Designing and Manufacturing the control system of an underwater robot

by

MD. Maidul Islam (131456)

MD. Shums Sumon (131453)

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Department of Mechanical and Chemical Engineering

Islamic University of Technology (IUT)

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Designing and Manufacturing the control system of an underwater robot

Approved by:

Prof. Dr. Md. Nurul Absar Chowdhury

Dean, Faculty of Engineering

Islamic University of Technology

Boardbazar, Gazipur -1704

Date: ……

Contents

List of Figures

Abstract

As the ocean attracts great attention on environmental issues and resources as well as scientific and military tasks, the need for and use of underwater robotic systems has become more apparent. Underwater robotics represents a fast growing research area and promising industry as advanced technologies in various subsystems develop and potential applicatareas are explored. This project is an attempt to develop a Remotely Operated Vessel (ROV) for underwater exploration. To provide some guidelines this ROV is being developed according to the Marine Advanced Technology Education (MATE) competition requirements, with emphasis on being able to freely improve the dynamics of this particular design. The requirements being attempted include surveying, research, and recovery of objects.Design constraints will primarily be concerned with providing power to the ROV from the surface, maintaining dimensional constraints and being able to reach a predetermined depth. With the growing applications of ROV's on a daily basis and the scope of their requirements, considerations in the development of this project are being focused towards maintaining a minimal cost and increasing the ability to freely modify the ROV to include other tasks within their potential to assist in reducing the need to invest in multiple ROV.

Chapter 1

Introduction

During the last 30 years the need for oceanic cartography, sea exploration and underwater oil extraction has led to the creation of an underwater vehicle that can be controlled from distance. Remote Operated Underwater Vehicle shortened as ROV is a tethered underwater vehicle. In this thesis from here on the term "Remote Operated Underwater Vehicle" will be referred as ROV. ROVs were created to help people to fulfill their needs fast and with minimum risk for their lives. The first advanced ROV was created in the 1970's and used to recover practice torpedoes and mines. ROVs were also created by offshore oil and gas industries in order to assist in the development of offshore oil fields later on, when the new offshore development exceeded the reach of human divers. Nowadays you can find ROVs designed for different purposes, such as science, education, military and for hobby as well. In this thesis the main goal is to explain the theoretical, but also the practical aspects of ROV in order to understand how a small scale ROV works. In the following chapters step by step instructions will be given in order explain how to make a fully operated ROV, which is able to maneuver in any direction the water. The maneuvering of the robot is achieved with the help of four brushless motors. The ROV has an on board camera for monitoring and recording the underwater life. Finally, the robot is tethered with the controller's side via an Ethernet cable.

Background and Motivation:

The motivation to design an ROV comes from the fact that as engineers we are constantly trying to push the development of technology. With ROV’s there is already an established industry which has many opportunities for growth and bettering the understanding of our underwater environment. Part of the reason much growth is possible comes from the fact that many of the instruments used are industry specific with minor attempts at expanding the applications for these tools. ROV technology is still relatively new due to the fact the operating environment is within water causing communications.
and waterproofing issues. This project requires a collective use of the engineering knowledge attained such as Fluid Mechanics, Mechatronics, Materials, Mechanics of Materials, Manufacturing and Dynamics. With the applications of this knowledge our design will be effective and successful. The combination of the designers on this project also fuels the motivation with experience from scuba diving and the Navy.

2.ROV

2.1 History of ROVs

The first ROV known, called “Poddle”, was created by a French scientist, engineer and explorer Dimitri Rebikoff in 1953. The first funding attempt of the early ROV technology was made by the US Navy in the 1960’s. They invented the so called "Cable-Controlled Underwater Recovery Vehicle" or also known as CURV. The CURV was able to per-form series of deep sea rescue operations, as well as recovering objects from the ocean floor.

Another technology development of the ROVs was made by commercial firms that saw the future in ROV support of the offshore oil fields. These ROVs were first used as in-spection vehicles and a decade later as vehicles for maintenance of the offshore oil fields. Nowadays ROVs are responsible for numerous tasks in many fields. ROVs can do something as simple as an inspection of an underwater structure, but more de-manding work as well, such as inspection and maintenance of pipelines all the way to connecting pipelines together and placing underwater manifolds. All in all, ROVs can work on all stages, from construction to maintenance.

