Outboard Electric Propulsion (May 2013)

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Abstract— As oil prices rise and people get more aware of the implications of global warming, the demand for alternative energy use rises. The fishing industry is one of the branches looking for cheaper propulsion systems. This is why the company of Innovanautic saw the need for designing a new electric outboard propulsion system, to be used in the local fishing industry to get their boats out of the harbor. The overall purpose of this project was to design a complete outboard engine, thinking about the mechanical structures, the electrical controls and the overall design. Furthermore, a marketing strategy was needed to make the product profitable.

I. Introduction

The need for this project came forth from the fishing industry. Fishermen need small boats to maneuver from the ports to deep sea safely and with great precision. Nowadays people are aware of importance of using the clean forms of energy to reduce the level of pollutions as well as find more sustainable solutions. The fact that fossil fuels are running out and the prices are getting more expensive causes that people try to find other technology to use. This project tries to find a solution to these problems, specifically for the fishing industry. The main goal is to design and build an autonomous electrical outboard propulsion system, capable of propelling fishing boats safely out of the harbor. To do this, an international multidisciplinar team was created, who try to realize these specific demands.. The engine should be completely autonomous, meaning it has to be a complete system which can be easily connected and disconnected from the vessel in one piece. The main assumption is to create the whole system for boats with a length around ten meters mainly used for fishing. The maximum speed obtained by the system is about 5 knots. The final step of the project will be to indtroduce the final product into the market. For this purpose, a market strategy will be prepared.

It is very important for companies look for more sustainable solutions in these days. Innovanautic has adapted to this trend and because of it they are building electric engines for boats. But what is the difference between electric engines and normal combustion engines? What is so positive about the electric engine?

The positive aspects include the electric engine's positive environmental impact and the electricity price. Another upside of the electric engine is you get much more energy out on the propeller, if you compare it to the same amount of fuel in a normal fuel engine. A normal combustion engine will get around 30% out of energy on the propeller from the fuel, because of the great amount of losses for example in friction and heat. Especially the engine used in this project has very little losses in friction and heat, because the engine will be at the bottom of the whole system and we will just use one shaft. If the engine would have been at the top, it would have been necessary to connect different shafts with different kinds of gear shafts. A system like this would take a lot of energy which could be used on the propeller instead. This is one of the main reasons why the company would like to use this kind of engine.

Another benefit of the electric engine is the price of the "fuel". The electricity price in Spain is around 0, 19488 €/kWh and the fuel price is 1,441 €/l for E95 and Diesel 1,361€/l. So it's a big different in price if you are going the same distance with an electric engine and fuel engine. A normal fisherman would spend about 28 € (normal fuel engine) each time for back and forth when they go out fishing. This could be reduced a lot with this electric engine.

The reason the electric engine is good for the environment is that no fuel or oil is needed which could leak out in the sea and pollute the water. Spilling oil or petrol is quite common at sea. The engine will often leak somehow when it gets old or when it has to lubricate the bearings and so on. The cooling water will also take some oil with it back to the water which is not good either. But with electric engine you do not need these polluting substances, just something to lubricate the engine sometimes, only once a year.

The speed of an electric engine is very hard to compare to that of a combustion engine. If a fast electric engine is needed, the size of the engine will also increase. For this project it is critical that the engine is as light as possible, because it should be easy to carry. A more powerful engine with a large amount of horsepower will require more or bigger batteries, which also means more weight, and is to be avoided.

As a conclusion it is safe to say for this project the electric engine would be ideal. It is green, more efficient, less

expensive, lighter and perfect for low power applications. All these properties fit this project perfectly.

The team is also aware of existing competition on the market. At this time, there are a few other similar products available, like Torqeedo, Parsun Electric Outboard or Minn Kota. However these products were not designed specifically for the purposes of fishing industry. There are mainly used by people during they leisure time. It is the goal of this project to design a product which is more specific to the company's demands and appropriate for fishing industry.

II. Mechanical

This section deals with all of the mechanical parts that needed to be designed for the outboard engine. Most of these parts were calculated with applied statics. The start of these calculations was the electrical engine itself, because this part would impose the forces exerted on all the different parts. The type of engine was decided on in cooperation with the company, who asked for an engine of about 5 HP.

