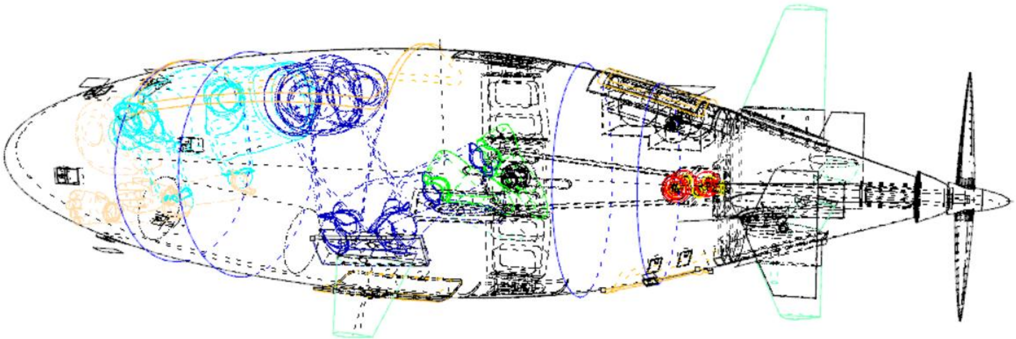
Final Design Report

THR-1



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國立成功大學

National Cheng Kung University

CONTENT

Preface(前言)

This report mainly expounds the concept of the first human-powered submarine designed by Cheng Kung University. The team is mainly composed of six students and one professor from the Department of Systems and Naval Mechatronic Engineering. The main outline is that a pilot will drive a submarine which energy source is by manpower, and its breathing equipment will be placed inside the submarine. Cooperating with the propulsion system and electromechanical system, the sub will move forward under the water depth of about 3 meters. With many efforts, our purpose is to participate in the 2022 human-powered submarine race at the qinetiq basin in Gosport, UK.

First of all, we would like to say thank you to all the manufacturers who have helped or sponsored our team. Because of you, we have been able to accomplish this feat of creating Asia's first human-powered submarine. Second, we are grateful to the UK competition organizer, thank you for giving us this opportunity to express ourselves and show the rich creativity of college students. Finally, we would like to appreciate all the professors and team members of this team, for being able to help and cooperate with each other to achieve our ideals.

1. Introduction

1.1 Team

This time the team is mainly composed of six bachelors from the Department of Systems and Naval Mechatronic Engineering of National Cheng Kung University, ranging from freshmen to seniors. In order to have a unique feat before graduation, six college students spontaneously set up a human submarine club to design and build a submarine, and all have the main goal of participating in the 2022 human powered Submarine Competition. Considering that there are only 6 people, most of our work is done together, but it can still be roughly divided into management (contact and inquire about competition details), design (submarine appearance, propulsion system, electromechanical system, stability), manufacturing (hull and some parts) and practice (diving, wet test) four parts, as shown in the table below.

In terms of manufacturing, due to the huge amount of engineering, (the hull part is gradually stimulated by the team members in a hand-to-hand way) so we also invited other three bachelors from the same department to help us. And to ensure safety during practice, we have hired a team of diving instructors to assist us with diving and wet testing, thank them for their efforts again. Although there are not many people, with everyone's strong sense of responsibility and the guidance of our instructors, our team was very efficient in the integration part, and participated in this year's competition as scheduled and as expected.

1.2 Goal

The winning conditions in competition are nothing more than speed and maneuverability. The speed depends on the shape of the submarine, the pedaling power of the driver and the efficiency of the propeller, so the trade-off of the three will be our goal, in order to achieve the optimization of the submarine's low-resistance shape, high-power output driver, and high-efficiency propeller.

The maneuverability of the submarine is governed by the adjustment of the buoyancy, the position of the center of gravity and the control surface. A well-functioning submarine must be neutrally buoyant so that it can freely control the deep dive of the submarine. The design of the control surface must also be carefully considered. The characteristics of the airfoil make it increase the resistance for the whole sub, so the smaller the control airfoil area, the better.

Considering that this is our first time participating in the competition, we have reference to foreign team competition experience, as follows:

1. WASUB team, Delft University of Technology, Netherlands
   The current world record holder, the speed is 7.43 knots, using a counter-rotating propeller with a smaller chord. The length of the boat is 2.8 meters, the speed increase ratio is 1:3.5 (the maximum speed is 350 RPM), and it is designed and tested by MARIN company.

