Development of an Electric Golf Club Cleaner

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MASTER THESIS

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Abstract

This master thesis is based on the need for an efficient and user-friendly cleaning device adapted for golf clubs. The background and the idea for this project comes from the author himself, who is an experienced golfer. The market need is determined partly from a market research and partly from an interview with a former employee at a golf club. Both the commercial and private market shows an interest of a new improved cleaning device. The goal of the project is to develop a product that meets the market demands. Two concepts were built, first, a simple concept to ensure the functionality of the cleaning method where rotating brushes cleans the face and the sole of the club. The second concept, the proof of concept was constructed with a water tank, a brush driven by a small electric motor and an Arduino. The brush starts automatically when a club is inserted and by inserting the club in two different directions, both the sole and the face is cleaned. The second concept was tested and evaluated with inputs from potential users where the result came out positive with a cleaning rate of 88% in average. Once a working system was built and tested, the work went into phase two, where the goal was to develop a final product design that would serve as a consumer product. The final design consists of three main parts, a water tank, a cover for the electronics and a removable lid to easily clean the washer. The brush is driven by a standard 12v DC Worm motor which is triggered automatically by an IR Sensor. The washer can also by adding mounts to it be used on golf cars. The next step and suggestion for further development is to build and test the final design in a user environment.

Keywords: Product development, golf club cleaner, consumer product, development process.

Sammanfattning

Detta examensarbete bygger på behovet av en effektiv och användarvänlig tvätt anpassad för golfklubbor. Idén och bakgrunden för detta projekt kommer från författaren själv som är en erfaren golfspelare. Behovet är fastställt dels från en marknadsundersökning samt dels från en intervju med en före detta anställd på en golfklubb. Både den kommersiella och privata marknaden visar ett intresse för en ny förbättrad tvätt. Målet med arbetet är att utveckla en produkt som uppfyller marknadskraven. Två koncept byggdes, det första, ett enkelt koncept för att säkerställa tvättmetoden där roterande borstar rengör träffytan och sulan. Det andra konceptet som byggdes för att testa produktens funktionalitet och användarvänlighet, konstruerades med en vattentank, en borste som drivs av en elektrisk motor och en Arduino. Borstens rotation startas automatiskt och genom att föra ner klubban i två olika positioner kan både träffytan och sulan rengöras. Det senare konceptet testades och utvärderades med inputs från potentiella användare där resultatet var positivt med en rengöringsratio på 88% i genomsnitt. När ett fungerande system hade byggts och testats gick arbetet in i fas två där målet var att ta fram ett produktkoncept som skulle fungera som en konsumentprodukt. Den slutgiltiga konstruktionen består av tre huvuddelar, en vattentank, ett skydd för elektroniken och ett avtagbart lock för att enkelt kunna rengöra tvätten. Borsten drivs av en standard 12V DC motor som startar automatiskt med hjälp av en IR-sensor. Genom att montera lösa fästen på tvätten kan den även monteras på en golfbil. Nästa steg och förslag för vidareutveckling är att bygga och testa den slutgiltiga designen i en användarmiljö.

Nyckelord: Produktutveckling, tvätt för golfklubbor, konsumentprodukt, utvecklingsprocess, golf.

Preface

This master thesis has been performed at the Division of Product Development at Lund University, Faculty of Engineering. This was a project created and founded by myself and I would like to thank my examiner Olaf Diegel and my supervisor Damien Motte for giving me this opportunity to develop my own product. I would also like to thank Damien Motte for all the guidance, inputs and help along the way during this project. A special thanks to Johannes Ekdahl Du Rietz who assisted me and shared both knowledge and ideas regarding the electronics and the function of the washer. Without Johannes a working prototype would not have been possible and the contribution from Johannes made this project both more interesting and entertaining.

This project was both challenging and a lot of fun. Along the way I got a lot of inputs and thoughts by friends and colleges which I am grateful of and helped me a lot along the way.

At last I would like to thank my friends who lend me their dirty clubs to test the cleaning methods and proof of concept.

Lund, August 2018

David Josefsson

Table of contents

1 Introduction

This section contains the ground foundation of the project, the background of the author, the project, the problem and the goal of the project as well as the limitations for this thesis.

1.1 Background

The author, David Josefsson has a great interest in golf and over 15 years of experience in the sport. The author has a wide knowledge of the existing products on the market and the idea of this project came from the author since this device is missing on the market.

The general design of iron golf clubs consists of two parts, a shaft and a club head, see Figure 1.1. To generate a certain amount of spin, the face of the club head has a number of grooves milled on the surface. The design and layout of these groves varies but the direction is horizontal. These groves grip the ball on impact which implies a spin on the golf ball. To ensure a consistency it is important that the face, especially the grooves is clean and free from dirt.

Figure 1.1 Picture of two iron golf clubs.

The looks of the clubs are an important aspect for the physiological factor when a golfer chooses their brand. In the magazine Svensk Golf, and the review of the iron

clubs, the clubs is given scores based on three parts, forgiveness, feel, and looks [1]. The design and appearances of the club is in this review considered to be one of the three most interesting aspects, verifying the statement. A clean club is therefore important for the greater impression of your club set.

1.2 Problem Description

The golf clubs need to be cleaned to ensure a better play both for beginners and experienced players. The grooves must be cleaned to improve the performance, as well as the sole to ensure a shinier look. Dried dirt stuck in the grooves can be hard to clean and lack of time and tools leads to that many golfers play with dirty clubs.

A device for both private and commercial use that in an effective method cleans the club heads is currently missing on the market.

1.3 Goals

The aim for this thesis is to investigate and develop a cleaning method for irons and wedges. The goal is to generate a proof of concept for this method and in theory, construct and design a product that will suit the market.

1.4 Limitations

This project will only be based on cleaning wedges and irons. This category of clubs is suffering the most of an unclean club head face since they hit the ground on every strike. Grooves are also less common on woods and drivers. The general design of all the wedges and irons is the same and differs from the woods. Therefore the concept will be adapted to perform for this category only, which are the dirtiest clubs.

2 Methodology

This section will cover the plan, the process and method used for the project as well as how the pre-study was performed.

2.1 Plan

The project was calculated to be performed during a 20-week period. The timeline and the schedule were discussed and created with inputs from Damien Motte and is shown in the Gant-schedule in Appendix A. The schedule is shown in weeks with the duration and end date for each deadline. A detailed list of the including activities is also shown in Appendix A with the start and end date for each activity as well as the number of days for each activity. This schedule was updated along the project and the actual time-line is also shown in Appendix A. The work was only performed during weekdays, Monday-Friday.

2.2 Development process

The process of this project will be based on Ullrich and Eppingers book *Product Design and Development* [2]. Some modifications need to be done to apply this method to this project which will be presented in section 2.2.3.

2.2.1 **Product development process**

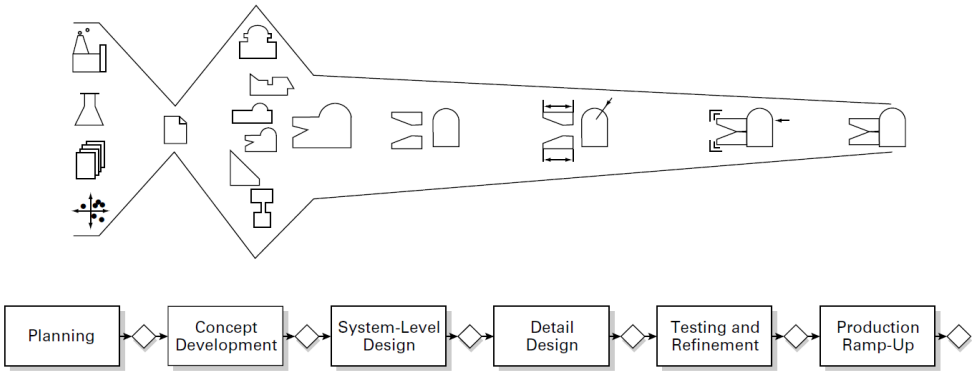


Figure 2.1 Product development process [2].

Figure 2.1**Error! Reference source not found.** shows the general product development process. These six steps will be performed with some overlap to ensure a product that fulfills the requirements from both the customers, techniques, and production. The last step, Production Ramp-Up, will not physically be achieved since a finished prototype not will be made due to budget limitations. Therefore, this process needs to be modified to suit this project.

The biggest step in this process is the Concept Development where both the cleaning method will be defined, and a proof of concept will be developed and built. In the next step, the System-Level Design, the cleaning method and concept will be adapted to a final design that meets the market needs.

2.2.2 **Front-End Process**

The Front-End Process seen in Figure 2.2 below, is a detailed description of the Concept Development phase in Figure 2.1.

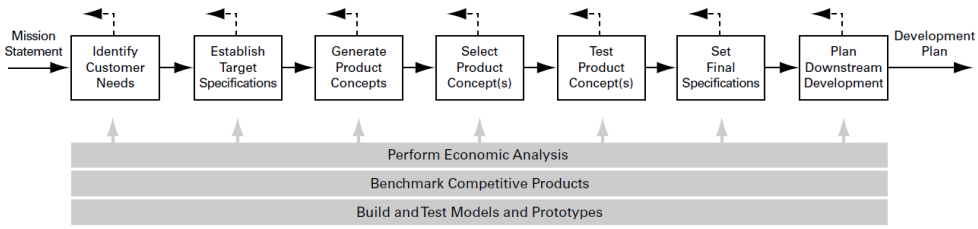


Figure 2.2 Front-End development process [2].

The Front-End Process suits this part of the project very well. This is an iteration process where many activities are overlapped. Some modifications need to be done to adapt this process to suit this project which will be shown in section 2.2.3.

2.2.3 **Modified product development process**

To fully suit this project the development process will be modified with some additions. The product development process that will be used for this project can be seen in Figure 2.3 below.

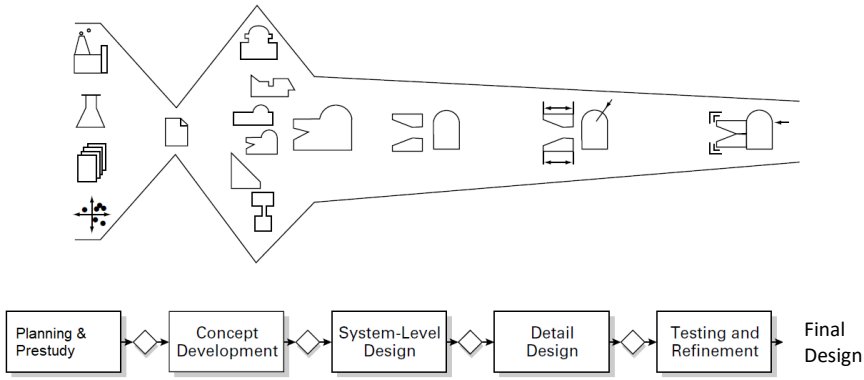


Figure 2.3 Modified Product development process.

Before the Concept Development phase begins, a pre-study will be conducted. This pre-study will contain an external analysis where the collected knowledge will be taken into account in the Concept Development phase. The Concept Development phase will focus on finding a suitable cleaning method for the project. In this step a proof of concept will be built to ensure that a successful product is generated in the end. At the next phase, System-Level Design the proof of concept will be developed into a final design where the design fulfils both the market and production needs. The next step, Detail Design will cover the material choice and the economic analysis of this product. This will then be evaluated both by the author and by potential users and the final design will be presented.

2.2.3.1 Pre-study

A wide external analysis must be made for this project, both on existing products and on the market, to see whom to specify the product for.

An external analysis will be made for existing products on the market. This analysis will be made to prevent this project from developing an already produced product. Another reason for this is to collect inspiration and ideas as well as gain knowledge of the products todays golfers use. This analysis will be performed by browsing the stores both in Sweden and internationally for their supply. Another key function for this external analysis is the authors experience of what is available on golf courses and amongst golfers today.

To ensure that the final design fulfills the market requirements, a market analysis must be made. This will be done by interviews, dialogs, and a survey. Neither of these methods have a high reliability as seen in Figure 2.4 but the advantages are that these methods collect a large amount of information for a low cost which is critical for this short project. As compliment, the author can be seen as a user due to his experience in golf which can be seen as a source with high reliability. The Interview will be held to a former employee at Ullared Flädje GK. Along the project, dialogs between the author and golfers will be held. The survey will contain a small amount of questions to understand whether such a product is needed on the market and which need it would fulfill.

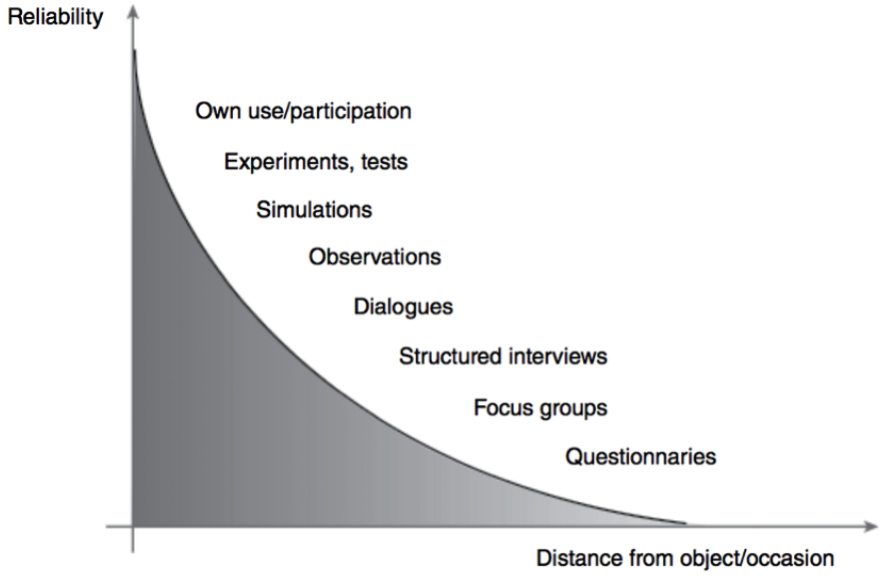


Figure 2.4 Reliability of different consumer insight methods [3].

2.2.3.2 Modified Front-End Process

Figure 2.5 below shows the modified Front-End process that will be used in the concept development phase of the project.

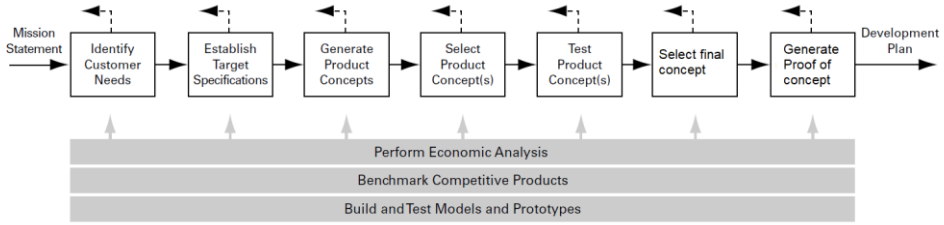


Figure 2.5 Modified Front-End process.

For the two last step the selected cleaning method will be adapted into a suitable solution for the proof of concept, which will be designed and built in the last step of the Concept Development phase. Step 3, 4, and 5 will be an iterate process with a cost-based approach. This means that the cheapest method and concept will be tested first. This is due to the budget limitation of the project.

3 External analysis

This section will cover the external analysis including benchmarking and market research. The benchmarking will focus on existing products with the intention of cleaning clubs and existing cleaning techniques for cleaning other sort of products.