In the bottom part of the system, the forces need to be directed from the motor to the propeller. It is essential for the motor to be free of any external forces, it van only give torque to the shaft. To take in these forces, a shaft adapter was designed, which will act as a buffer.. An extra piece from the outgoing motor axel to the propeller, which has the bearings to smooth the movements and has the connection to both the motor and the upper profile.

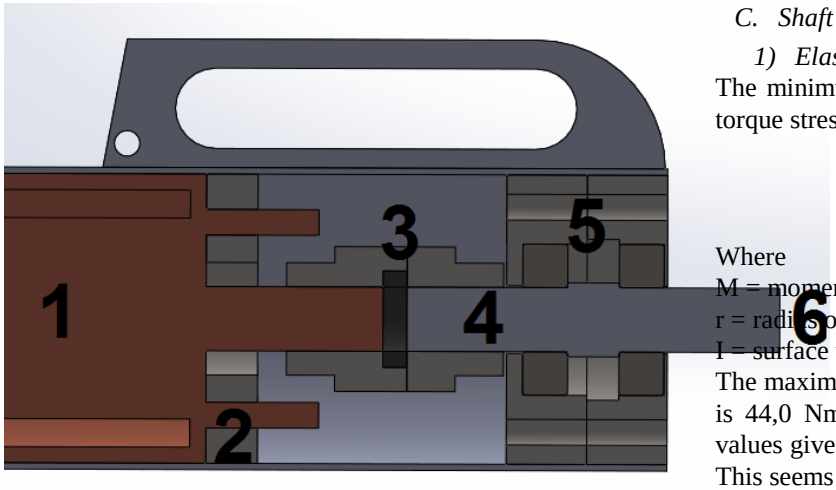

Fig. 1. Shaft adapter and motor connection; (1) Motor, (2) Connection piece motor to outer pipe, (3)Elastic clutch to adapt axel diameters, (4) Second axel to propeller, (5) Shaft adapter, (6)

A. Engine

The engine used is chosen from the given PDF file '4" Encapsulated Motors', which was a given from the company. Since the system had to be around 5 horsepower, which is about 3,75kW, the 4.0 kW motor from the table is chosen. In the end the axel is supported by an axial bearing and close to where the axel is going out it is supported by a radial bearing.

B. Propeller

For the propeller, a number of parameters should be taken into account. The pitch, diameter, number of blades and material are the most important parameters when choosing the right type of propeller

The propeller pitch is a number which represents the theoretical distance the propeller would travel when one rotation is made. A high pitch propeller will have a higher top speed, but will accelerate slower than a low pitch propeller. For this project, top speeds were less important, and a higher acceleration would be an advantage in maneuvering, so a low pitch propeller was chosen.

The number of blades will also affect the speed and acceleration. Four blade propellers will mostly be used on high power engines and will result are more suited for rough seas. For this reason, a three blade propeller was selected for this project.

The propeller is the part of the engine which will produce the actual movement of the boat, by pushing the water away from the boat and by doing this, pushing the boat further against the water. In deciding on the propeller, there are a few characteristics about propellers to be taken into account. The most important are the number of blades, the propeller diameter and the propeller pitch.

As for the material, aluminum was selected in this case, mainly for its low weight.

C. Shaft adapter and outer pipe

1) Elastic clutch

The minimum diameter of the propeller axel is calculated on torque stresses.

$$\tau = \frac{M * r}{I} = \left(\frac{M * r}{\frac{\pi r^4}{4}} \right)$$

Where

M = momentum of torque

r = radius of axel

I = surface variable

The maximum torque according to the given facts of the motor is 44,0 Nm. Putting the formula in Excel and changing the values gives a stress of about 55 Mpa at a diameter of 20 mm. This seems to be an acceptable value to go with.

Though, the outgoing axel of the engine is about 15,5 mm in diameter and it is also very short. This is what the clutch is for, connecting a new axel, changing the diameter and correct any flaws in the direction so is spins straight.

Fig. 2. Elastic clutch

2) Axel to propeller connection

From the clutch a new axel has to be designed to go to the propeller. It has to be supported by bearings in the shaft adapter. Earlier calculations give a minimum diameter of 20 mm.

Fig. 3. Axel to propeller connection

From left to right in figure 3, the first diameter will be 20 mm, this part fits in the clutch. The second diameter will be just slightly larger, this is where the first bearing will be mounted. By making the first diameter less, mounting will be a lot easier since the bearing doesn't have to go over a tight fit for the entire length. The third diameter will be slightly bigger again, about 22,5 mm. this is to stop the bearings and fit them into place. After this, another part for bearings and the last piece will be for the propeller to be mounted on.