2. The OMER team of the Higher School of Engineering and Technology in Quebec
   The former speed record holder was 7.28 knots, and the variable pitch propeller was adopted. The airfoil of the propeller blade simply used naca 2411 and scaled according to the length, so the length was relatively large. The length of the sub is 2.63 meters, the speed increase ratio is 1:2 (the maximum speed is 200 RPM), and the design software is maltlab program.

1.3 Structure of the report

2. Design Philosophy

Through the algorithm of the audio-visual platform, we can see the live competition of the European Human Powered Submarine Competition in the United Kingdom. Each university designs and builds the submarine by itself, and drives it through human power to complete the straight-line acceleration, the 25-meter turning track, as well as many different aspects challenge. This competition has aroused the interest of our team. As shipbuilding students, of course, We are eager to try it out, hoping to promote ourselves. It is hoped that through this competition, the vitality of Taiwanese youth will be promoted to the world.

The human-powered submarine is a huge systematic project, which needs to be dismantled to the smallest detail to improve the design. The electromechanical system still needs to be added inside the hull structure to facilitate the pilot's various operations in the submarine. When the sub is started, the driver's face will face down, and he has no time to take into account the forward vision and cannot judge the current speed of the sub with the naked eye. Therefore, it is necessary to provide the ship's velocity, rotation speed, submarine pitch and yaw attitude to the driver to ensure the safety of both. According to the competition experience of foreign teams, the driver will spend a lot of physical strength stepping on the propeller, so the simplification of the instrument display and the pressure resistance are also the key points of the design.

3. Hull

3.1 Requirements

1. There should be enough space for pilot to drive inside
2. Submarines must maintain neutral buoyancy
3. Must have the ability to quickly fill and drain water
4. The pilot must clearly see the outside environment. Similarly, the divers outside must also clearly see the pilot.
5. The hull must reserve space for adding counterweight or foam
6. Parts need to be set up to place the horizontal and vertical tails
7. Some moving parts should be painted with high-visibility colors
8. The surface is as smooth as possible and the volume is as small as possible

3.2 Design method

3.2.1 Critical points of mannequin

3.2.2 Hydrodynamic design reference

3.2.3 Shaping of the hull with SolidWorks and Ansys Fluent

3.2.4 Final result

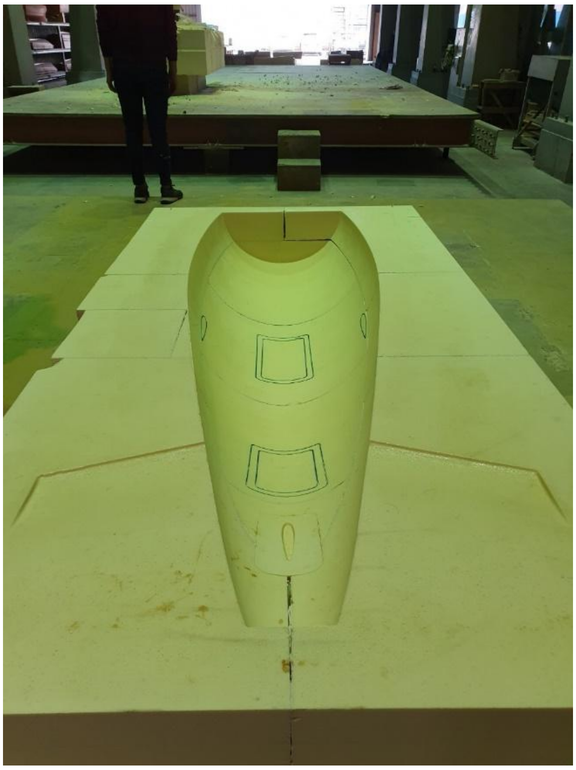
3.3 Production method

After discussion, we finally chose Horizon Yachts Co., Ltd. located in Xiaogang District, Kaohsiung City to cooperate. After negotiating and inquiring about the materials that their company can provide, we finally decided that the material of the hull should be glass fiber. And the horizontal stabilizer needs to withstand greater impact, so carbon fiber is used there. The production method is to use the sandwich method, wrap the foam material in the middle, and arrange the glass fibers of different unit weights symmetrically before and after. Here are the detailed steps to make the hull

1.Make ship models

Next, we use the hull as a symmetrical structure to disassemble it into two parts (as shown below), and use the flange to fix it. There are two main advantages: the first one is to disperse the risk, to avoid the mold design error or accidental damage during lamination, which leads to all the hull need to be remade. The second one is convenient to laminate relative to the entire hull.