3.1 Benchmarking

3.1.1 **Personal Use**

There are several products with the same purpose on the market today, both for the private and commercial market. For the private market, there are both fixed and portable solutions, for cleaning your clubs either at home or on the go during the round. The technical solution behind these are very similar, manual work with brushes, either with or without water.

Figure 3.1 a) Manual brush with a water dispenser [4], b) Manual brush tool [5].

Figure 3.1 a) and b) shows two existing tools currently sold at Dormy. Both of these two products target the cleaning process during your round. Both tools are manual and are time consuming and require a sink if you are about to clean the whole set at once. There are similar tools like this with the same purpose but with a slightly different design.

There are products with a further developed design with a combination of a rotating head to make the process more rapid, see Figure 3.2. This is a good complement out on the course but dirt and grass that has dried is hard to clean with these products.

Figure 3.2 Brush with rotating head [6]

Figure 3.3 Stand with brushes [23]

Figure 3.3 shows another type of solution available on the market. This sort of device is suited for a home use and not a portable device intended for use during the round. This product is based on the same technology as the previous, Figure 3.1, and Figure 3.2 where brushes with or without water cleans the club head with a manually work load. This sort of device is not effective for cleaning the grooves since the groves is not aligned by the direction of the brush. The club is inserted with the sole down and the grooves is then in a horizontal position, when the axis of movement is vertical. The relative speed between the face and the brush is slow and therefore a longer time is needed which makes this device ineffective.

3.1.2 **Professional Use**

Figure 3.4 Industrial sonic cleaner [22]

Figure 3.4 shows a solution for a professional use where ultra-sonic vibrations cleans the whole club. This is an expensive product and it is rarely used among golf courses. This is an advance product that are both expensive and time consuming. One cleaning cycle takes approximately 15 minutes.

Another solution more frequently used is shown in Figure 3.5**Error! Reference source not found.**. This is a bucket filled with water and brushes. This product comes in various forms and can be found on most courses, either at the practice area, club house or along the course.

The water bucket in Figure 3.5 is similar to the product seen in Figure 3.3. It is hard to sink the club with the groves vertical and still reach down until the whole face is covered without the shaft hitting the edge of the bucket. Therefore golfers insert the club with the grooves horizonal and then suffer from the same problem as the product in Figure 3.3.

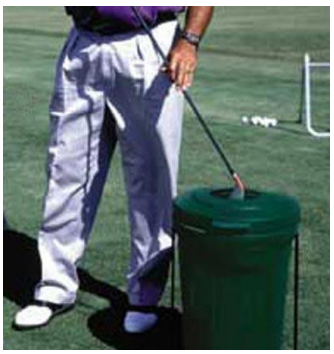


Figure 3.5 Water bucket with brushes for professional use [20].

3.1.3 **Technologies**

There are several cleaning technologies on the market available today. The following chapter will cover available technologies that can be designed for a cleaning device for golf clubs and therefore be a potential technology used.

Figure 3.6 Philips SmartClean [24].

Philips SmartClean in Figure 3.6 is a cleaning station for electric shavers. This device uses a pump to create a circular water flow around the head of the shaver. The dirt is dissolved by the detergent and then transported by the pump to the water container.

Figure 3.7 Philips Sonicare [7].

Philips Sonicare in Figure 3.7 is an electric tooth brush that uses a sonic technology that vibrates on a high frequency to create many small bubbles that drives the water and toothpaste between your teeth. These vibrations set the water into movement which dissolves the dirt.

Figure 3.8 Kärcher K5 [26].

A pressure washer, as seen in Figure 3.8 is frequently used and an effective tool for removing dirt and clean many sorts of materials and application.

Figure 3.9 Ultrasonic cleaning station [8].

This ultrasonic cleaning device seen in Figure 3.9 has a similar technology as the electric tooth brush with the difference that it only uses a water bath which the components are submerged down into. The ultra-sonic sound creates small bubbles which cleans the components.

Figure 3.10 Rotating brush [25].

A rotating, vibrating, or moving brush as seen in Figure 3.10 could be an alternative technology used, either by its own or combined with other technologies. This technique is on the market today for cleaning cars where water sprays out from the brush head.

3.1.4 **Summary**

There are many available products on the market with similar purpose. However, all of the products made for personal use require manual work load and are time-consuming to use. While the professional products do a good job but are expensive and large. What is missing on the market is a small device with the technology from one of the bigger machines, suitable for either homes or on golf cars.

The technology available vary in complexity and functionality. Many of these technologies can be combined such as moving brushes and ultra-sonic sound or together with a pressure washer. The electrical toothbrush uses a combination of sonic vibrations and brushes where the brush creates the movement of the water. This combination, ultra-sonic and brushes can be seen in other cleaning products such as body scrubs and cleaning devices for example bathrooms. This is a functional technique that can be adapted for different purposes. These products need water to be functional and for some applications detergent as well.

3.2 Market research

3.2.1 **Interview**

The interview was held together with a former employee at Ullared Flädje GK, in this report called "Andersson", with the purpose of understanding the needs and use of cleaning devices on golf courses. Andersson explained that at Ullared Flädje GK, the staff does not clean any clubs on a regular basis and that there was not any need for a tool among the staff at the golf course. However, there are manual cleaning stations provided for the players which are frequently used. There is always a need to further supply the players with services, and a tool that could improve the satisfaction of the customer experience would be of interest. Such a tool would be suitable near the practice area, the club house or on golf cars. Andersson explained that such a tool needs to be rigid with high quality and it is important to the staff that it would not need regular or time-consuming maintenance. Andersson also mentioned the importance of that it should be easy to use for the players. Regarding if such a product should be designed for one or several clubs, the answer was that it depends on the purpose. If the product is meant to be for the players before or after a round it should be designed for one club at a time according to Andersson. On the other hand, if it is supposed to be designed for the employees it could be a better choice to go with several clubs at a time, or the solution that takes less time.

Requested specifications from Andersson:

- Easy to use for the players.
- A rigid construction that could be mounted near the club house or on golf cars.
- For one club at a time.
- Low maintenance.

The full interview can be find in Appendix B.

3.2.2 **Survey**

The survey was handed out trough social media. In total 30 answers was received, and after a cleansing from respondents who did not play golf, 26 answers were remaining. Three questions were asked, the first question *How often do you clean the head of your golf club*, answered which routines the end consumer has today regarding the cleaning process of their clubs. The second question, *If you consider yourself to rarely clean your clubs, why?*, was asked to target the end consumers who currently don´t have the routine to clean their clubs often, to provide a understanding of the problems and difficulties of the cleaning process. The third question, *Would a tool make you clean your clubs more often*, answered whether the market was positive and curious of a potential product that could improve the cleaning process.

3.2.2.1 Result

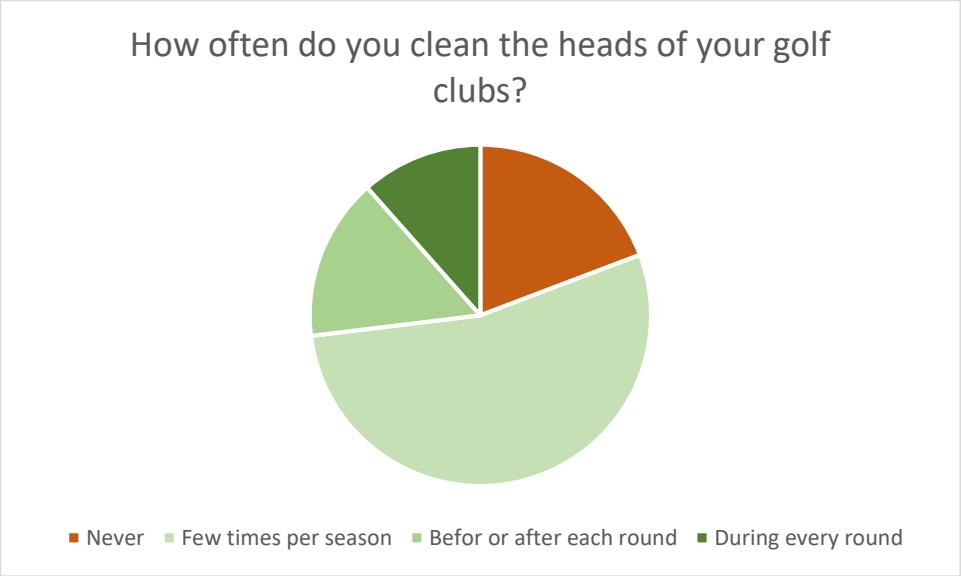


Figure 3.11 Chart of the answers from the question "How often do you clean your clubs?".

Figure 3.11 shows the results of the first question. Over 80% clean their clubs at least one time per season and most answered that they clean their clubs a few times per season (54%). Out of the 26 answers, three answered that they clean their clubs during each round, none of these answered the second question.

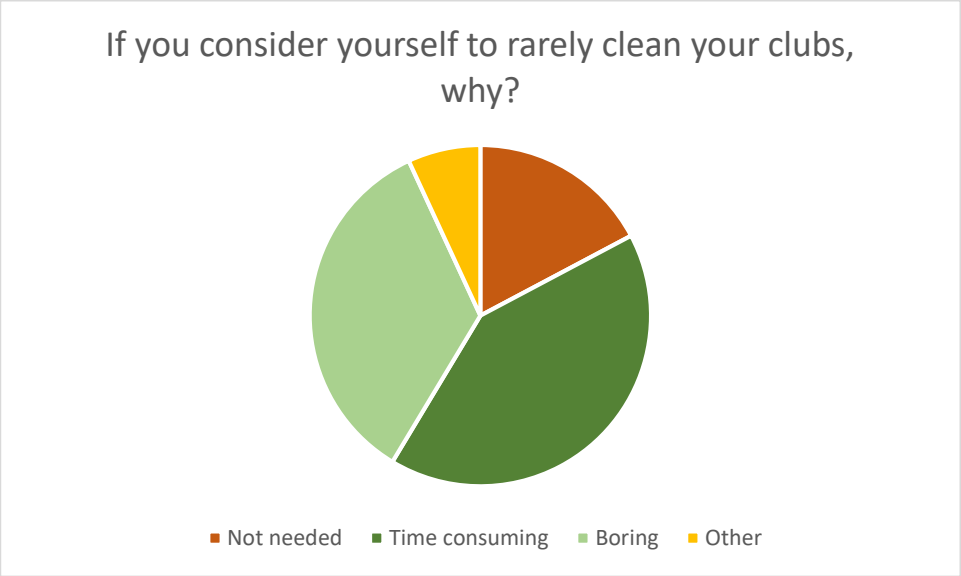


Figure 3.12 Chart of the result from the question "If you consider yourself to rarely clean your clubs, why?".

As seen in Figure 3.12, 78% answered the second question where 46% answered that at least one of the reasons was time consuming. 38% answered that at least one of the reasons was because it was boring and 8% gave other reasons. 19%, representing 5 persons answered that the reason was that it is not needed. Out of these 5 persons 2 also answered that they never clean their clubs and 3 answered that they clean their clubs few times per season.

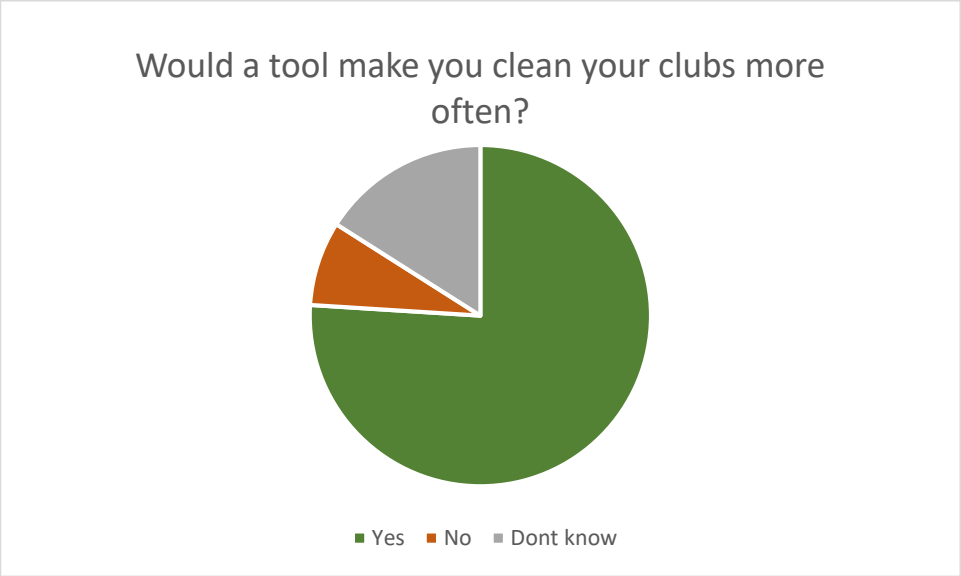


Figure 3.13 Chart of the result from the question "Would a tool make you clean your clubs more often?".

The last question seen in Figure 3.13, was supposed to give a result of the curiousness of the participators for a product that would help them in their cleaning process. 76% answered that such a tool would be appreciated and would make them clean their clubs more often, as shown in Figure 3.13. Only 8% answered that a tool would not make them clean their clubs more often, however, these two already clean their clubs regularly according to the second question, Figure 3.12.

3.2.3 **Summary**

Both the survey and the interview show an interest of a product that could improve the current cleaning process and the demands are for some aspects similar but at some points they differ. The similarities between the two markets are the operational aspects where the product should be easy to use and a faster alternative than the products on the market today. It should also be small enough to be practical to have in your home. For golf courses the quality, maintenance and reliability are also very important aspects.

4 Concept Development

This section will cover the development process of the cleaning method with the stages mentioned in 2.2.3, the modified Front-End Development Process.

4.1 Identify Customer Needs

The customer needs differ some between the commercial market and the private. The private market mainly wants to have an effective and simple product whilst the commercial market puts a higher demand on the reliability. These customer needs are described in very general key needs. The reason they are not separated in to smaller and more specific needs, is because many of these are correlated and are overlapping each other. Therefore, it is easier do develop a product with the general needs in mind.

Key needs;

- User friendly
- Effective
- Reliable
- Low maintenance
- Mounts for walls and golf cars
- Low cost

4.2 Specifications

The customer needs are transformed into specifications. To ensure that the washer is perceived as effective it must be faster than the manual washers on the market today. These manual washers clean the club in approximately 20 seconds pending on the amount of dirt. A cleaning cycle of five seconds is chosen to ensure the competitiveness advantage over manual washers. The maximum price of 1500:- SEK is set to be in the same price ratio as other electronic accessories for golf such as sensors and watches. The washer should be able to fit on a golf car and therefore

the dimensions is an important factor. The washer should not exceed 200x200x200mm to ensure that it is portable and would fit on a golf car.

The specifications for the cleaning method is divided into two categories, Must and Should as seen in Table 4.1. The requirements in the category Must are considered more important and needs to be fulfilled. The requirements in the category Should, should be fulfilled as long as it is not of cost of any of the Must requirements.

Table 4.1 Specifications for the washer.

Specification		***Category***
Life time	3 years	Must
Effective	Cleaning cycle, 5 sec	Must
Both irons and woods		Should
Cost	Selling prize < 1500:-	Should
Size	200x200x200mm	Must

4.3 Generate Product Concepts

Due to the complexity of some available technologies, this will be an iteration process where the most cost-effective technology will be tested and evaluated first. When a suitable technology is found, concepts of how this technology can be used and mounted within a product, is made.

The available technologies that will be taken in consideration are those from the external benchmarking.