3) Shaft adapter

As mentioned earlier, the shaft adapter will hold the bearing for the axel and will direct the forces to the outer pipe and with that to the top of the system. Since the motor is probably beared with an axial and radial bearing, the shaft adapter will have the same. With this composition the axel is free to turn around its own length axel and forces away from the motor will be smoothed out because of the extra axial bearing. The two pieces of this part have the same hole pattern so they can be bolted together. On the sides are the same holes as the motor connection piece to connect all the parts to the same outer pipe.

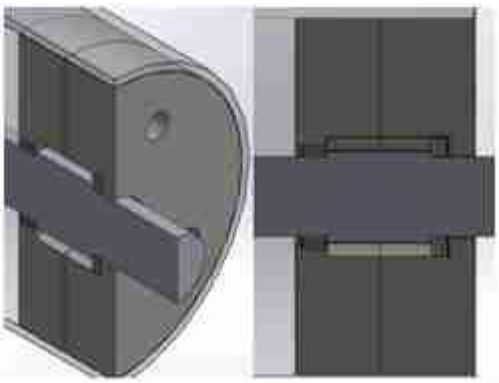

Fig. 4. Shaft adapter

4) Connection piece

The entire system shown in figure 1 will be kept in one pipe. The shaft adapter will have holes in the sides to connect this pipe, the motor only has four bolts in the frond for connection. Therefore an extra piece is designed to make the same connection possible.

Fig. 5. Connection piece shaft adapter – engine

5) Outer pipe

The last piece of the bottom part is the outer pipe, which holds the shaft adapter and the motor connection piece. The holes shown in the picture below will be for bolts, holes in the other pieces will have thread for easy mounting.

Fig. 6. Outer pipe for engine and shaft adapter

D. Engine flipping system

For the system to be easily transported, it was necessary to come up with a system which could flip the bottom part of the engine upwards, to a vertical position. To do this, a hinge was created in between the connection of the outer pipe and the vertical profile. To lock it in place, holes were created on the outer pipe and the vertical profile where a pin could be inserted to keep the motor part in the right position. A handle was created on the outer pipe to improve the accessibility for the user.

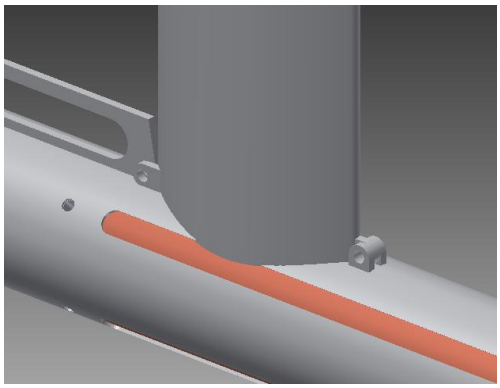

Fig 7. Hinge system

E. Vertical Profile

The Vertical profile connects the bottom part of the engine to the bracketing system and the upper part which contains the electronics. This part is 1,2 meters long and should be able to withstand the forces exerted by the propeller thrust. The

profile has an oval shape, consists of aluminium and is manufactured by a company in China. It also contains a hook where the engine can be attached to when flipped vertically.

F. The bracketing system

The bracketing system is the connecting piece between the vertical profile and the vessel the engine system will be attached to. It is connected to the vertical profile by a hinge which makes it possible for the user to rotate the motor and hereby steer the boat. The bracketing system connects to the boat by a screwing system, by which the entire system can easily be mounted and dismounted. It also features a system to adjust the height of the engine in the water, depending on the conditions of the sea. The height can be adjusted by pushing down on a button and pulling the engine up to the preferred position. The handle which controls the rotation will also be attached to this system.

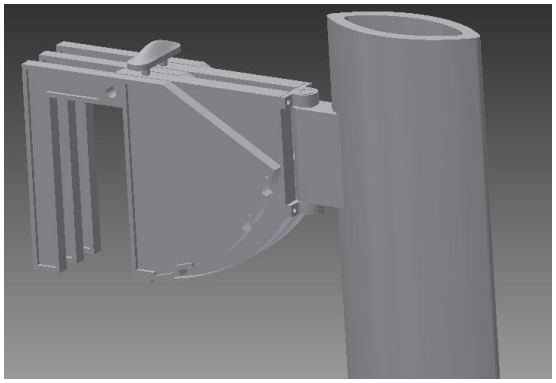

Fig. 8. Bracketting system

III. Electricity and Electronics

This section of the project will be about the electrical and electronics. The electronics system will control the motor speeds and will provide it with the correct power source. Firstly, a general view about the different electrical systems and their technology will be made. Afterwards, a proposition will be made for what parts to use, selected from commercial existing products.