2.

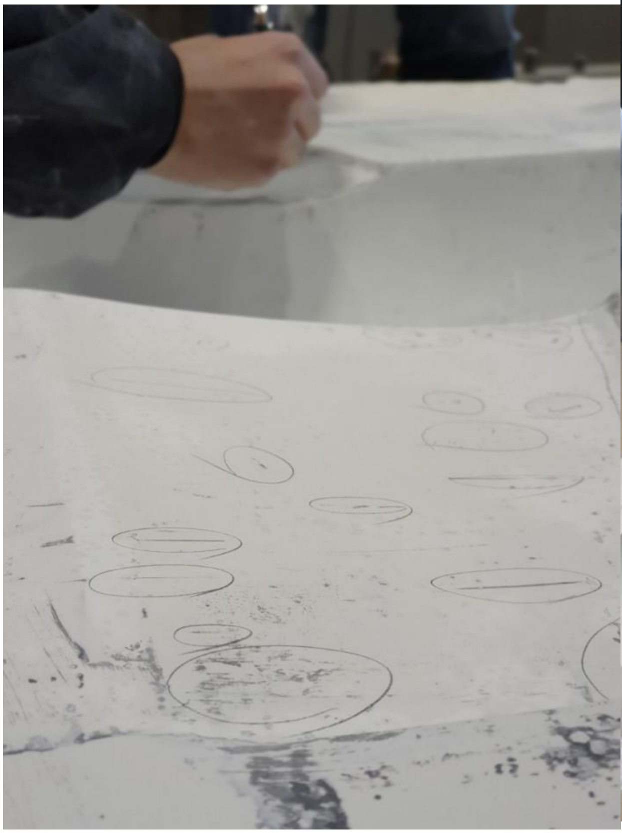


2.Hull making

Following the advice of shipyard professionals, we finally decided to use hand layup instead of vacuum layup. The first step is to fill the soil in the ship model. In order to ensure that the mold is smooth and seamless, we use coarser sandpaper at the beginning, and use hand grinding and a grinder to make our hull model smoother and more seamless. If there are any holes after grinding off the ink, it means that there are holes there, must quickly fill up with soil. With repeating the same steps for four times, we use finer sandpaper to ensure that the hull can be smooth without resistance.

Ink Inspection

Sandpaper Grinding



Circle the hole **repatch**

3. Start laminating

After confirming that the ship model is smooth, we will first apply a layer of shell paint on the outermost layer of the submarine to ensure that water will not leak into the submarine (as shown below), and then use the previously determined glass fiber (M300, LT600 and LT800) arrangement, with resin glued between each layer, foam material in a symmetrical pattern in the middle, and cover extra near hatches and drain cover for added bending resistance. Basically, the production process of the hull is the same as the above. After the resin is dry, the next layer of glass fiber is laid. After laying 5 layers, the hull is roughly completed.

討海人

1.A high-visibility float is required. The float can be released when the driver encounters an emergency (unconsciously), and the float can float to the surface to warn the surrounding people that the driver needs rescue.

2. The emergency exit (main hatch) needs to be marked with a bright color, especially the handle part is.

3. The hatch cover shall be easily opened from inside and outside.

4. Any means of restraint of the pilot (seat belt, toe clip) must have a release mechanism.

5. The crew's face and head area must be visible to the diver at all times.

6. The main cylinder needs to be fixed with a bracket to prevent it from falling off or rolling to cause danger.

7. Divers need to carry a spare cylinder with them for emergencies.
8. The safety of pilot and divers is paramount under all circumstances.