Experts from companies providing equipment for cleaning different applications where asked whether their product may consist of suitable techniques that can be implemented for the golf club cleaner. Companies asked was ULTRASONIC.SE and BEJA NORDIC. The response for the two experts said the same thing, an ultra-sonic cleaning device would do the job and similar applications already exist for golf clubs. But both of the replies also implicated that the cleaning cycle would take around 15-20 minutes. This would be a critical factor in this project due to that cycle time is an important aspect. After consulting with Linus Eckerljung, founder of Aldmek AB, regarding his thoughts on which cleaning technology would be suitable, rotating or moving brushes was a more suitable solution. Linus explained that for cleaning farming machines from dirt and grass which can be seen as a

similarity, a brush together with water was the easiest solution that gave the best result.

The technologies listed in Table 4.2, were then given a score upon possibility to work based on inputs from the several companies and experts, ULTRASONIC.SE, BEJA NORDIC, and Linus Eckerljung. The complexity and costs score are based on information from supplying websites and by inputs from Johannes Ekdahl Du Rietz.

Table 4.2 Scoring table for cleaning techniques.

Technology	*Complexity*	*Possibility*	*Cost*
Water pressure	3	3	2
Ultra sonic	2	2	1
Sonic brush	2	5	2
Moving brush	4	5	4

Based on this scoring and the short budget the first technology tested is the moving brush.

4.3.1 **Brushes**

Three different types of moving brushes will be tested, see Figure 4.1 a)-c), to see which type and direction that will clean the grooves in the most proper way and perform the best regarding complexity and spill.

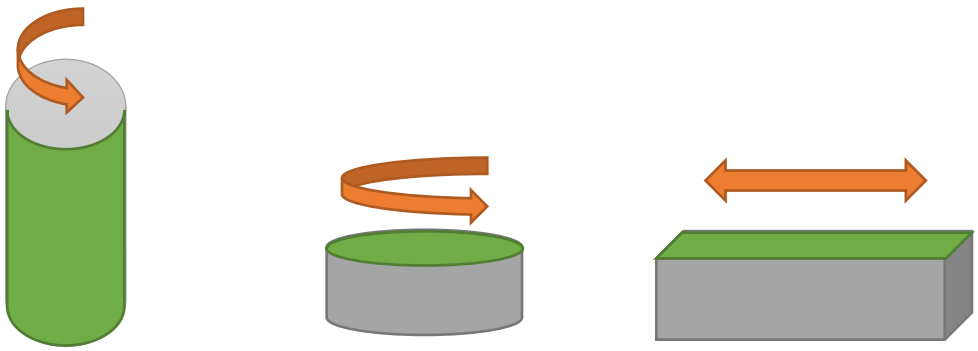


Figure 4.1 a) Brush named A, b) Brush named B, c) Brush named C.

4.3.1.1 Test 1

The test will be done manually, with the help of a screw driver. Brush C will be moved by hand. The test will be done with water and for the first iteration, three wedges will be tested with each brush. After the first iteration an evaluation will be made, and one or two brushes will be taken into a second iteration.

4.3.1.1.1 Result Test 1

Table 4.3 displays the before and after pictures of the club as well as the calculated cleaning rate.

Table 4.3 Results of Test 1.

Brush	***Before***	***After***	***Cleaning rate***
A			94%
B			48%
C			63%

4.3.1.1.2 Evaluation and discussion Test 1

The result was calculated by dividing the nominal length of dirty grooves afterwards the cleaning process by the nominal length of dirty grooves before it was cleaned. The three tests were performed with the same time scope of 5 seconds and with approximately the same amount of pressure against the face of the club.

The three different brushes gave a different result. Brush A and C moved in the same direction as the grooves which therefore performed better.

A significant difference can be seen in the result of these three tests, where the brush rotating in the same direction as the grooves made a very pleasing result. Brush B performed worst which also was expected since it is harder for the brush to reach into the grooves when rotating in that direction. Therefore, this type of brush will not be taken into further consideration. For the next iteration, Brush A and C will be tested again to confirm the result in Test 1 as well to be tested with other brands of irons.

4.3.1.2 Test 2

This test was performed with the same method as Test 1 with a cleaning cycle of 5 seconds. The test will further evaluate Brush A and C to get a wider understanding and knowledge of which technology and method that can be suitable for the final design.

4.3.1.2.1 Result Test 2

Table 4.4 shows an extraction of the result for the most dirty clubs which are the most difficult ones to clean.

Table 4.4 Results of Test 2.

Brush	*Before*	*After*	*Cleaning rate*
A			92%
C			69%

4.3.1.2.2 Evaluation and discussion Test 2

The second attempt gave the same result as previous for the wedges. The brushes seem to clean the different clubs in such an effective way that this is a suitable method for this project.

A scoring table based on the cleaning rate result and the simplicity of the method is shown in Table 4.5. The simplicity score is based on how easy it would be to mount the brush in a device. For the test it was very simple to drive brush A but since brush C is moving back and forward in one direction it is more likely that vibrations and leaks will occur. Therefore, this brush was only given the score of 2 in this category.

Table 4.5 Scoring table for the three brushes

Brush	*Cleaning rate*	*Simplicity*	*Total*
A	4	4	4
B	2	4	3
C	3	2	2,5

Brush A received the highest total score. Therefore, this brush will be further tested and evaluated. Working with Brush A, gave the knowledge that speed, water and the amount of pressure against the club face where aspects of importance.

4.3.1.3 Test 3

For this test, only brush of type A will be tested. From previous test, this brush performed best and important aspects to test further is the amount of water and speed. A different size of the brush will be tested and compared to the previous results. To test the impact of the water, a wet brush will be compared to the previous tests where the club is completely covered with water.

4.3.1.3.1 Results Test 3

Table 4.6 displays pictures of the before and after state as well as the calculated cleaning rate.

Table 4.6 Results of test 3.

Brush	***Before***	***After***	***Cleaning rate***
Larger diameter			91%
Soaked brush			86%

4.3.1.3.2 Discussion and evaluation Test 3

The brush with a larger diameter gave approximately the same result as the smaller brush, however the brush with the larger diameter covered a larger surface of the club face. The larger diameter led to a higher speed which meant a higher amount of splattering. This brush also requires a larger construction for the product. For the test with a soaked brush above the water, the brush was only soaked once before the club was cleaned. Even if the brush was not continually watered, the result turned out to be similar to the completely water covered test.

Conclusions that can be made out from these tests are following;

- The cleaning method with a brush would fulfill the requirements
- A brush of type A is the most suitable solution
- The brush with a smaller diameter are preferable
- The club does not need to be covered with water, but water is needed
- This solution could clean a very dirty club in 5 seconds

4.3.2 **Prototype 1**

4.3.2.1 Club orientation

First step was to identify the possibilities and difficulties of inserting the club in a washer. This was investigated first since this would have a great impact of how the internal design with the brushes would be arranged. Two ideas of possible ways to insert the club into a washer was thought out and tested. One, where the club is inserted straight down and one of where the face is angled 90 degrees with the grooves vertical. To test and evaluate these two, molds was designed and made to insert he club either straight or angled. The two molds can be seen Figure 4.2 a)-b).

Figure 4.2 a) Mold with grooves vertical, b) mold with grooves horizontal.

4.3.2.1.1 Result and evaluation

The vertical design allows a thinner frame around the club and a small construction would be possible. This solution also means that the brush would be mounted horizontally to align the rotation with the grooves. To mount the brush horizontally, it would be possible to have the water line below the axis and decrease the risk of leakage at the bearings. Therefore, this solution gets a high score for both required size and simplicity. However, to insert the club head vertically, the club shaft needs to be angled. This can for some clubs, if the washer is mounted on the floor, implies an unusual position for the user since the club must be held at a lower height. If the washer is placed above ground level, this will not be an issue since the whole construction will be placed at a more ergonomic level.

The horizontal solution would imply a more ergonomic solution if the washer is mounted on the floor, however as seen in Figure 4.2 b), a cut out would be necessary for the shaft. Since this angle can differ between different clubs and especially since the washer needs to be suitable for both left- and right-hand players, the cut out would have to be at a significant size to ensure that the washer fits all sort of irons. The brush would need to be mounted at a vertical direction to satisfy that the brush rotates in the same direction as the grooves. This means that the bearings for the brush needs to be mounted at the bottom and on the top, which implies a higher demand of waterproofness on the lower bearing. Therefore, this solution will get a lower score on both simplicity and required size, see Table 4.7.

Table 4.7 Scoring table for club orientation.

Type	***Ergonomic***	***Required size***	***Simplicity***	***Total***
Horizontal	5	1	4	10
Vertical	4	5	5	14

The vertical solution gets the highest overall score and are the cleaning method that will be further tested and evaluated.

4.3.2.2 Test of design

A simple box made out of cardboard was built to further evaluate if this design solution would be suitable. A brush was attached in the box and driven by a screw driver to test the system.

Figure 4.4 Brush in Prototype 1.

Figure 4.3 picture of Prototype 1.

Figure 4.3 above shows the prototype with the lid and the brush. The clubs tested was cleaned in a cleaning cycle of 5 seconds with a wet brush. The setup can be seen in Figure 4.4.

4.3.2.2.1 Result and evaluation

After testing the ergonomics and design of the lid, areas of concern are to fit the whole club deep enough into the washer to let the brush clean the whole face, since the shaft don't fit the hole. To solve this issue a redesign of the cut out was made to enable the club further down the hole. The redesign can be seen in Figure 4.5.

Figure 4.5 New lid design.

This solution performed well, and this system design will be further developed into a fully working prototype as proof of concept.

4.4 Proof of Concept

4.4.1 **Brainstorming**

A brainstorming session was held to generate ideas of how both the construction and design could be arranged for the proof of concept. The main target of this prototype is to show the function of the cleaner and to further test the cleaning method. The prototype should also function as a test product for potential users.

The specification for the brainstorming sessions was following;

- Clean the face of the club within 5 seconds with the use of a brush
- The grooves of the club should be vertical
- Both the face and the sole of the club head should be cleaned
- The prototype should perform as an actual product

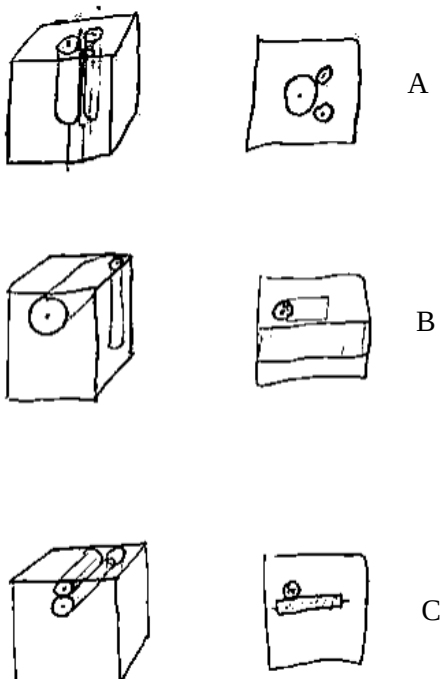
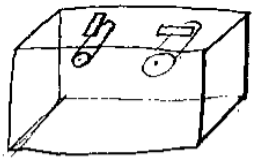


Figure 4.6 a) Vertical brushes for face and sole b) One horizontal and one vertical brush for sole, c) Two small horizontal brushes for face and one vertical for sole.

D



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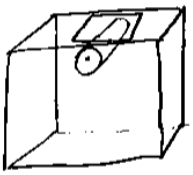

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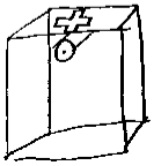

Figure 4.7 d) Two separate brushes for sole and face, e) One brush for sole and face, large opening, f) One brush, cross opening.

Figure 4.6 shows different variations of the brush layout. The idea behind these three layouts was to clean the whole club, both the face and the sole at once with several brushes in both directions. After a consultation with Damien Motte, the focus was shifted from having several brushes to having either one or two brushes and clean the face and the sole in two different steps, to cut down both the complexity and cost. The ideas based on this concept can be seen in Figure 4.7.

Table 4.8 Scoring table of brush layout.

Type	*Complexity*	*Effectiveness*	*Functionality*	*Total*
A	2	4	3	9
B	2	4	2	8
C	1	4	4	9
D	3	2	3	8
E	5	2	3	10
F	5	2	4	11

Table 4.8 above lists the concepts and their score for each category. The score of complexity is based on the number of brushes and their orientation, where more brushes in different direction gets a lower scoring. Effectiveness is based on wether the club can be totally cleaned in one or two steps. Functionality is a very subjective scoring where the author predicts how the layout would work in a practical test.

The layout that was chosen to take into further development was layout F. This layout only uses one brush and instead have a lid that allows for the club to be washed in two directions, both the sole and face, without causing a greater amount of splattering because of a larger hole. The chosen layout of the lid can be seen in Figure 4.8.

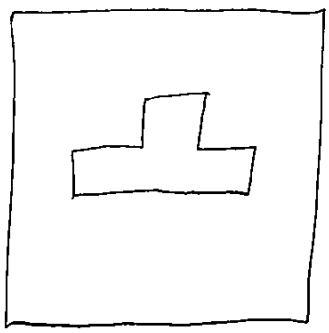

Figure 4.8 Chosen lid design

Several iron clubs and wedges was measured to identify the needed dimensions of both the cut out on the lid and the dimensions of the water tank. The sole width and length as well as the hight of the face was measured. These dimensions can be seen in Table 4.9 Dimensions of different club models.Table 4.9.

Table 4.9 Dimensions of different club models.

Club	*Sole width*	*Sole length*	*Face height*
Mizuno MPH5 - 4	26	82	54
Mizuno MPH5 - P	18	77	61
Cleveland RTX 588 - 60	20	77	62
Links2Links - 60	24	75	53
TaylorMade R11 - 8	25	80	51
TaylorMade R11 - A	20	80	51

Based on this, a simple sketch with the needed dimensions was made, seen in Figure 4.9.

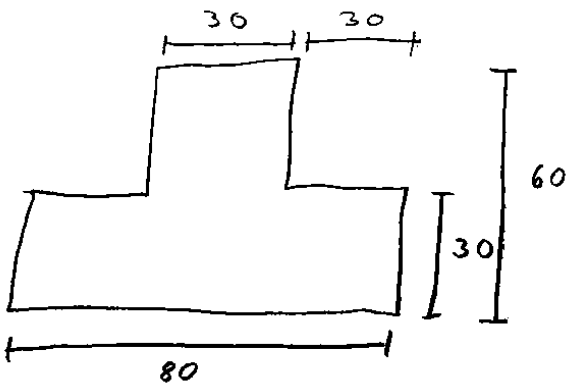

Figure 4.9 Lid hole dimensions

4.4.2 **Components**

4.4.2.1 Water tank

Three options were chosen, either to weld a metal container, glue an acrylic box or to buy a box that would be able to suit the prototype. After a meeting with Bert Berglund at the work shop located in IKDC, where these three options were discussed, it was cleared that both a metal and an acrylic box would be both time consuming and expensive since it was required to be water proof and stable enough to handle the components.

After browsing the market for a suitable box, a EURO BOX with the dimensions 200x150x145 was purchased, seen in Figure 4.10. This box has a wall thickness of 2mm and are made out of Polypropylene.