The electrical system consists of:

- Battery
- DC / DC Converter
- Variable frequency controller
- Potentiometer control (represented by joystick)
- motor.

The user will control the motor speeds by handling the potentiometer, which is inside of the control handle. The potentiometer is connected to the variable frequency controller (VFC), which gives the correct signal to the engine. The VFC also powers the engine and is powered itself by the converter, which gets its power from the battery and converts it to the correct voltage.

A. Battery

Batteries are the components that store and deliver energy to the engine, they can be found in many different forms, depending on what they are used for. For this system the most important parameter is the weight, because of the portability of the system. For this reason, a lithium-ion battery was selected, a battery type which can deliver a lot of energy while keeping a small size. Lithium-ion batteries are one of the most used batteries in the world and this has granted them a level of development which has large advantages over others, such as;

- In voltage terms, it generates the equivalent to three batteries of alkaline type.
- It has the best value of energetic density. the order of 90 up to 190Wh/Kg
- It does not use pollutant metals.
- Energy supply is very linear (it is independent from the level of battery load)

The selected battery focuses on maximum capacity and minimal weight.

B. DC/DC Converter

The electrical power converter is the element which converts the voltage from the battery to a different level, which is suitable for the motor. For this application, a direct current (DC) to direct current (DC) is needed, because the variable frequency functions in DC current.
It's a complex drive element, which is used to convert from 48 Vcc to 300 Vcc and work under highest energy demand, because when the motor starts with charge it consumes more power than normal.

C. Variable frequency

A variable-frequency drive (VFD) (also termed adjustable-frequency drive, variable-speed drive, AC drive, micro drive or inverter drive) is a type of adjustable-speed drive used in electro-mechanical drive systems to control AC motor speed and torque by varying motor input frequency and voltage. The VFD selected had to be compatible with the converter and the engine, so the communication between these parts would run smooth.
The VFD selected for this project is the ACS 355. The ACS 355 is optimal for this project because it allows to connect DC feed by a common DC bus. The electrical scheme for connecting to the motor will look as following:

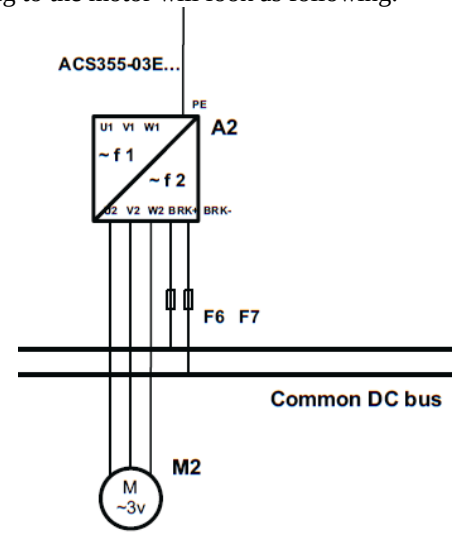

Fig. 9. VFD scheme

D. Potentiometer control (represented by joystick)

A potentiometer is a resistor which has a variable resistance. This means it can change the electrical resistance the current is experiencing by controlling the device. In the case of this project, a potentiometer is used to control the motor speed. As the user changes the resistance, the VFD will give a different signal to the motor, thus altering the rotation speed and by this ultimately altering the ships speed. The potentiometer will be mounted in the handle of the ship for easy access and control. Various types of potentiometers exist, the most common being the ones which use a mechanism which can be turned left or right to control its resistance and. In most cases, the potentiometer will stay in a certain configuration until the user decides to alter the turning mechanism again. In this project however, there was a need for a potentiometer which would automatically change back to its original state. This is necessary because when the user would fall off the ship, the engine needs to stop immediately. For this reason, a special type of potentiometer was selected; the Softpot.
The softpot is a special type of potentiometer, which does not use a turning mechanism to control its resistance. Instead, it is controlled completely by simply touching a touch-sensitive strip. With this potentiometer, the user can control the engines speed by touching a specific part of the sensitive strip. By sliding the finger to a different part, the speed can be altered

and when there is no contact, the engine will automatically stop. This means safety is preserved at all times.

