	HEPA Filter	Standard Part	75	1	Glue Surface	ASA
35	1	Cylinder2 Battery Connector Module	ASA	76	1	Front Tube Connector	ASA
36	1	Cylinder2 Motor Connector Module	ASA	77	1	Container Connector	ASA
37	1	Brush Cylinder	ASA	78	1	Casing Left	ASA
38	2	Hard Brush	Nylon	79	1	Casing Right	ASA
39	2	Soft Brush	Nylon	80	1	Washable Filter	Standard Part
40	1	Belt-Drive Window	ASA	81	6	M1x5	Standard Part



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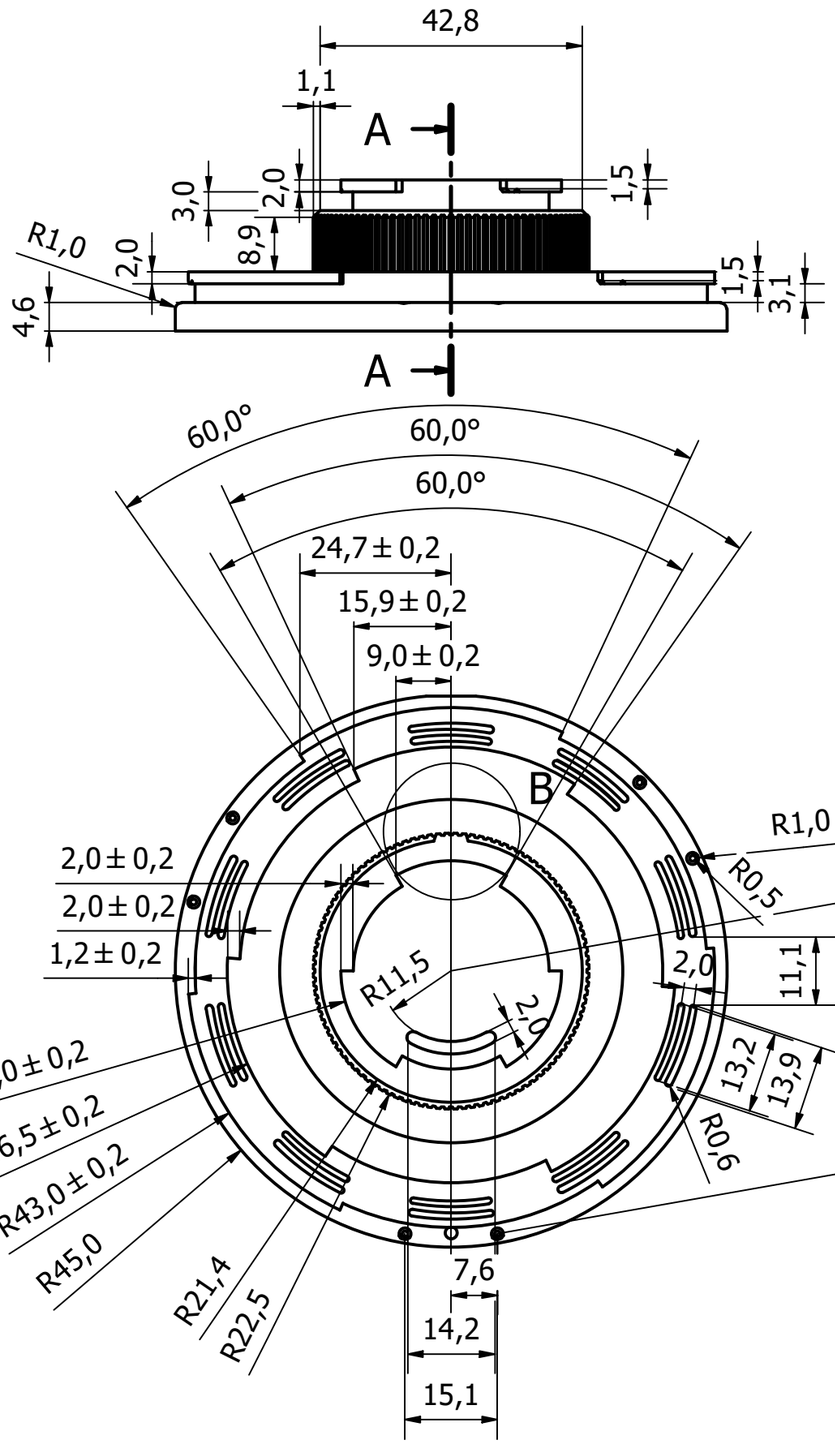
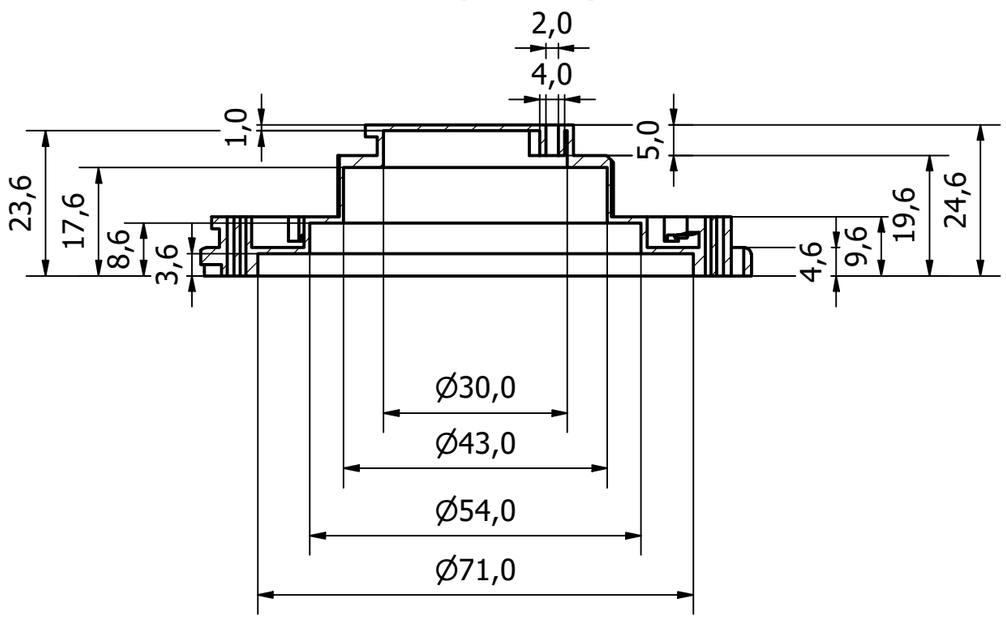
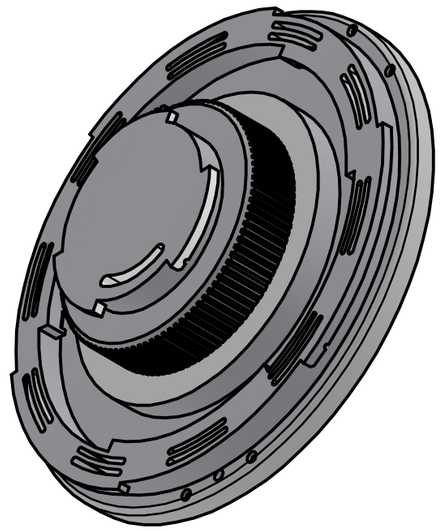
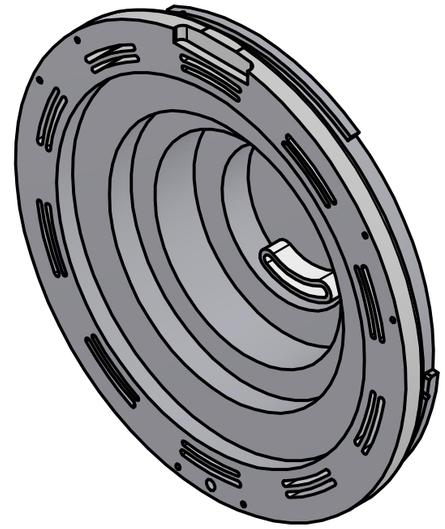
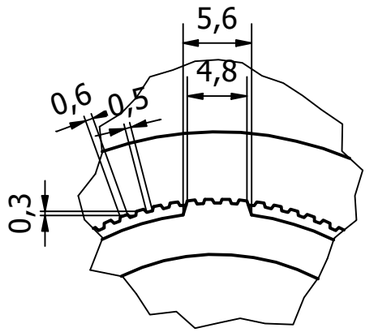
Nilfisk	Cylinder1 Subassembly	Scale 1 : 1	Sheet 4 / 7