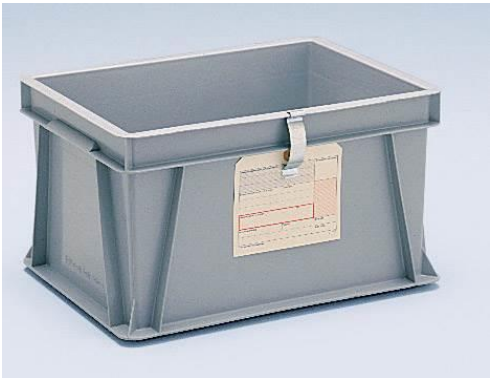

Figure 4.10 The water tank used in the proof of concept [21].

4.4.2.2 Brush

The previous tested brush had a suitable diameter and design for the prototype. A research for better adapted tailor made brushes was made, but the budget of this project did not cover such a purchase. Since the previous brush worked well this brush was used and adapted to suit this prototype. The brush is originally designed to work as a bottle cleaner. The diameter is 50mm for the brush and the shaft have a 5mm diameter.

Figure 4.11 shows the brush before and after it was adapted for the prototype.

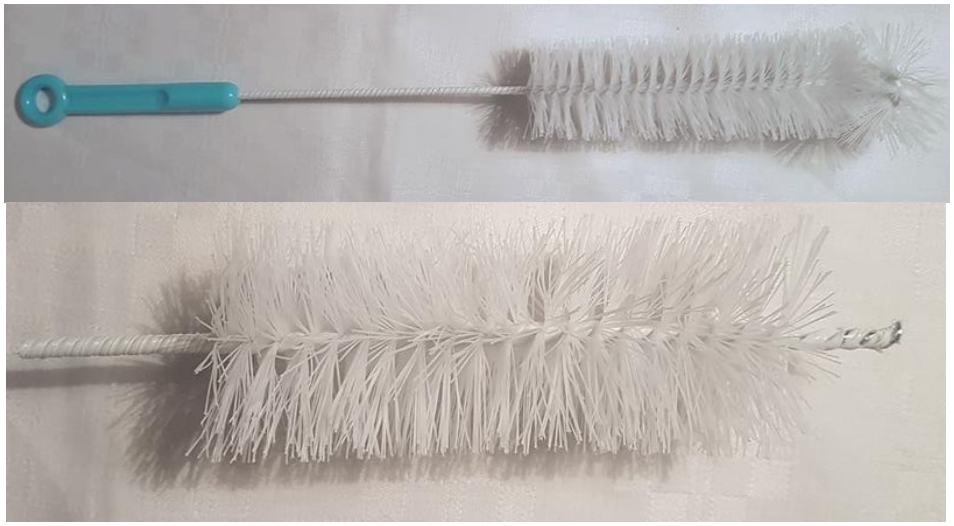

Figure 4.11 Brush used for the proof of concept.

4.4.2.3 Motor

Since the product are tended to be used both at homes and on golf cars, it was preferable to use a 12V DC motor. The motor chosen was a 12V DC motor originally mounted in a screw driver together with the gear box mounted on the motor. The battery source, a 12V Lithium battery was used to drive the motor.

4.4.2.4 Electronics

To control the speed and cycle time a transistor controlled by an Arduino was connected between the battery source and the motor. To start the cleaning cycle a microswitch was used.

4.4.3 **Construction**

To fix the brush's position and to ensure a water proof construction, two bearings was used, see Figure 4.12. The box was enforced with a laser cut acrylic plate at each bearing to ensure a secure fit, which can be seen in Figure 4.13.

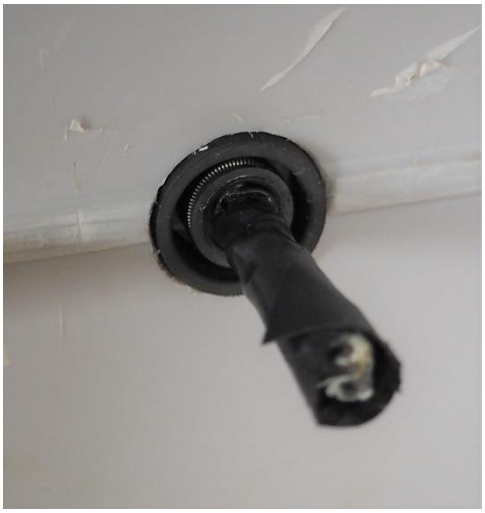

Figure 4.12 Picture of the bearing from the outside.

Figure 4.13 Picture of the bearing from the inside.

The motor is fastened with two clamps on a motor plate made out of laser cut acrylic. The motor plate is resting on two supports. Both the supports and the motor plate are designed in CAD to fit the box and the motor. The 2D CAD for the support and motor plate can be seen in Figure 4.15 and Figure 4.14.

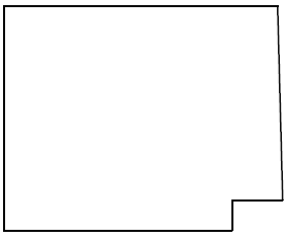

Figure 4.15 Motor plate support.

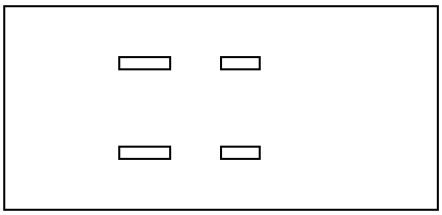

Figure 4.14 Motor plate.

These plates are glued together and then glued to the box. The motor is then fastened with two metal hose clamps on the motor plate, see Figure 4.16.

Figure 4.16 a) & b), Pictures of the motor plate and support.

The lid is designed in CAD which can be seen in Figure 4.17. The hole for the clubs are designed with the dimensions from Figure 4.9 and with the extra cut out shown in Figure 4.5 for the shaft. The lid was then laser cut in acrylic. A rubber seal is glued to the inside of the lid, sealing the lid to the box as well as prevent splattering from occurring when cleaning the clubs.

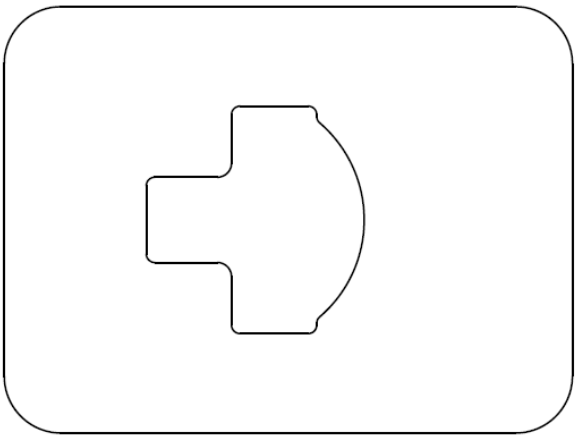

Figure 4.17 2D CAD of the lid.

4.4.4 **Electrical schematic**

To regulate the motor a mofset Q1 of type IRF520 was used. A diode D1 was placed parallel to the motor to protect the mofset. The motor is driven by a 12V Lithium battery. To control the mofset an Arduino UNO is used. Output pin 3 is used to regulate the mofset transistor. The microswitch, S1 is connected with a 5V output from the Arduino and a 100K resistor, R1, and then connected to input pin 8. An extra switch, S2 is placed parallel with the microswitch in case of a failure of the microswitch. The electrical schematic can be seen in Figure 4.18.

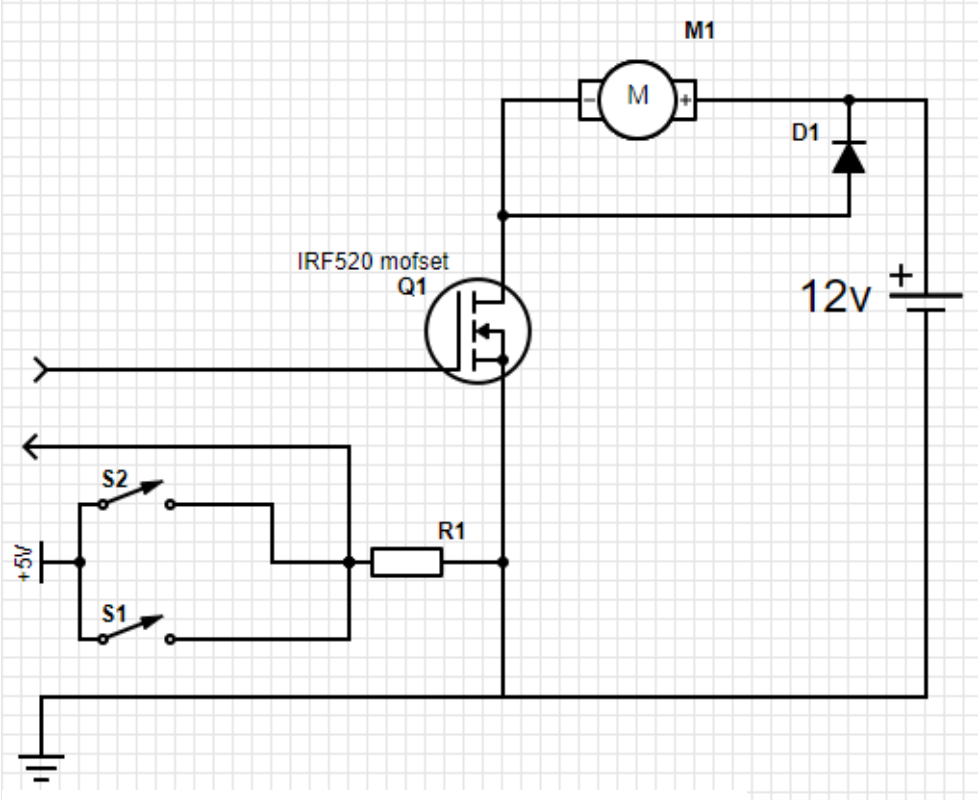

Figure 4.18 The electrical schematic used for the proof of concept.

4.4.5 **Concept**

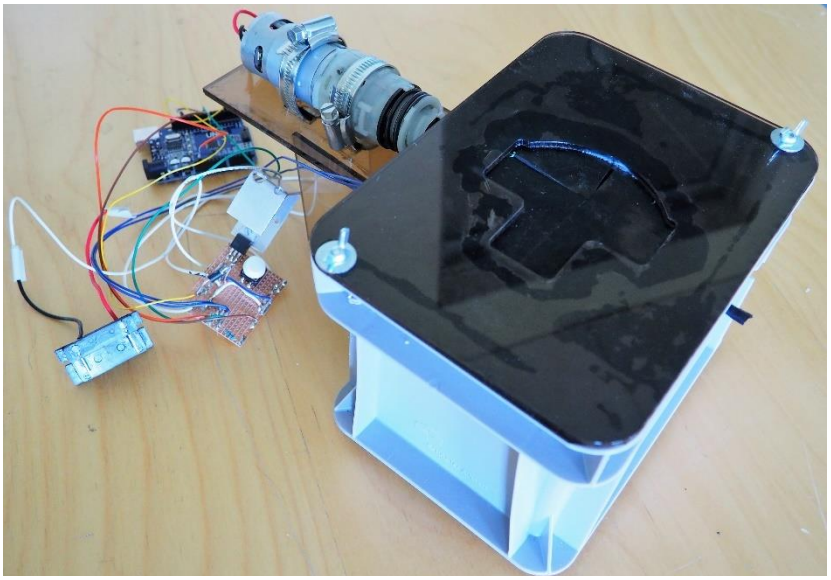

Figure 4.20 Picture of the proof of concept.

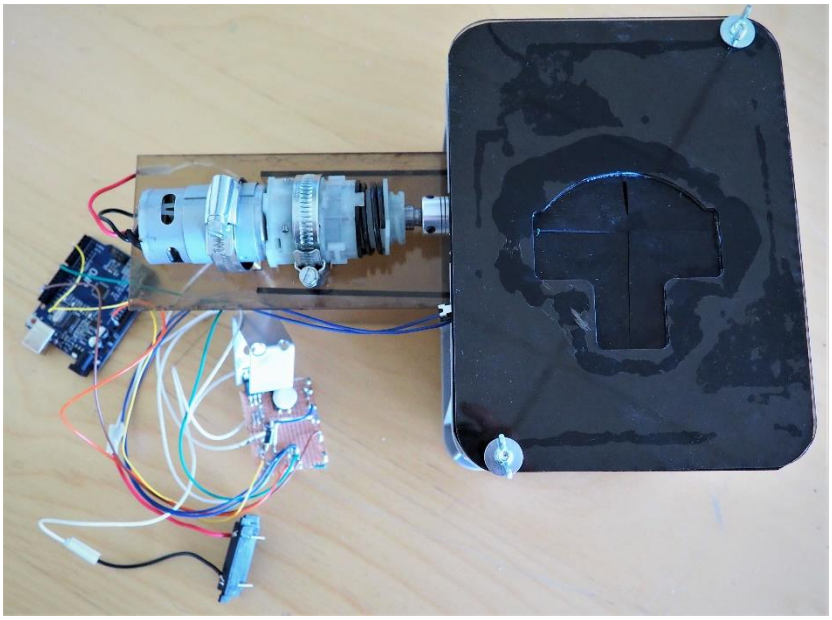

Figure 4.19 Picture of the proof of concept

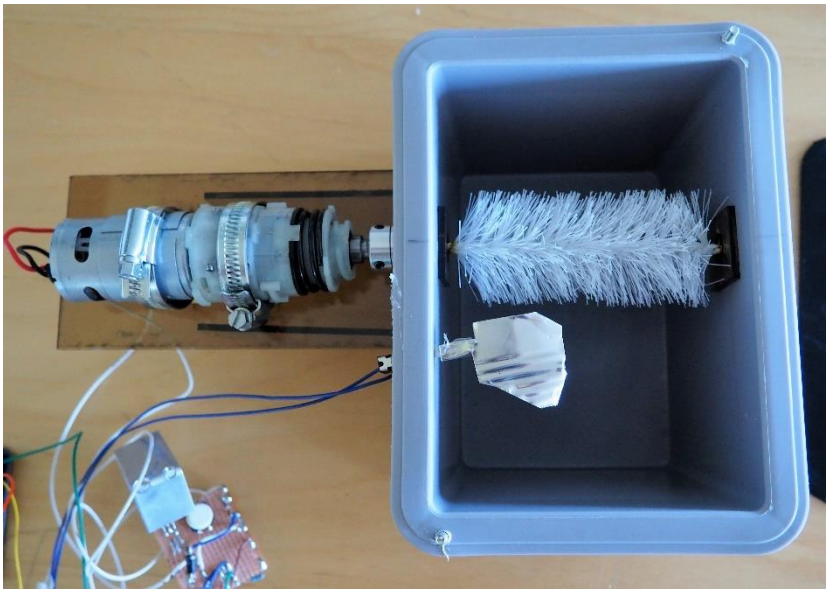

Figure 4.21 Picture of the proof of concept without lid

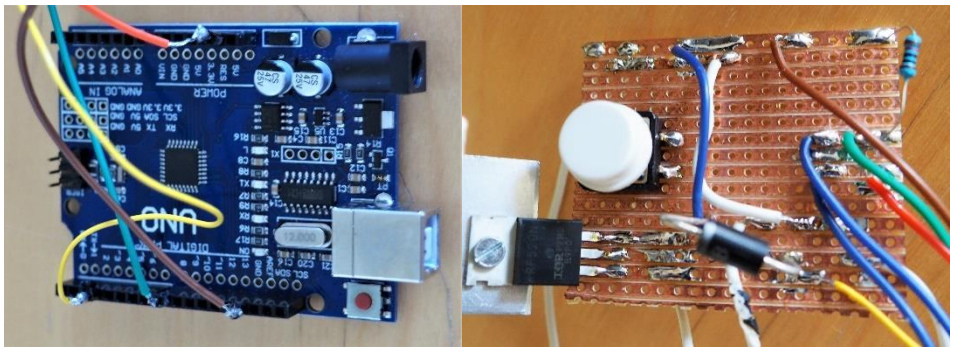

Figure 4.22 a) electric wiring on the Arduino, b) Electric circuit board.