E. Engine

The motor is the component which drives the propeller and thus creates thrust. The shaft driven by the motor is connected to the shaft adapter, which acts as a buffer for the lateral forces exerted by the propeller, as the motor is not fit to take all these forces. From a variety of motors, the Franklin 3 phase electric motor was selected. This type of motor is fit to be used under water and has a power of 2,2 kW, which is just within the range needed for this project. The characteristics of this engine can be found here:

3-Phase Standard Performance Data 50 Hz

P_N [kW]	Thrust F [N]	U_N [V]	n_N [min^{-1}]	I_N [A]	I_A [A]	η (Eff.) [%] at % load		
						50	75	100
2,2	4000	400	2845	5,5	29,8	69	74	75

cos φ (Pf.) at % load			T_N [Nm]	T_A [Nm]
50	75	100		
0,52	0,66	0,77	7,37	22

Fig. 10. Engine specifictions

F. All system

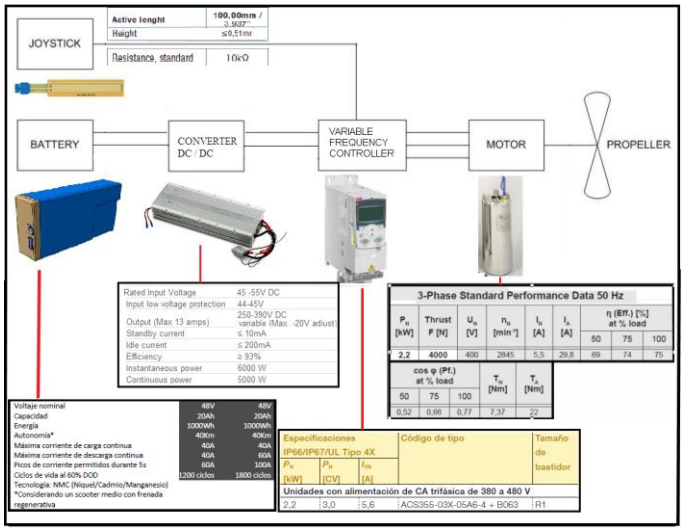

Fig. 11. Electrics overview

IV. DESIGN

The design of the objects is changing and now all products are designed for the user, and their needs, so, when a product is developing it is important to pay attention to the design and not only the mechanical part. All product should to be intuitive, accessible and ergonomic, if the object does not have these characteristics it is probable that it would not be accepted by the society, so it would not be successful.

A. The users

We are going to talk about the characteristics of our users and costumer, in order to design the most accessible, useful and easy to use product. To conduct the analysis functional table was helpful. In this analysis we take into consideration type of user, context of use, characteristic of the use and differential characteristic like physical, cultural and social, geographical.

1) Conclusion

To summarize the users analysis of the external things, firstly we should take care about the user characteristics, both physical and cultural. Those facts could change the behaviour and sizes of the design.

Secondary, we should take care are about the level of the lighting environment, which will leave the user see enough to be able to operate and handle with the product, so if it is a fair or cloudy day or if is night the user could be manipulate this without problems. It is important to design something that will be possible this fact.

On the other hand, the characteristics of the use are also important because the design will be very different depending on the distances that the boat will be doing. Furthermore, the time that the motor should be attached will condition the design and the facility of the use it. It should be easy to remove and carry on and to transport it.

To sum up, our user will be within the 95 percentile and they will be experts and have experience with boats. Their nationality will be basically European and they will not have any disability. The context of use will be in the Mediterranean Sea and the length of the distance will be shorter. The time of the use will be flashing and the batteries must be changed frequently.

A. The ergonomics and the accessibility

The aim of the ergonomics parts is to design factors, as for the workplace, intended to maximize periodicity by minimizing operator fatigue and discomfort. The ergonomics and the accessibility could be divided in two parts; the static and the dynamics dimensions, these concepts are important to take into account when you do the design of any product.

Firstly the static dimensions of the humans anthropometry, which studies the standard dimensions. There is the ergonomics percentile, which is the concept of the kind of people that you want to take care when you design a product, if you use the 5 percentile it means that you take care of the minority but if you use the 95 percentile it means that you take care of the majority. We are going to use the 95 percentile because of the users of the outboard electric propulsion, in theory, do not have any motor disabilities.