8.2 Emergency Buoy

8.3 Strobe light

8.4 Secondary air supply

The final safety measure is the secondary air supply. This is mainly used in emergency situations (such as the main cylinder is exhausted), and it should be carried on the driver normally. This oxygen capacity allows the pilot to swim from the submarine to the surface, as shown below:

9. Stability

9.1 Neutral buoyant

The most important point to maintain stability is to maintain neutral buoyancy when driving the submarine! That is to make the average density of the submarine equal to the density of fresh water (1000kg/m^3), but to simplify the analysis, it can also be regarded as the Force and moment are balance at the same time.
Therefore, our first step is to list all the items in all the submarines and their weights, as shown in the following table:

components	weight(kg)
hull (horizontal stablizer included)	58.883
mid fins	0.73
mid fins flange	0.13
propulsion support	3.4
propulsion system(front part)	3.14
transmission chain	0.38
propulsion system(rear part)	4.92
emergency Pop Up buoy	1.16
rudder(uper)	0.21
rudder(lower)	0.16

main shaft	1.68
stern cap	0.42
propeller	3.12
tail cone	0.54
electronic system	1.78
front hatch	1.35
servo motor box *4	0.8
pony bottle two liters	4.147
cylinder	15.05
weight	9

We can calculate that the total weight is111kg, which is 1087.8N. And the buoyancy part is related to the volume of the object because the submarine is immersed in water. The calculated buoyancy is 878.62N, which means that we need to add foam material to increase our buoyancy. The density of the foam material is 24.2kg/m^3, with the following formula:

$$\frac{m_{foam}(kg)}{24.2} * 1000 = buoyancy(kg)$$

We can get the conversion formula, that is, **1 gram of foam can provide 41.32 grams of buoyancy at the bottom of the water**. After calculation, we need a total of 516.6 grams of foam to get the force balance.

Next, to get the moment balance, first we need to ask for the position of the center of gravity and the center of buoyancy. Therefore, we list all the equipment positions of the submarine, and then substitute the formula for the center of gravity for one direction (so is the center of buoyancy), as follows:

$$LCG = 1/M_{total} \sum_{1}^{n} m_i * \overline{OG_i}$$

$$LCB = 1/M_{total} \sum_{1}^{n} m_i * \overline{OB_i}$$

If the origin is set at the bow of the submarine, we can obtain that the center of gravity in x direction is 1.167m, -0.002m foy y, and -0.05m for z. The center of buoyancy in x direction is 1.223m, -0.016m for y, and -0.04m for z. With this data, we can roughly confirm the stability of our submarine.

What needs to special attention is that when the propeller rotates, it will give the submarine an opposite moment. This factor must be taken into account, and based on the static balance of the submarine, the position of the counterweight is adjusted to make the submarine balance when moving forward. As for how much distance to move, it is necessary to make enough successive fine-tuning in the test. After enough water testing, we can get the neutral buoyancy state we want.

12. Summary

At the end of this report we conclude with three key points. The first is proper design. This is the most important step. Don’t recklessly start to implement without sufficient design and thinking. Although most projects cannot be designed only once and will be continuously improved, you can save “a lot of” time as long as this step lays the groundwork. What needs special attention is that when drawing the design drawings, the error of the production process must be taken into account. It is absolutely impossible to make "just right", which taught us a lesson when making the cavity plate of the hull.

The second is a sufficient test. Be sure to allow enough time to do multiple tests (including dry and wet tests) before the competition, such as the submarine's weight (stability), the activation of the emergency buoy system, the tightness of the propulsion system or the oxygen consumption of the diver himself. Even after careful design, there must be details we overlooked, so be sure to do enough tests. Also, don't be discouraged when you find that the design doesn't match the actual results. This is very common. We encountered this problem when the counterweights brought the submarine to neutrally buoyant, but in the end we still made adjustments based on the test results.

The third is enthusiasm. Our team started with a small number of four people. After the workload is shared, everyone's burden is actually quite large. What makes us continue to support is enthusiasm. No matter how superb a blueprint, or no matter how excellent a design, if there is no enthusiastic support, it will never last until the last moment.

Finally, the content of this report contains all the design concepts, construction and operation methods of any part of the submarine, as well as all references to date. As it is our first time participating, our ultimate goal is to complete the competition and learn from it so that we can pass on this valuable information to the next class of students in our department. Therefore, we have produced this report, which covers from the initial concept to the final implementation results. We hope that this report, which bears the efforts of our team, can be used as a reference material to help the next students to participate in the competition.