Figure 4.19 to Figure 4.22 shows the prototype built. The brush moves in a cycle of 5 seconds and the bottom half of the brush is intended to be covered with water and by this always keep the brush soaked. The rubber sealing also acts as a cover and protection between the club and the microswitch.

This prototype will be tested, both by the author but also by others to collect inputs and thoughts that can be useful when designing the final design.

4.4.6 **Test and Results**

The washer was tested to evaluate the performance and functions and to understand the handling of an electronic golf club washer. The clubs where washed for one cycle at 5 seconds, both the sole and face was washed. The result can be seen in Table 4.10 and Table 4.11.

Table 4.10 Results of the face cleaning test.

Before	***After***	***Cleaning rate***
		85%
		87%
		91%

Table 4.11 Results of the sole cleaning test.

Before	*After*
	
	

4.4.7 **Evaluation and Inputs**

The test was performed both by the author and by two invited golfers to collect outside inputs and thoughts. The washer was easy to handle and the size of the hole for the clubs seemed to be correct for these irons. The clubs tested where very dirty with both dried mud and grass. The mean cleaning rate of 88% is a good result for these clubs regarding the amount of mud in the grooves. However, the cleaning cycle of 5 seconds was perceived as short for both the author and the golfers. For such muddy clubs a longer cleaning cycle would be preferable. The insights from the golfers was that this prototype had such a size that it would be tough to have a place for it in his home. To be useful for home use the size is a very important factor. However, the golfers were surprised by the result and how easy it was to use and would rather use this at the golf course than the cleaners mounted there today, see Figure 3.5.

The golfers do not regular clean their clubs today, which they say can be improved by this product. One of the golfers also implies that the price would be an important factor since it to him would be a gimmick and not a product he seems to have a need for today. But for the right price the golfer says that he would like to have it at home and in that case, he thinks that he will clean his clubs on a regular basis. The other golfer is positive that he would like to have this at home but also mentions that the price would be important.

Both the authors and the golfer's insights are that this prototype could lead to a potential product that the market would appreciate. The design and cleaning method seems to be suitable. For the final design it would be preferable to have a cleaning cycle that varies dependent of how long the club is held in the machine rather than a fixed time.

The design where both the face and the sole are cleaned with the same brush works well and are suitable for the final design.

5 System-level Design

This chapter will present the development and result of a final design appropriate for the market. It will contain both the final design, included components, a suggestion for the production, material choice and economic aspects.

Key functions and details the product needs to fulfill based on the consumer needs and experience gained after testing the prototype;

- Be able to change the water and clean the washer
- Have one brush that can clean both the sole and the face
- Have a variable cleaning cycle
- Have a slim design
- Have a low production cost
- Be able to mount on golf cars

Thorough the whole development process the production process was develop along the concept generation as well as the cost aspect. A CAD model was developed along this process which was continuously improved to fulfill all key functions.

5.1 Design Solution

5.1.1 **Change the water**

For the first step a brainstorming session took place where multiple solutions for the construction design where generated. The three most promising of these ideas and concepts are shown in Figure 5.1 to Figure 5.3.

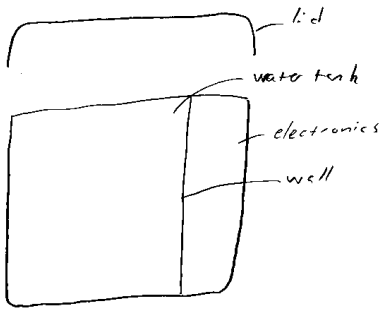

Figure 5.1 Concept with a water tank, a lid and a cover.

The construction in Figure 5.1 is seperated into three parts, a water tank, a compartment for the electronics on the side with a cover and a lid.

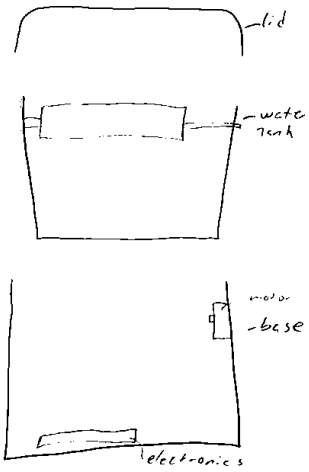

Figure 5.2 Concept with a base unit, a water tank and a lid.

This construction in Figure 5.2 is seperated into three parts, a base unit where the motors and electronics is mounted, a removable water tank which can easily be cleaned and a lid.

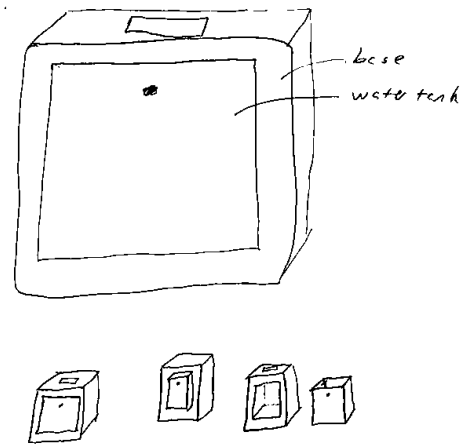

Figure 5.3 Concept where the water tank can be removed like a drawer.

The design in Figure 5.3 is similar to the design in Figure 5.2 with the difference that the water tank is removable acting like a drawer.

In general, two categories if ideas were presented, either to have a removable water tank or a fixed. The benefits of having a removable water tank is to simplify the cleaning process of the washer but with the cost of a more complicated construction to ensure it is water proof and reliable with the connections between the motor and the brush. This would increase the cost of the washer. The construction where the water tank is fixed was therefore chosen to be further developed.

Ideas of having a two-part construction where the lid acts as a cover for both the water tank and the electronics was considered but was dismissed due to the lack of protection for the electronics when the lid is removed for cleaning. The chosen construction for the washer is to divide it into three parts, a water tank, a lid and a cover for the electronics.

5.1.2 **Outer design and mounts**

A general idea of the outer design was sketched and are shown in Figure 5.4.

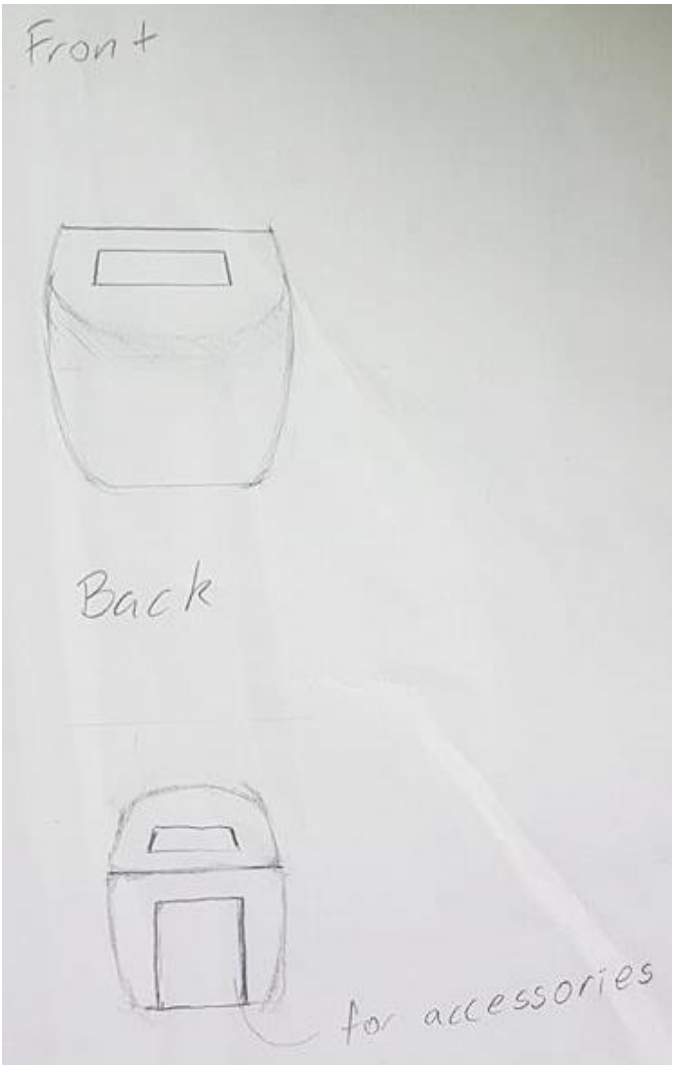

Figure 5.4 Sketch of the outer design.

The idea shown in Figure 5.4 above, builds on a system where accessories such as mounts adapted for either walls, golf cars or for the floor can be attached. By this, the washer can be used in several different areas, both at home and on a golf course where the customer choses what accessories they want to pay for. By this, the price for the base unit can be decreased. These concept ideas can be seen in Figure 5.5 below.

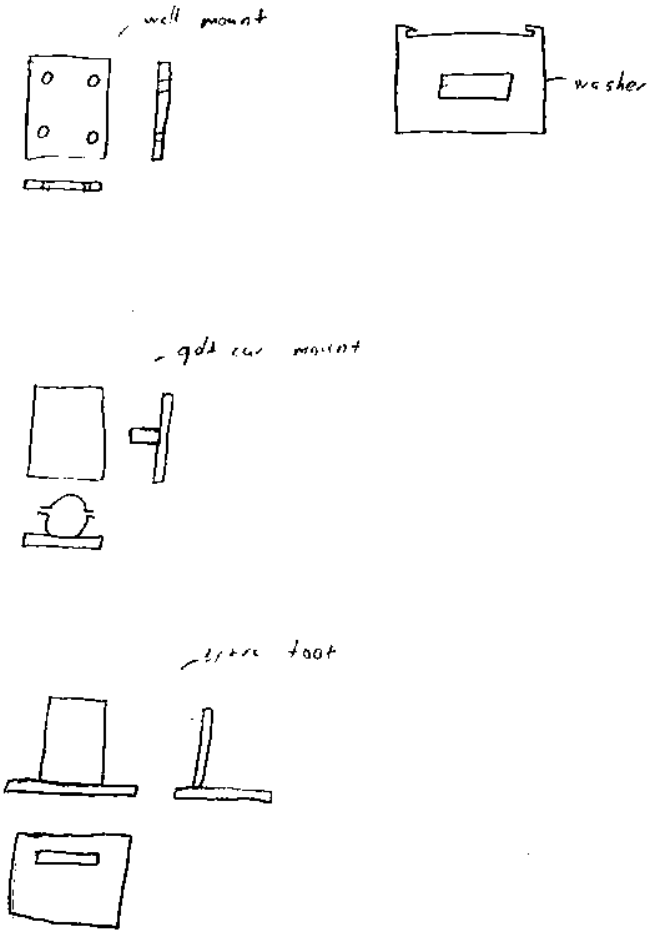

Figure 5.5 Concept sketches of mounts.

The idea is to slide the washer on the mount. By this, the washer can easily be removed and cleaned. The CAD result of these mounts can be shown in Figure 7.5 and Figure 7.6.

5.2 Functions and Details

5.2.1 **Brush**

Similar to the Proof of concept, a single brush system would be used, possible to clean both the face and the sole. The lid design in the proof of concept was a well working design and was chosen to be kept for the final design. There are no standard brushes on the market for this purpose. However, there are many suppliers that can customize and deliver brushes on demand. An example of brushes is shown in Figure 5.6 which are made by YIDABRUSH [9].

Figure 5.6 Example of a suitable brush [9].

The water sealing bearings used on the proof of concept worked well and will be used in the final design. These can be shown in Figure 5.7.

Figure 5.7 Picture of the bearings.

5.2.2 **Trigger system**

The automatic function used in the proof of concept was considered to be a function that satisfy the user-friendly need. The micro switch can malfunction if the club is not inserted correctly which is not desirable. After a consultation with Johannes Ekdahl Du Rietz, the idea of a sensor would solve this problem. The sensor intended to use for the final design is the same sort that is used for automatic water taps. This infrared proximity sensor, seen in Figure 5.8 comes in various sizes and specifications.

Figure 5.8 Sharp GP2Y0A51SK0F 2-15cm Infrared Proximity Distance Sensor [10].

A sensor that detects an item between 2-10 cm would fulfill the need of the trigger device.

5.2.3 **Other components**

The motor used for this final design is a standard 12V DV Worm motor with a fixed gear box mounted directly on the motor. This keeps the cost down as the same time as it is easier to get hold of and to mount. The motor can be seen in Figure 5.9.

Figure 5.9 DC 12V 110rpm Worm Gear Box Reduction Motor [11].

The system is driven by a 12V DC supply to easily be mounted on a golf car. The power supply used is a standard power adaptor which can easily be bought in large quantities. This power adapter manufactured by XyyPower is shown in Figure 5.10.

Figure 5.10 AC 220v to DC 12v 4a led light power adapter CE ROH UL FCC [12].

5.2.4 **Composition**

Based on the drawings and ideas of the design and the included components, a CAD model was designed to fulfill all the functions and needs. Figure 5.11 below, shows the water tank. On to the water tank the bearings, brush, motor, and sensor will be mounted. On both the cover and the water tank, a small hole in the bottom can be seen with the purpose of drain water from the electronics compartment.

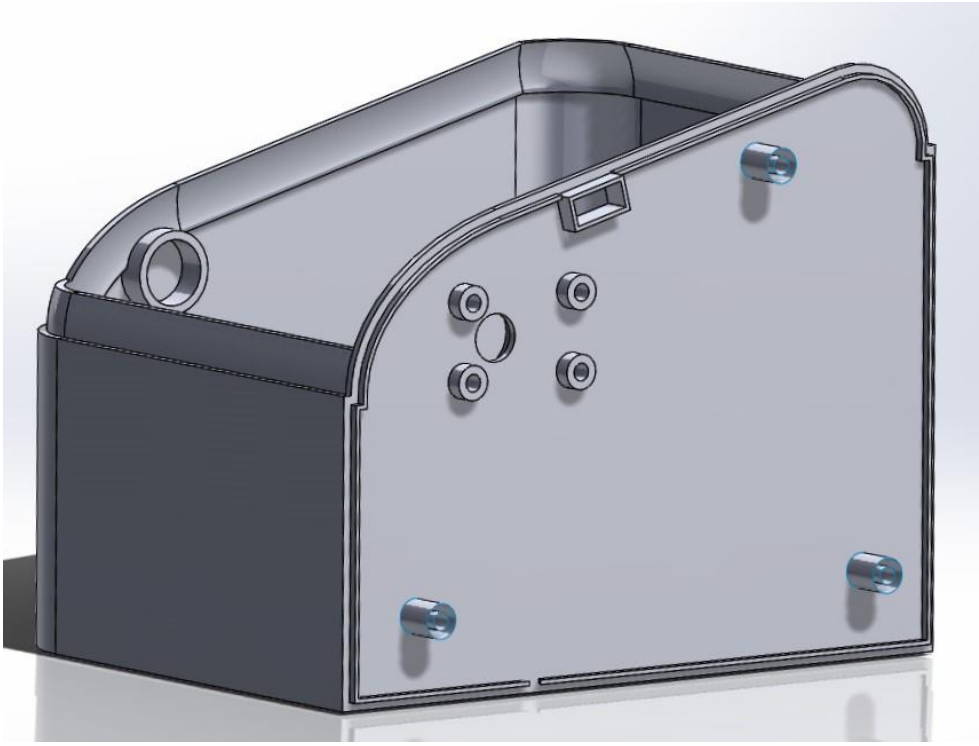

Figure 5.11 The water tank for the final design.