Dimensions of the hand are important for the design of the handle and the user command. Dimensions of the arm are important for the design of the entire outboard propulsion, which has to be good for the handle dimensions.

There is also the dynamics aspect, which studies the articled movement. It measurements and evaluated the magnitude of the articled movements. That is important because the user should interact with the product and do some movements. The parts that we are going to study are, the hand, the arm, the head and the backbone. The hand can do two different movements, the wrist and the fingers movements. The wrist can do the flexion, extension and deviation movements. On

the other hand, the fingers can do the abduction and the flexion movements. Both facts are important to design the handle and the user command. The arm can do the shoulder and the elbow movements. This depends of the anatomy dimensions and the capacity to do this kind of movements the user could access to do more things. It will be interested for the manipulation of the outboard propulsion.
The head could do three types of movements, which helps to the user to have more visibility and possibilities of seeing things.
The backbone movements it is important, as the arm movement, to manipulate the objects.

B. *Colours and font study*

The fore- and the background colour have to be in contrast. This fact will reduce the visual effort of the user at the moment that he should identify the information.
For this reason, the choice was made to use the bright and obscure contrast, the font is going to be dark and the background is going to be bright, and there are going to be an option, which are going to allow the change and invert this.
For the colour scheme, inspiration was found in Innovanautic's logo. For this reason, it was decided to make the main colours black, white, green and blue.
We are following the colours used in the Innovanautic's company, but we chose the black and white colours because are the neutral colours. On the other hand, we are going to use blue colour, which means the colour of sea, and the green one for the ecologic and electric part of the product.
Moreover, we have done a contrast study of these colours, which we use it for the foreground colour and also for the background colour. Has we could see, the best results of the contras are:

Fig. 12. Colour study

When applied to the project, the colour scheme looks like this:

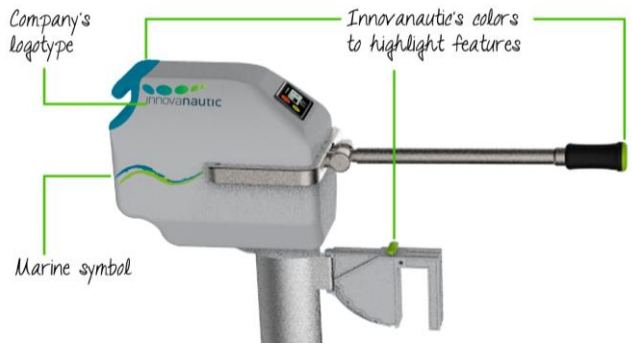

Fig. 13. Engine colours

C. *Cover design*

The cover consists of two parts, a top and a bottom part. The top part has a fixed part and a movable part, used to insert the battery. This moving part will also contain the control screen. A principle sketch can be found here:

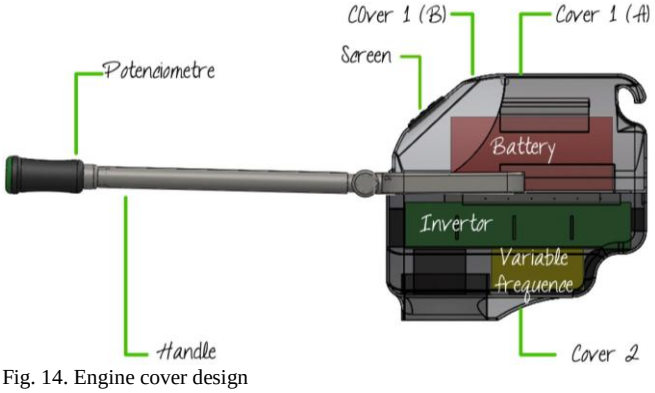

Fig. 14. Engine cover design

D. *Handle*

The handle is designed based on the ergonomics study, which helps to define the shapes and the dimension of this in order to design it with the best shape for the user because it is the part that the user manipulate more.
The dimensions used in the handle are those decided on in the ergonomics study earlier in this report. The handle is a part of the lock system, as was explained, so the shape of this part is most important for the interactive part with the user and also for the lock system.
The system which was chosen to give power to the engine is the safe touch system, which means the user should take the handle and move the finger across the surface, which is safe because if the user does not touch the handle the engine has not power.