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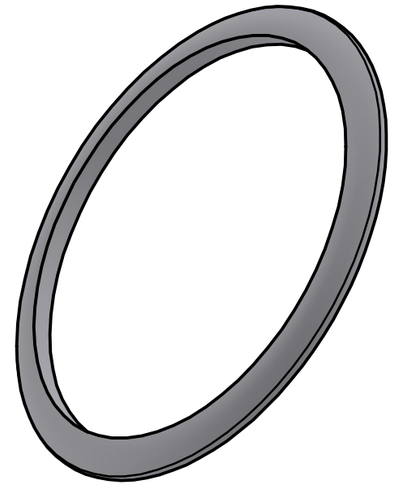
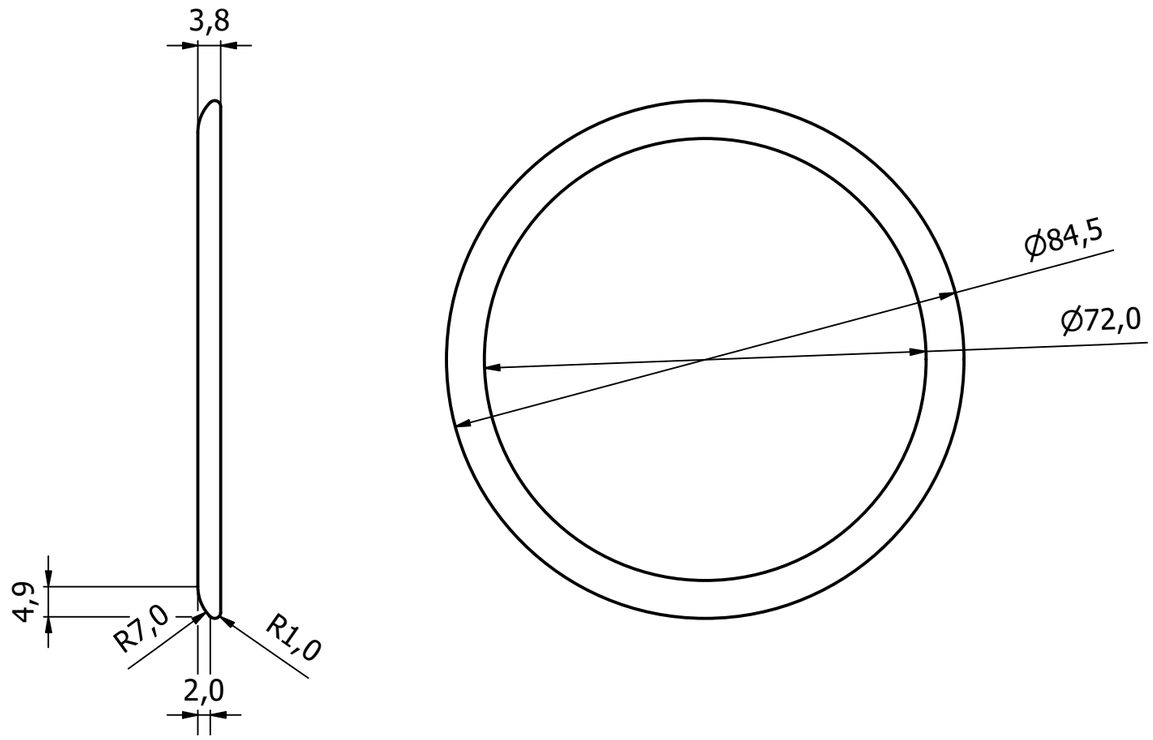
Erik Helleshøj	Katrine Nielsen	Christina Palsten		5/26/2023	

Nilfisk	Cylinder1 Connector Module	Scale 1 : 1	Sheet 5 / 7





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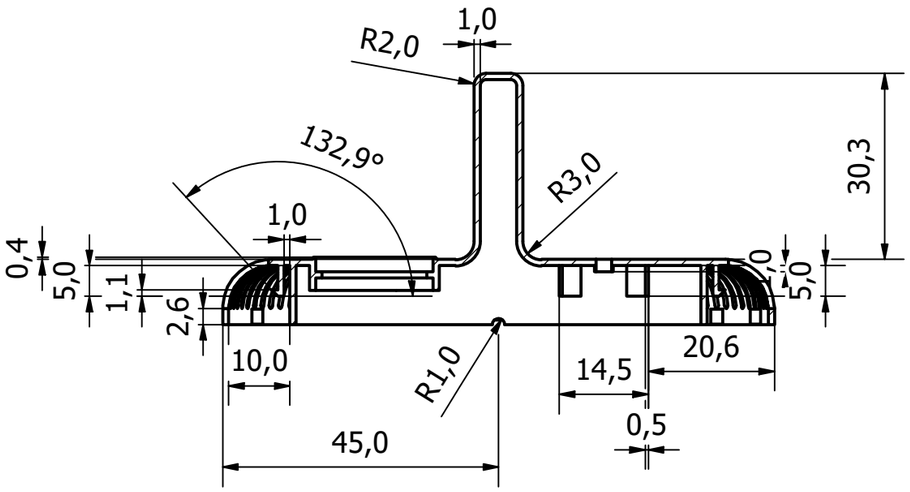
Nilfisk	Air Guide	Scale 1 : 1	Sheet 6 / 7