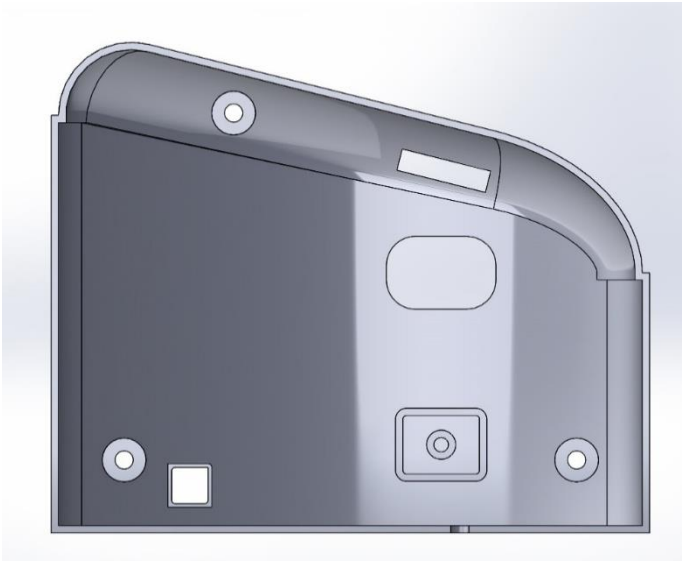

Figure 5.12 The cover for the final design.

On the cover seen in Figure 5.12, the power supply port and a release button for the lid will be mounted before the cover is screwed together with the water tank. The release button is shown in Figure 5.13.

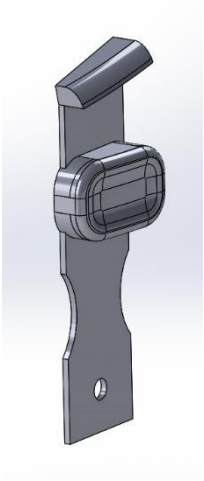

Figure 5.13 Release button for the final design.

The lid will have the same cut out for the golf club as the proof of concept. Inside the lid, ribbons is used to prevent the water to splatter and seal the water tank. The lid can be seen in Figure 5.14.

Figure 5.14 The lid for the final design.

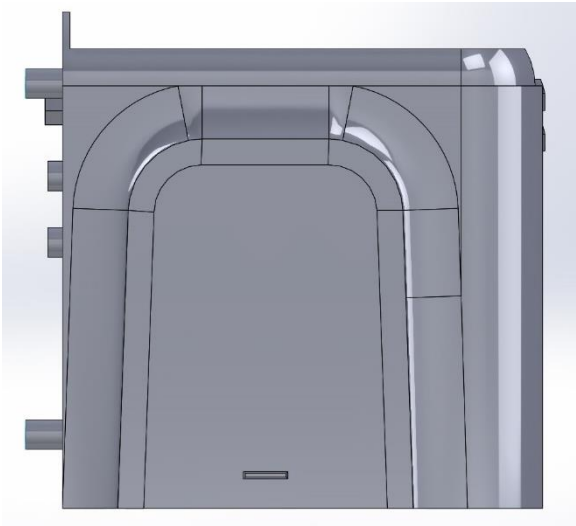

Figure 5.15 Back of the water tank for the final design.

The back of the water tank will have the mount for the assessories, which enable the washer to be mounted on both a golf car, a wall or on the floor. This can be seen in Figure 5.15.

The four parts put together can be seen in Figure 5.16 and Figure 5.17.

Figure 5.16 All parts mounted, left side.

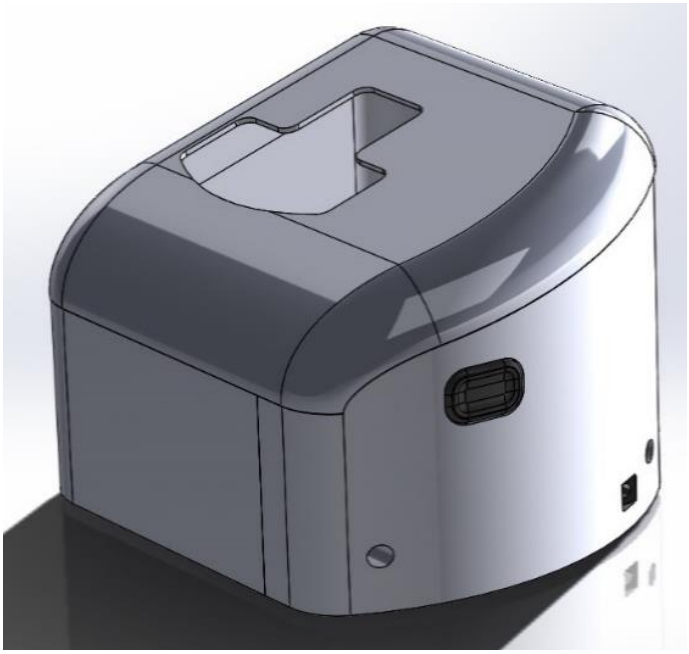

Figure 5.17 All parts mounted, right side.

6 Detailed design

6.1 Material

There are many ways of construct a product like this, both in metal and plastic or a combination. The choice is pending mostly of the specification the product must fulfill but also on the economics. Since this product is meant to be a consumer product the produced volume assumes to be large. Therefore the product will be produced in plastic. Molded plastic also allows for more a more complex design which also facilitates the assemble procedure.

The first step is to specify the demands of the material and by this evaluate a number of possible materials for the final design.

6.1.1 **Material specification**

Both the production method and use of the product sets a number of specifications on the material. The Product should function outside and should be resistant against UV radiation. Many plastics are sensitive for continuously contact with water, and since this product will contain a water tank this should be taken into consideration. The material should also be suitable to be injection molded to ensure that the complex design is feasible. The plastic also needs to be rigid enough to withstand the possible exposure of violent usage. The material should also be cheap to keep the cost down.

- Water resistance
- Cheap
- For injection molding
- Rigid
- UV-resistance

The button to release the lid will function as a spring and therefore have other demands. This will not be in contact with water but needs to be UV-resistance and have spring characteristics.

6.1.2 **Materials**

In general, there are two categories of plastics, amorf and semi- crystalline where semi crystallin is generally more suitable for injection molding. Therefore this project will only consider semi-crystalline materials. To keep the cost down, only large volume plastics and engineering plastics will be considered. Table 6.1 lists the different plastics and are given a score of 1-5 for each category.

Table 6.1 Scoring table for different plastics.

Property	***PE***	***PP***	***ABS***	***PA***	***PET/PBT***
UV-resistance	3	2	1	3	5
Strength	2	3	5	5	5
Surface	3	5	5	4	5
Moisture absorption	4	5	5	2	4
Price	4	5	2	2	4
Total	**16**	**20**	**18**	**16**	**23**

The scoring table is based on information from Ulf Bruders book *User´s Guide to Plastic* [13].

The two most proper plastics for the water tank, lid and cover, are either Polypropylene or Polyester. Polypropylene is a very common plastic, lightweight and with a low price, however the UV-resistance is fairly low, and the mechanical properties is not as good as the Polyester. Polypropylene does not absorb moisture and with the right additive the UV-resistance can be improved [13].

6.1.3 **Evaluation and selection**

Polyester have better characteristics for this product but are more expensive. Polyester have a very good resistance to UV-radiation which is a critical attribute if the washer is used on golf cars outside on sunny days. Based on these properties the most suitable plastic for the water container, lid and cover is Polyester.

For the button there is one material that sticks out and is commonly used for products that functions as a spring. Acetal, POM in short, is the most suitable plastic for this part. POM is commonly used on snap fits since this is the most metal-like plastic due to its crystalline structure [13]. Therefore the release button will be manufactured in this plastic. However, Acetal is sensitive to stress concentrations such as sharp corners which is something that needs to be taken into consideration when designing the button.

6.2 Production method

6.2.1 **Parts**

The only production method suitable for this product due to the advance design in a large volume is injection molding. This production technique has a high start up cost for the tools. The number of tools can be reduced with a family tool where several parts are manufactured at the same time. The plastic components differ in both size and design and therefore a family tool is not suitable for this product. One tool for each component is needed.

The water container has an advance geometry that requires either a tool with moving cores or to be split and molded in two parts. The second alternative, to be molded into two parts and then welded together with laser is a method that leaves a watertight seem and would be possible with a family tool. There will be an extra cost for the welding procedure, but the tool would be less complex and therefore cheaper. Figure 6.1 shows a suggestion for the split line.

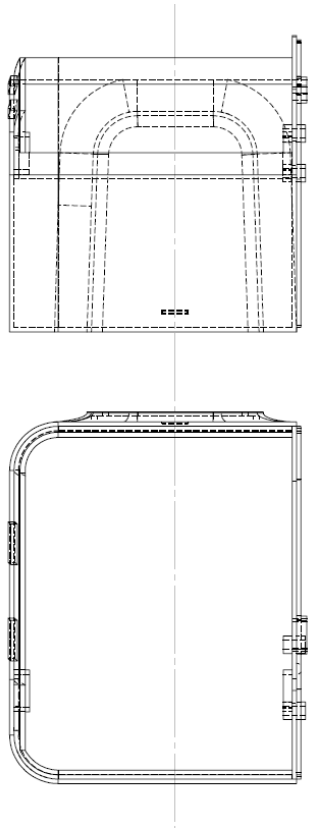

Figure 6.1 Split line for the water tank.

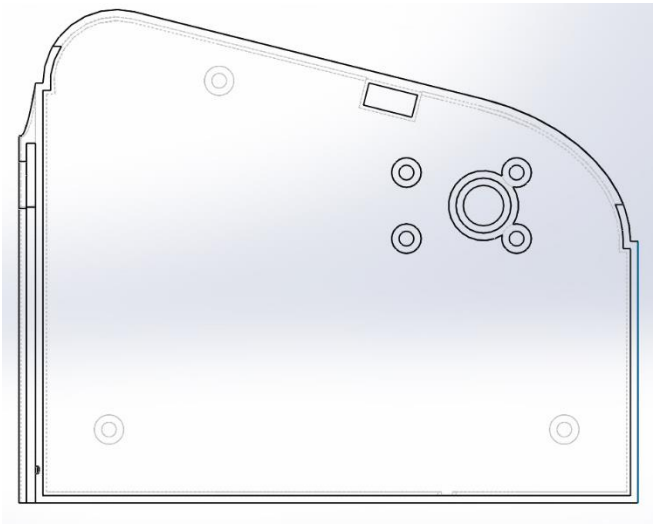

Figure 6.2 Cross section of the water tank

Figure 6.2 shows the cross section of the water tank, and the plane of the split line.

The lid will need to be molded in an angled position to align the release angles with the tools direction.

Figure 6.3 shows the suggestion for the tools split lines for the lid. Figure 6.4 a) and b) shows the split-line plane and the cross section of the lid.

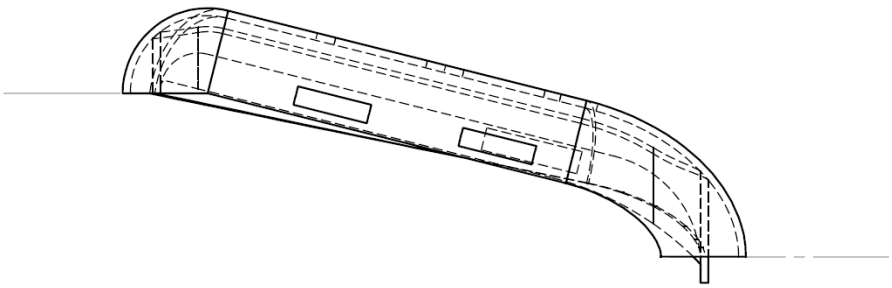

Figure 6.3 Split line for the lid.

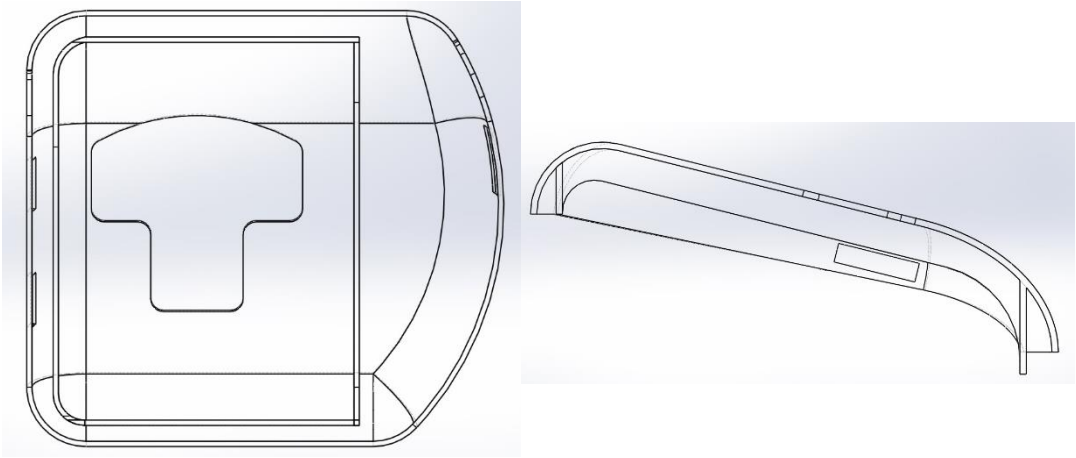

Figure 6.4 a) picture of split-line plane b) cross section of the lid

Figure 6.5 shows the suggested split line of the tool for the cover.

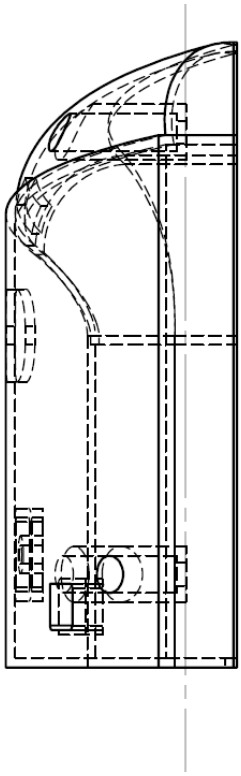

Figure 6.5 Split line for the cover.

6.2.2 **Assembly**

The exploded view of the washer can be seen in Figure 6.6. All of the components are mounted on the water tank with the exception of the button and the rubber cover on the lid. The bearings are pushed into place, and the motor is mounted with four M4 bolts. The brush is mounted in place with a bussing that connects with the motor. These components are standard components available on the market today, except from the brush. The next step is to mount and connect the sensor and electronics board to the water tank. The button is mounted on the cover which is then screwed together with the water tank. The rubber sealing is glued to the lid which then can be attached to the washer. The procedure is simple and by using only standard components, both the assembly time and cost is reduced. The washer can be disassembled which helps if a component breaks. The total time for assemble is estimated to 2 minutes.