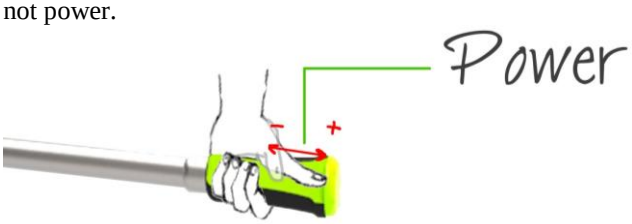

Fig. 15. Handle control

E. *Changing the battery*

The system for opening the housing and changing the battery was designed as follows:

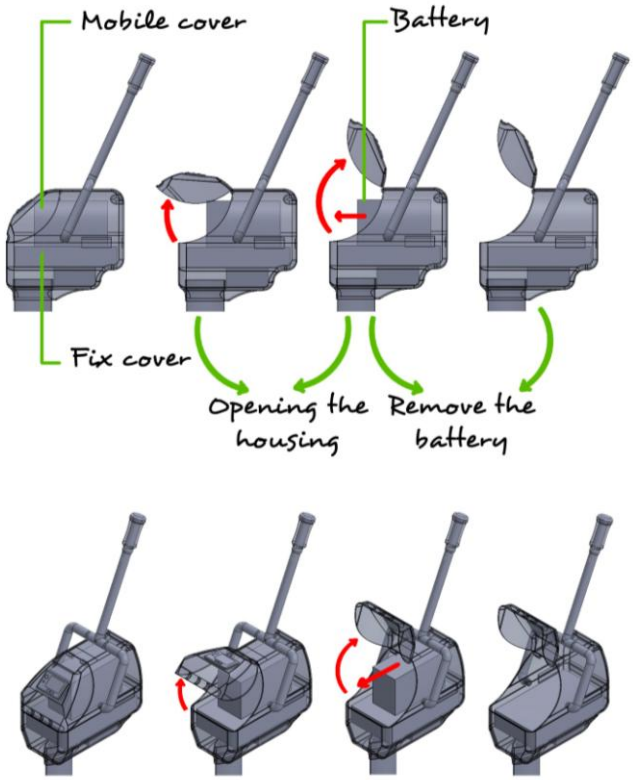

Fig. 16. Battery replacement

F. *User command*

To control the engine, a user command needed to be designed in order for the user to view the current speed and inspect the battery life. The following design was made for this user command:

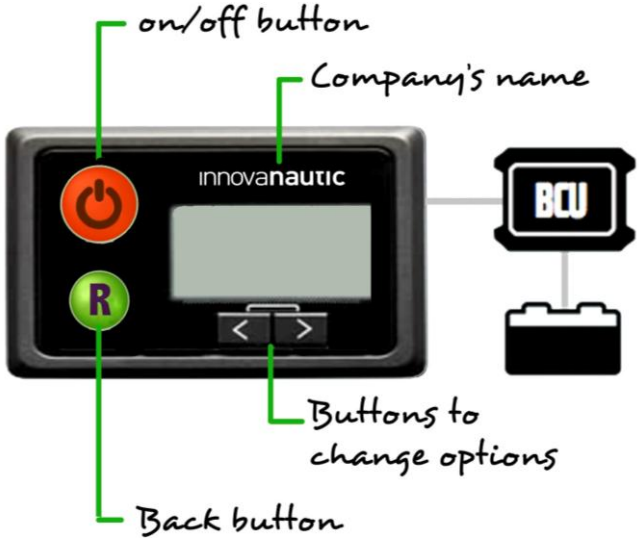

Fig. 17. User command

The characteristics of each part are:

1. Screen: the dimension is 4" (inch), the background colour is grey, a neutral colour, without light, that's because if there are glare the user could see the information 's displays and the found ground colours I black, that's because the contrast it's really good.
2. Buttons of the screen to change the options that it displays: that are the smallest buttons and that's because it are less important. The user could change the information that the screen displays if they press it.
3. On/off button: if the user press it and the motor are off this will set and contrary if the engine is turned it will turns off. That is the biggest button and is because it is the most important. It is red because it colour is really easy to see. There are the international symbol of the on/off which are going to facilitate the user identify it.
4. Back button: it is yellow because that colour is important and easy to see but not like the red colour. That is smallest that the on/off button and that is because it is not so important. When the user presses it, the engine will change the direction of the board.

V. MARKETING

Preparing the electric outboard propulsion is not the end of the project. It is a beginning of introducing the product on the market and what is more find and satisfy the customers' needs and expectations.