C-C (1 : 1)



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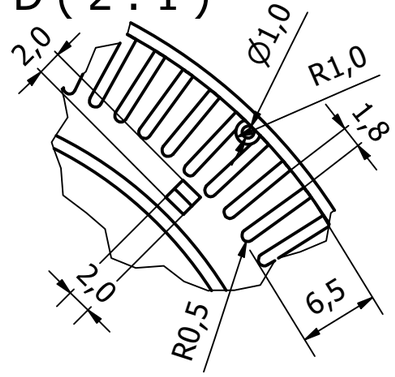

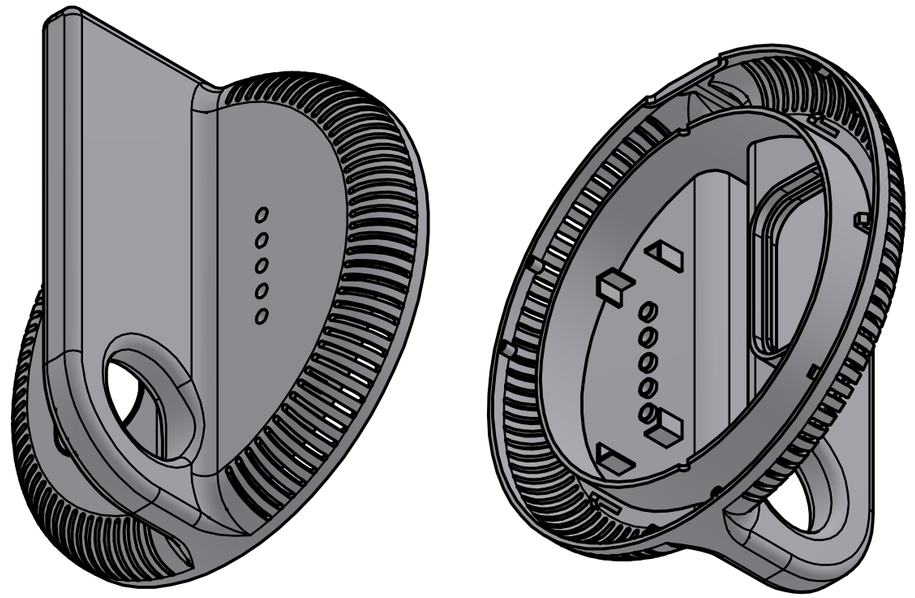

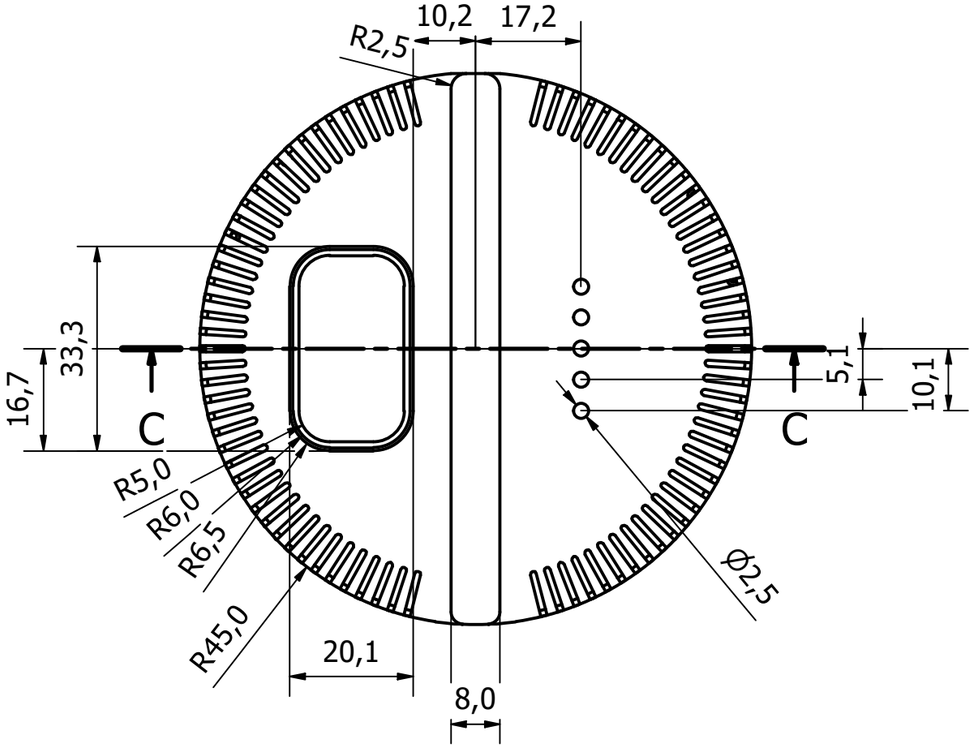