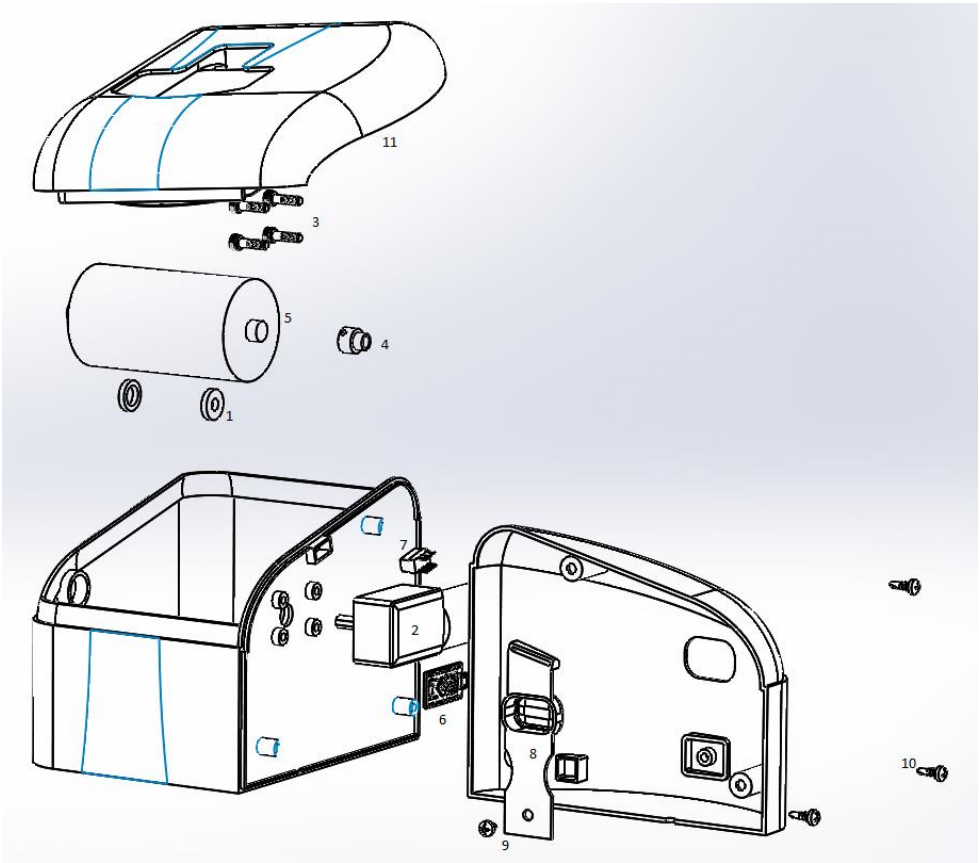

Figure 6.6 Exploded view of the washer.

6.3 Economics

6.3.1 **Assumptions**

The cost for this washer will depending on the number of produced units. This is very difficult to assume so therefore different cases will be used for the calculations. These cases will be based on several different factors such as who the end user is and for which geographical market the washer would be sold to.

In Sweden, there are today 374 golf courses with 18 holes or more, which can be seen as potential customer [14]. An assumption is made that there are approximately four golf cars at each golf course. Which leads to a total of 1 496 golf cars in Sweden. There are today 491 768 active golfers who also can be seen as potential customers [14].

In Europe there are in total 6 803 golf courses and 4 184 205 players [15]. The same assumption of four golf cars per golf course is made here as well. In the world there is a total of 34 011 golf courses and if the average golfers per golf course in Europe represent the world, it adds up to a total almost 21 million golfers [16].

Table 6.2 Number of golfers and golf courses in different regions.

Region	*Golf courses*	*Golf Cars*	*Players*
Sweden	449	1 796	491 768
Europe	6 803	27 212	4 184 205
World	34 011	136 044	20 916 765

Table 6.2 shows potential customers. Since the price is pending on the number of sold units and the number of sold units is pending on the price an assumption for number of sold units is made to calculate the price. The assumption made is that 5% of every golf course would buy four units over a three-year period and 1% of the players would buy one unit over a three-year period. The number of sold units over a three-year period is listed per region in Table 6.3.

Table 6.3 Number of sold units in different regions.

Region	*Golf courses*	*Players*	*Total*
Sweden	90	4 918	5 007
Europe	1 361	41 842	43 203
World	6 802	209 168	215 970

6.3.2 **Cost calculation**

To calculate the production costs of the base, cover, lid and button the cost calculating file provided from Bruder Consulting AB is used [17]. A number of assumptions is made for the calculation which can be seen in Table 6.4.

Table 6.4 Table of assumptions on which the cost calculation is built upon.

Assumption	*Value*	*Unit*
Nbr of calls per year	2	pcs
Waste	1	%
Material price	30	SEK/kg
Operating level	50	%
Operator salary	300	SEK/h
Administrative expense	10	%
Pcs per box	1	Pcs
Price per box	1	SEK
Masterbatch	2	%
Masterbatch price	35	SEK/kg
Utilization	95	%
Machine cost	400	SEK/h
Set time	1	h
Post expense	5	%

These assumptions are based on the example perceived from previous course litterateur, *Kostnadsberäkning exempel isskyffeln "IceBreaker"* by Katarina Elner-Haglund, which can be found in Appendix C. The cost is calculated based on a tool cost of 300 000 SEK per part and a production over three years.

The cycle time seen in Table 6.5, is calculated by adding the injection time, cooling time and opening/closing time. The injection time is calculated by the formula time=t*0,5sec (where t=wall thickness) which are perceived from previous course literature found in Appendix C, *Tumregler för beräkning av cykeltid* by Katarina Elner-Haglund. From this example, the opening and closing time is also perceived. The cooling time is based on the cooling time calculator provided by Biesterfeld, for the specific material and thickness [18].

Table 6.5 Cycle time for each material.

	Time for PET	*Time for POM*
Injection	1	1
Cooling	4,66	1,47
Opening/closing	4	4
Total	**9,66**	**6,47**

Post processing is assumed to 30 seconds for the base unit since this might need to be divided into two parts and 5 seconds for the other parts.

The total cost for each part produced for the three different market sizes is listed in Table 6.6.

Table 6.6 Production cost for the plastic components.

Part	*Sweden*	*Europe*	*World*
Base	82	22	16
Cover	75	15	8
Lid	78	18	12
Button	70	10	4
Total	**304**	**65**	**40**

Table 6.7 shows the list price for the components in the washer. An assumption is made that for this production volume a 20% discount will be given for the components.

Another assumption is made that the price for the components is the same for each market size.

Table 6.7 List price of components.

Part	*List price*	*Discount*
Power supply	30	24
Brush	80	64
Shaft seal	40	32
Sensor	52	42
Electronics	10	8
Rubber seal	5	4
Motor	76	61
Other	5	4
Total	**298**	**238**

Assembling time is assumed to be 2 min and the cost of this is assumed to be 10:- SEK per unit.

Table 6.8 Total production cost.

Part	*Sweden*	*Europe*	*World*
Base	82	22	16
Cover	75	15	8
Lid	78	18	12
Button	70	10	4
Power supply	24	24	24
Brush	64	64	64
Shaft seal	32	32	32
Sensor	42	42	42
Electronics	8	8	8
Rubber seal	4	4	4
Motor	61	61	61
Other	4	4	4
Assemble	10	10	10
Total	**554**	**314**	**289**

As seen in Table 6.8, this gives a production cost of 554:-, 314:- and 289:- for respective market size.

6.3.3 Evaluation

This cost calculation is based on a number of assumptions due to the difficultness to receive the correct prises for both the components and tools. A great limitation is the calculating of the market size. The market size is highly depending on the price for the washes which is highly depending on the market size. It was previous discussed that the demands and needs could differ from the private and corporate market when it comes to reliability and the maintenance. Table 6.3 shows that only 2-3% of the market share are the golf courses. This means that the corporate market size is relatively small, and the product should address the players personal need and prioritize the demands of this market. The assumed numbers of the cost for the production is based on European salary and prices. To locate the production at low cost countries could decrease the production cost as well as cheaper parts and components. If this is done, the production cost could be decreased and so the selling price. This would result on a greater selling point where the product could be seen as a fun and useful gimmick. This production price should only be seen as a guideline to approximate a selling price. To improve the approximation and calculate a more correct price it is needed to contact a number of suppliers for each component. A major impact on the price especially in smaller volumes is the tool

cost. This cost is approximated to 300 000:- SEK per tool which will be payed off after three years. The cost for the tool is difficult to approximate but for this calculation a slighter higher cost was assumed than the example *Kosnadsberäkning exempel isskyffeln "IceBreaker"*.

7 Final Design

This chapter will present the final design and its functions.

Figure 7.1 to Figure 7.8 shows the final design. The washer has the outer dimensions of 180x168,5x105mm (width, depth, height). The hole in the lid have a rubber protection that prevents water from splatter when the brush is in movement as the proof of concept. Located on the side, the button is found that releases the lid which can be removed for cleaning purposes. On the same side the inlet power supply port can be found.

Figure 7.1 Final design, right side.

Figure 7.2 Final design, left side.

When the lid is removed, the brush and the water tank is revealed. This simplifies the cleaning process of the washer and makes it easy to change the water.

Figure 7.3 Final design, without lid.

Figure 7.4 Final design, back.

On the back of the washer the mount for the accessories can be found. In this slot, mounts for either walls or golf cars can be attached. These mounts can be seen in Figure 7.5 and Figure 7.6.

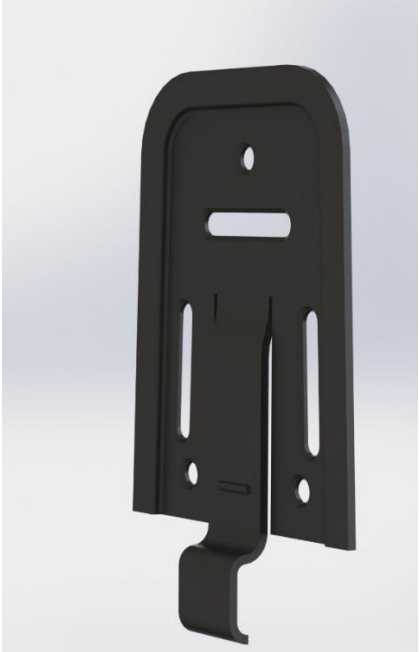

Figure 7.5 Final design, wall mount.

Figure 7.6 Final design, car mount.

When the cover is removed the electronic components are revealed mounted on the water tank, see Figure 7.7. Figure 7.8 shows how the motor is attached with four screws.

Figure 7.7 Final design, components compartment.

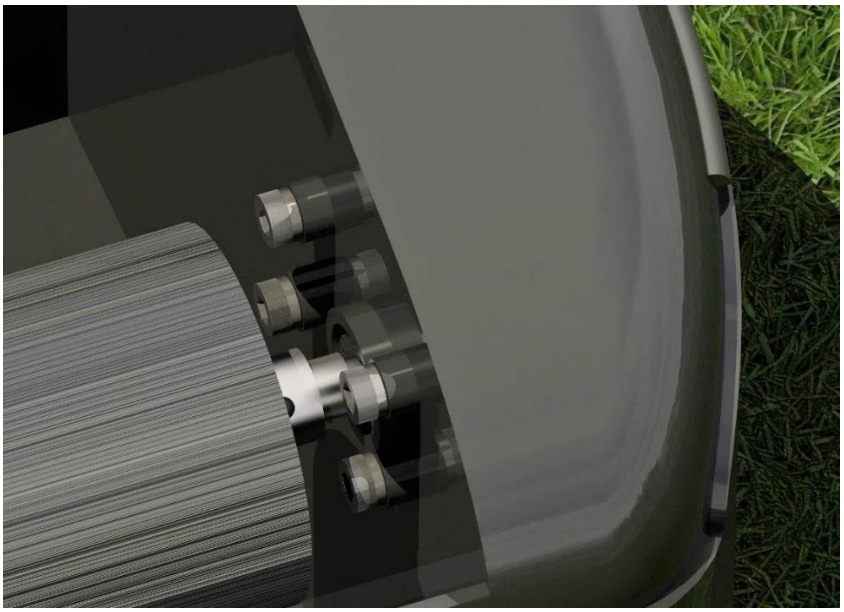

Figure 7.8 Final design, motor and brush attachment.

8 Discussion

This chapter will contain a general discussion over the different steps in the project. It will also contain a section where speculations and recommendations of further development to take this project into the next step.

8.1 Discussion

Many of the steps in this project could have been improved and the main limitation was time. Since the project needed to cover all of the steps in the product development process, these had to be shorten to fit the timeline. The market research survey was spread on Facebook, which leads to that a large number of replies can be collected in just a few days. The negative aspects of this method are that the spectra of the audience are narrow. To broaden the audience, it would be wise to also hand out questionnaires to golfers at the course. The interview was held together with one of the former personal at the front desk of a golf course. The golf course can be considered as a low to mid-priced golf course. To improve these inputs, it would also be wise to interview personal from several different golf courses. Interviews and non-online surveys are however time consuming and where therefore not included in the market research of this project.

The development process of the cleaning method had a straight strategy where the cheapest solution would be tested first and then taken into further development due to the budget limitations. It would be interesting to test the other methods as well, to see if the washer can serve several purposes such as cleaning golf balls and therefore be a better choice. Since the project was founded by the author and some techniques is rather expensive, this could not be tested when the cheaper solution worked. Another limitation was the time and availability of the different techniques. One company offered to rent an ultra-sonic cleaner but the shipping time and cost for this exceeded the limit of the project.

When the proof of concept was built, the main goal was to visualize the product, how it would work and how it was supposed to be used. In this part the time and availability of components was the main struggle. A motor similar to the one in the final concept would be preferable to test both the motor and the rotation speed of this. However, the shipping time for the cheaper motor of this sort exceeded four weeks. Since a functional proof of concepts was needed to proceed in the project, a

simple construction with the components available was built instead. This concept shows the functionality of the product and it performed well in the tests. The life time of the brush is of interest and was not tested in this report. Suppliers of brushes was contacted but there are no standard brushes on the market and they manufacture the brushes after request of both materials and dimensions. Therefore, it would be interesting to test different brushes, but again was both time and the budget the limitation in this case. To manufacture brushes after these demands would be highly expensive in a small scale. As reference, a supplier of shoe cleaners was contacted to get an estimation of the brush life time which exceeded 10 years of use.

The final design was developed to provide a fully functional product design as well as a production plan, material selection and a price. The initial idea was to develop a product that could function both as a consumer product but also as an accessory for golf cars and for golf clubs. This was designed to be optional with different mounts for different usage since the primary market and the largest market is the private. By this, the washer can be sold for private use at first and then be advertised for golf clubs as well. The washer is not designed to be weather proof, however, the design allows to add an extra sealing between the cover and the water tank. The lid is designed to prevent the water to enter the compartment for the electronics, but if water do penetrate either in the edge between the cover and the water tank, or by the motor shaft, the hole in the bottom of the cover will drain this area.

The material used for the parts are a cheap, commonly used plastic which will be injection molded. This is a technique that have a high start-up cost but allows for more advance design. Since the aim is to manufacture this product in a large quantity, the start-up cost is low per unit and therefore this is a suitable technology. By integrate functions and mounts in the plastic parts, the number of assembly's is reduced and therefore cheaper to manufacture.

The economic calculations are based on a number of assumptions. The costs are based on the example *Kostnadsberäkning exempel isskyffeln "IceBreaker"* with a marginal to ensure that the production cost not will be exceeded. However, as discussed previously, the cost is correlated with the number of sold units and vice versa. It is therefore hard to predict the cost as an exact number and the calculations will only provide an approximation of the manufacturing cost.

A critical part and a key function is the sensor. The sensor needs to sense if a golf club is inserted either with the intention of cleaning the face or the sole of the club. Nevertheless, it should not react if the water ripples around in the water tank if the washer is mounted on a golf car. If this becomes a problem the circuit can be programmed with timers. Both to have a 5-10 second cleaning cycle but also that the sensor must be activated for example 1 second before the cleaning cycle starts. By this the brush will not rotate by accident. It could also be adjusted so water that is faced to the sensor not will trigger the brush if the golf car is parked on a hill.