To be able to formulate the marketing strategy for Outboard Electric Propulsion it was important to evaluate the external and internal forces which have influence on this project. To achieved the goal strategic analysis was helpful. Strategic analysis is a basic process of gathering and evaluating necessary information. It consist of few marketing analysis like:

- Market investigation – to be familiar with the market situation in the target region and in the market segment – fishing and boats industry
- Although Spanish economy is the 13th-largest economy in the world and fifth-largest in European Union, based on nominal GDP comparisons1, the country is still trying to manage with the global economic crisis, and what the consequences of it are in regards of unemployment and debt. Under those conditions the introduction of a new product on the market is a real challenge.
- Communication strategies – to determine the target audience
- Our target audience – fisherman and other users of small boats in Catalonia region.
- Marketing Mix – to try the way how satisfying customers' needs profitably
- Products – It is a material good, physical object - an outboard electric propulsion for small boats.

[1] http://en.wikipedia.org/wiki/Economy_of_Spain

- Price- (not possible to make a correct estimate yet, the price should be profitable for the company but not too high)
- Place – The assumption was made that product will be delivered mainly to the Catalonian region but it is appropriate for all swallow see with waves approximately 1m high.
- Promotion - the way to reach a target audience. The method to encourage the customers to buy the product is promotion. When clients became familiar with the product they are willing to make purchase.
- PESTEL analysis - to assess the macro-environment of company
- SWOT analysis – internal factors like strengths and weaknesses as well as external factors like opportunities and threats will help to create an overview of the products market position

STRENGTHS	WEAKNESSES
• Environmental friendly • High efficiency system • Sustainable technology • User friendly • Portable • Quiet system • Low operational cost • Relatively light weight • Location: company located in the target region	• High initial price • Run time (approximately 3,5 hour) • Battery life • Max speed (just 5 knots)
OPPORTUNITIES	**THREATS**
• Spanish government encourage domestic business • Lack of the competitors in the target region • Strengthen the company name among the target group and potential buyers • Possibility of acquire the European Fishers Found for the project • Improve the local economy	• Growing the competitors pressure (especially from USA) • Opposition to change

Fig. 18. SWOT-analysis

- Competitors analysis – to be aware of existing competition on the market

A lot different of companies exist on the market who offer similar products. Keeping in mind that the goal is to present the product in Catalonia it was checked that in this region does not exist company which could deliver an entire electric outboard propulsion system. It creates the opportunity of introducing the product successfully on market, but nowadays products and services can be freely distributed all over the world so external companies became competitors.

A. Promotion Strategy

Nowadays a lot of promotional tools are available. In this project the most suitable are:

advertising - to focus the customers attention on the product, increase an awareness of the product and company name, create a desire for the product and to convince clients that the product fulfils their needs.

- posters - to communicate with the audience by visual message, poster should be eye-catching and also informative to gain the customers' interest.
- advertisement in local radio - clear and short information in local radio station is good way to reach to the target group.
- advertisement in local papers and special magazines - information about new product should be attached in the papers and magazines which are the most likely read by the target group, thus local papers and magazines about boats and fishing are the most suitable in this case.

direct marketing – to communicate with potential customers directly by providing straight message, without any intermediaries.

- direct mail – email contained a short promotional information about product send to the companies and potential customers.
- telemarketing – the method of promotion based on giving the information and explanation about product by phone call.
- catalogue – the company should provide an easy access to the catalogue with short description and picture of products. It could be printed version as well as the on-line one.

public relations - is used for crafting and maintaining the good corporation's image.

- presentation for companies – in order to present company product as a business investment.
- panel – contain the based information about product like product specification, short offer for companies.

personal selling - persuasive message based on face-to-face meeting in order to convince customer to purchase a goods

Internet and online marketing – advertising which use an Internet as a source of communication with customer.

- website advertisement - nowadays an Internet became easy to reach source of information due to this fact the information about new product should be available on the Internet. It could be created website, catalogue on-line, advertise on the other websites, forums or community walls.

B. Social Media Marketing

Social media marketing is a process of gaining customer attention through social media sites. Access to the social media platform have everyone who have an Internet connection. Social platforms increase awareness of the brand and create an opportunity to share information among users and companies with the social network. Due to such an interaction it is build relationship with client.

Social media performs several function such as shearing the information, discuss about products or services, involve the customer and promote products and services.

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