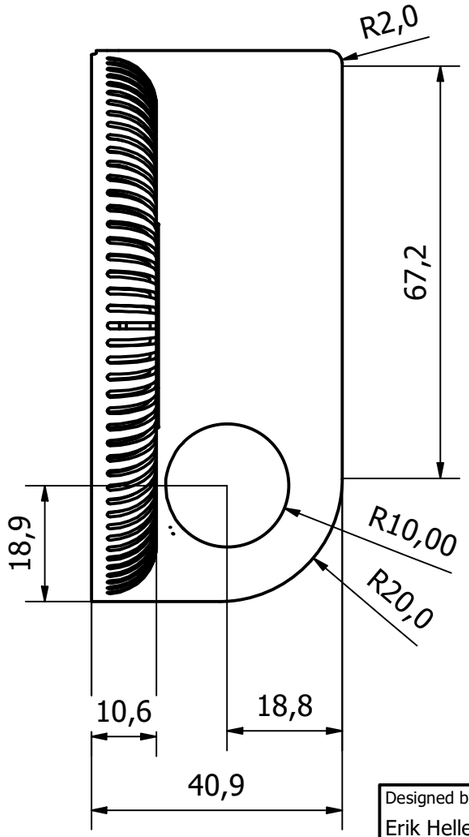

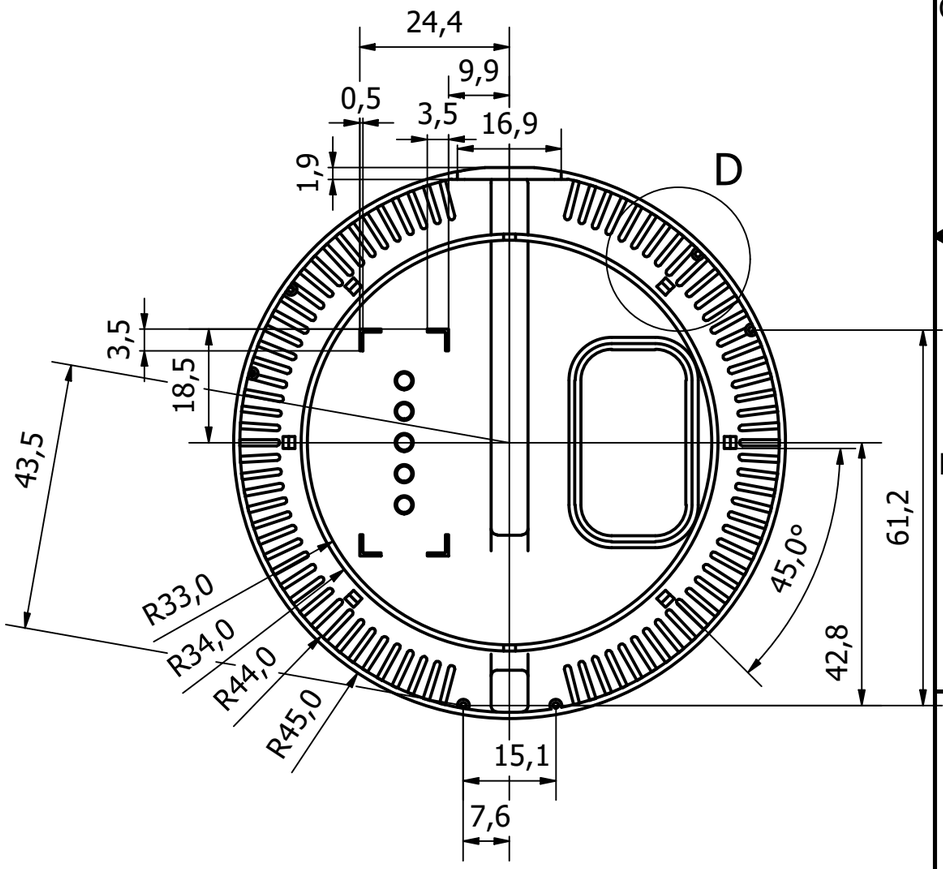

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Nilfisk	Cylinder1 End Piece	Scale 1 : 1	Sheet 7 / 7