The market at golf clubs is small compared with the private and the washer should not be primary adapted to this market. However, there is a need for golf clubs as

well and since this is a product that will increase the service level for their customers a higher price could be charged. The washer would be used in a much higher extent and a more solid construction could be needed. This is however something that should be tested with a final prototype.

8.2 Further development

The next phase would be to build and test the final design. The concept should be printed out and tested with the same components as above to test both the manufacture capabilities and the function of the components and products. The washer should then be tested both in a home environment by several users and on a golf course. Critical functions and components such as the brush and the sensor, should be tested to develop a fully working cleaning cycle without errors. The brush should also be tested to evaluate the life time.

The washer should be tested by observations of users to find potential faults and difficulties.

Manufactures should be contacted to calculate a more precise manufacturing costs to evaluate the marginal and profit the washer can contribute with.

The amount of leakage between the water tank and the cover should be tested to evaluate if an extra sealing is required. Then, either manufacturers or existing brands on the market should be contacted to take this product into production.

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Appendix A Project plan

A.1 Preliminary Project plan

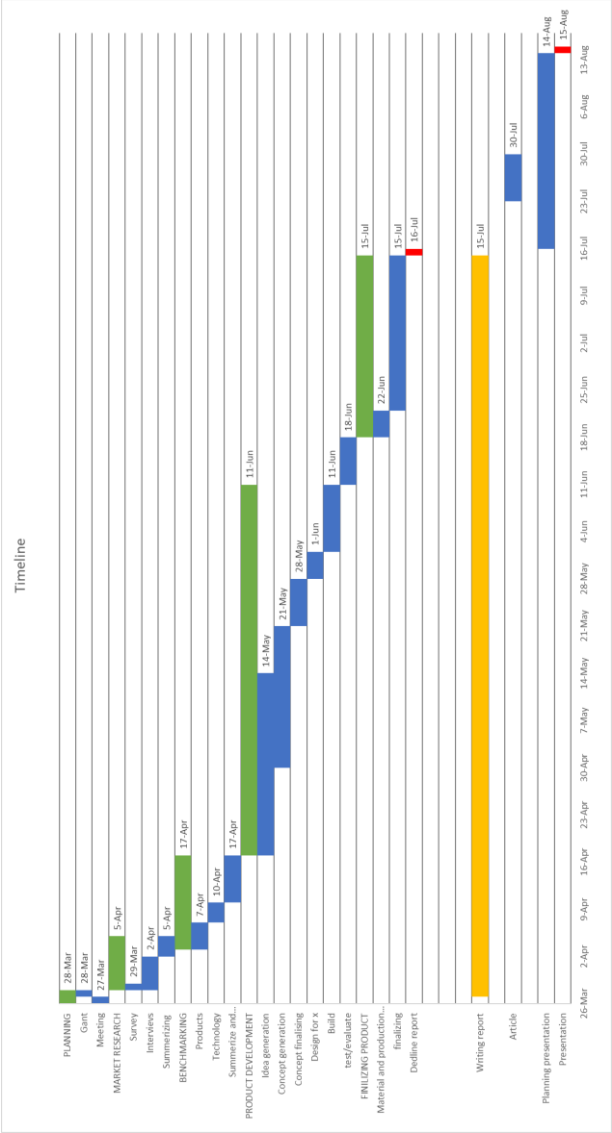

Figure 9.1 Preliminary outline

Activity	Start date	End date	Nbr of days
PLANNING	2018-03-26	2018-03-28	2
Gant	2018-03-27	2018-03-28	1
Meeting	2018-03-26	2018-03-27	1
MARKET RESEARCH	2018-03-28	2018-04-05	8
Survey	2018-03-28	2018-03-29	1
Interviews	2018-03-28	2018-04-02	5
Summerizing	2018-04-02	2018-04-05	3
BENCHMARKING	2018-04-03	2018-04-17	14
Products	2018-04-03	2018-04-07	4
Technology	2018-04-07	2018-04-10	3
Summerize and specification	2018-04-10	2018-04-17	7
PRODUCT DEVELOPMENT	2018-04-17	2018-06-11	55
Idea generation	2018-04-17	2018-05-14	27
Concept generation	2018-04-30	2018-05-21	21
Concept finalising	2018-05-21	2018-05-28	7
Design for x	2018-05-28	2018-06-01	4
Build	2018-06-01	2018-06-11	10
test/evaluate	2018-06-11	2018-06-18	7
FINILIZING PRODUCT	2018-06-18	2018-07-15	27
Material and production plan	2018-06-18	2018-06-22	4
finalizing	2018-06-22	2018-07-15	23
Dedline report	2018-07-15	2018-07-16	1
			0
			0
			0
Writing report	2018-03-27	2018-07-15	110
			0
Article	2018-07-23	2018-07-30	7
			0
Planning presentation	2018-07-16	2018-08-14	29
Presentation	2018-08-14	2018-08-15	1

A.2 Actual Project plan

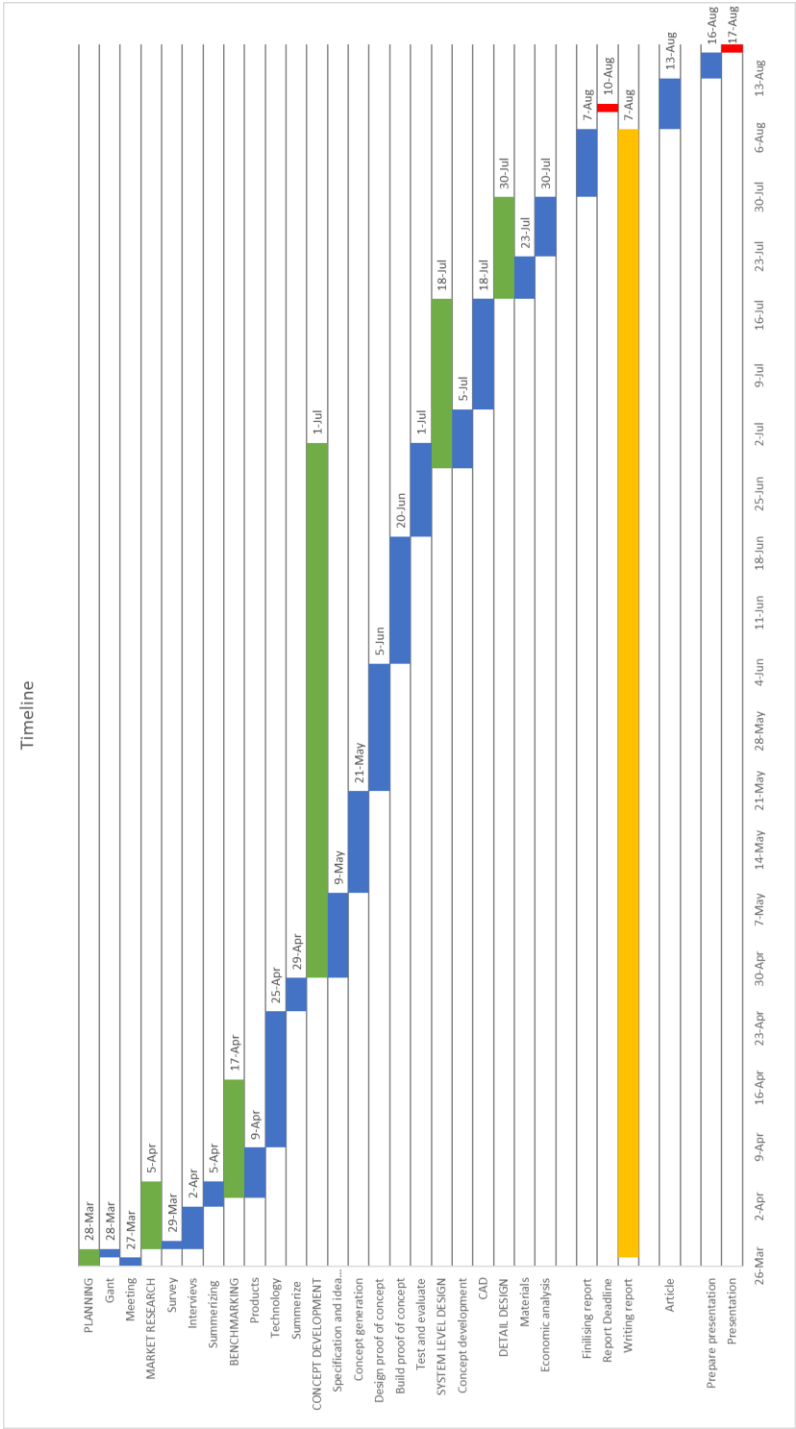

Figure 9.2 Actual project outline

Activity	Start date	End date	Nbr of days
PLANNING	2018-03-26	2018-03-28	2
Gant	2018-03-27	2018-03-28	1
Meeting	2018-03-26	2018-03-27	1
MARKET RESEARCH	2018-03-28	2018-04-05	8
Survey	2018-03-28	2018-03-29	1
Interviews	2018-03-28	2018-04-02	5
Summerizing	2018-04-02	2018-04-05	3
BENCHMARKING	2018-04-03	2018-04-17	14
Products	2018-04-03	2018-04-09	6
Technology	2018-04-09	2018-04-25	16
Summerize	2018-04-25	2018-04-29	4
CONCEPT DEVELOPMENT	2018-04-29	2018-07-01	63
Specification and idea generation	2018-04-29	2018-05-09	10
Concept generation	2018-05-09	2018-05-21	12
Design proof of concept	2018-05-21	2018-06-05	15
Build proof of concept	2018-06-05	2018-06-20	15
Test and evaluate	2018-06-20	2018-07-01	11
SYSTEM LEVEL DESIGN	2018-06-28	2018-07-18	20
Concept development	2018-06-28	2018-07-05	7
CAD	2018-07-05	2018-07-18	13
DETAIL DESIGN	2018-07-18	2018-07-30	12
Materials	2018-07-18	2018-07-23	5
Economic analysis	2018-07-23	2018-07-30	7
			0
Finilising report	2018-07-30	2018-08-07	8
Report Deadline	2018-08-09	2018-08-10	1
Writing report	2018-03-27	2018-08-07	133
			0
Article	2018-08-07	2018-08-13	6
			0
Prepare presentation	2018-08-13	2018-08-16	3
Presentation	2018-08-16	2018-08-17	1

Appendix B Interview

Interview with Andersson regarding use of cleaning station at Ullared Flädje GK

2018-04-01

Interviewer What is your professional experience within the golf industry?

Andersson I´ve been working at Ullared Flädje GK for a couple of years, until fall of 2017.

Interviewer What was your role at the golf club?

Andersson I worked both in the cafeteria and in the shop, assisting customers. As well as handling many of the administration tasks. In the shop and the front desk most of my tasks was to book customer, sell green fees and accessories for their round.

Interviewer Does the golf course rent out equipment such as golf clubs, and is this a common request?

Andersson We do have the service of renting or lending golf clubs, but it is not too common. Renting either golf cars or cars happens on a daily basis.

Interviewer Did your tasks ever included that you needed to clean any golf clubs?

Andersson No, I'd say not. Usually if we rented out clubs the customer cleaned them before returning them.

Interviewer Do you provide any form of help or tool for your customers to clean their golf clubs?

Andersson We have a bucket with water and brushes where the players can clean their clubs as many do. We also have a sink with a dish brush which they also can use.

Interviewer Do you believe that there is a need for an alternative method which can help the players?

Andersson Both yes and no, there is no specific need requested from the players that we need to provide them with any additional tool. But it is always nice to have more options and to provide the players

with as much services as possible for the right cost. We have cleaners for golf balls on most tee´s, so there is room for further tools. A stationary cleaner at the driving range would be nice.

Interviewer What do you think would be most suitable, an electric or a manual cleaner?

Andersson A manual cleaner is maybe more flexible but an electric that is nice and clean would maybe be preferable if it would be either inside or near the club house.

Interviewer What aspects do you think is important for such a product?

Andersson That it is very easy to use for the players. Also, that it is quick, and that no maintenance is needed. It should also look good and have good quality. It should also be quite rigid and be able to be "locked" where its placed.

Interviewer Do you think it should be designed to use with one club at time or for several?

Andersson It depends, if it is supposed to be designed for professional use for employees I'd say it should be designed for several clubs. But if it is designed for the players to use I would probably be easier if it cleans just one club at time, but then it need to be quicker than the manual bucket with brushes.

Interviewer What are your thoughts of the product?

Andersson I think it's a cool product, that golf courses could use. But maybe it is even better for personal use and then the golf courses could sell it instead? As long as it works better than the manual cleaners that are on the market today I think people would buy it. Especially golfers with a higher budget. It would be really nice if we could use it on our golf cars.

Appendix C

C.1 Konstnadsberäkning exempel isskyffeln "IceBreaker"

Kostnadsberäkning exempel isskyffeln "IceBreaker"

Årsvolym: 100 000 st

Antal avrop (=leveranstillfällen): 2 ggr (påverkar detaljkostnad eftersom dubbla kostnader för verktygsuppsättning)

Detaljvikt: 200 g

Materialkvalitet: "PP Snowflakes 3347" - en slagseg PP

Kassation: 1% (vanligt inom svensk formsprutindustri 0,5-2%). Bara nyvara används. Om återvinning räknar man om materialkostnaden istället.

Råvarupris: 16 kr/kg

Bemanningsgrad: 20%.

Operatörslön + lönebikostnader: 200 kr

Affärsomkostnader: 10% Små företag lägre, stora företag i storstad högre

Masterbatch 2% (normalt 1-5%)

Pris masterbatch: 35 kr/kg normalt med färgpigment

Cykeltid: 36 sek
Insprutningstid: 0,5 x väggtjockleken 4 mm = 2 sek
Eftertryck: 4 sek/mm godstjocklek PP, 8 sek/mm POM, 4 sek/mm PA = 16 sek
Kyltid: http://www.biesterfeld-plastic.com/nc/en/products/cooling-time-calculation.html 14 sek
Stöta ut/stänga ca 4 sek

Formrum: 1 st

Utnyttjandegrad: 95% (90-98% vanligast)

Maskintimkostnad: 400 kr

Avskrivning verktyg: 25 000 kr (verktygskostnad 250 000, livslängd 10 år => verktygskostnad 25 000 kr/år). Dubbelsprutningsverktyg 1,5 ggr dyrare.

Uppsättning/nedrivning verktyg + intrimning: 1 tim vanligt

Efterbearbetning material (stållist till skyffeln): 1 kr

Hanteringstid efterbearbetning: 15 sek

Omkostnadspålägg efterbearbetning (allmän overhead för stållisten, exvis godsmottagning, kvalitetskontroll, lager/hantering, fakturering): 5%

C.2 Tumregler för beräkning av cykeltid

Tumregler för beräkning av cykeltid

- **INSPRUTNINGSTID:** 0,5 x väggtjockleken
- **EFTERTRYCK:** 4 sek/mm godstjocklek för PP, 8 sek/mm för POM, 4 sek/mm för PA
- **DOSERA UPP:** ca 10 sek för ca 200 g skottvikt (sker parallellt med kylningen och räknas alltså inte in)
- **STÖTA UT/STÄNGA:** ca 4 sek

eller
istället för eftertryck och uppdosering
KYLTID: 3 x t^2 (t = godstjockleken)

eller
http://www.biesterfeld-plastic.com/nc/en/products/cooling-time-calculation.html
så får du kyltiden för olika material

Summera!