2.2 Classification of ROV

Submersible ROVs can be classified into categories based on their size, weight, ability and their power [1].

- Micro-Class ROVs are very small in size and weight. They usually weight up to 3 Kgs and are commonly used in places where a human diver cannot reach such as sewer, pipelines and places with small cavity.

- Mini-Class ROVs can weigh up to 15 Kgs. They can also be used as a diver alternative and they can complete a job without the need of outside help.

- Light Work-Class ROVs are used for heavier works and most of them are carrying manipulators (small three finger grippers). Their frame is made from polymers or aluminium alloys. The maximum working depth for the category of ROVs is up to 1000 meters.

- Heavy Work-Class ROVs are mainly used by offshore oil companies and they carry at least 2 manipulators and a sonar unit.

- Trenching & Burial ROVs are able to carry a cable laying sled and work in depths up to 6000 m.

- Autonomous Underwater Vehicles (AUV). These ROVs are autonomous and they work without an operator.

Table 1 below shows different classes and types of ROVs

Class	Type	Power (hp)
Micro Observation (<100meters)	Low Cost Small Electric ROV	<5
Mini Observation (< 300meters)	Mini (Small)	<10
Light/Medium Work Class (<2,000 meters)	Medium (Electro/Hyd)	<100
Observation/Light Work Class (< 3,000 meters)	High Capacity Electric	<20
Heavy Work Class /Large Pay-load (<3,000 meters)	High Capacity (Electro/Hyd)	<300
Observation /Data Collection (>3,000 meters)	Ulta-Deep (Electric)	<25
Heavy Work Class /Large Pay-load (>3,000 meters)	Ultra-Deep (Electro/Hyd)	<120
Trenching and Burial	Bottom Crawlers and Plows	
Towed Systems	Towed Systems	
Autonomous Underwater Vehi-	Untethered ROVs	

2.3Propulsion

As a part of any mobile robotic system, some means of locomotion is necessary in or-der to move the robotic system. For that reason, thrusters are used for the movement of the ROV. Thrusters are a critical design consideration for any ROV system. Without having the proper thrust, the ROV can be overwhelmed by the environmental conditions and thus unable to perform the desired tasks. Thrusters can be either electrical, hydraulic, ducted jet type or a combination of those four. The most important considerations that a ROV designer must take into account for choosing the size and type of the thruster used are listed below [3].

- The task that the ROV must perform and thus the work system and tools necessary for it.

- The necessary power system to support the work system, tools control system, lights and cameras.

- The size of the frame and the amount of buoyancy in order to support the power and work system.

- The physical and environmental conditions such as depth and sea current.

- The drag on the vehicle and cable.

As mentioned before, there are four types of thrusters that are nowadays used for the propulsion of the ROVs. There are electrically driven propellers, hydraulically driven propellers, ducted jet driven propellers or a combination of those. These different types are developed to suit the size of the vehicle and the tasks that it shall perform. In some cases the location where the ROV is operating, dictates the type of propulsion used. For instance, if the ROV requires heavy duty tooling for intervention, the vehicle could be driven with hydraulics. Hydraulic driven type of propellers are rarely used in small scale ROVs. This is because they operate though hydraulic pumps, and the energy conversion (from electrical to mechanical to hydraulic) makes it inefficient. Finally, the main goal for the design of a ROV propulsion system is to have high thrust to physical size/drag and power input ratios.

2.4Drag

In order the vehicle to have some kind of locomotion to take it to work site and perform the work, the vehicle must power itself and overcome the fluid drag of the vehicle/tether combination to travel to and remain at the work site [3]. The equation 1 [4] below shows the drag:

$$Drag = \frac{1}{2} \times s \times A \times V^2 \times Cd \quad (1)$$

s= density of the sea water/gravitational acceleration,
Density of the seawater= 1,025 kg/m3, Gravitational acceleration = 9.8 m/sec2 V= Velocity in meters per second

Cd is in the range of 0.8 to 1 based on the cross sectional area for most vehicles

A= Characteristic area on which Cd is nondimensionalized. For vehicles, it is usually the cross sectional area of the front or the volume of the vehicle to the 2/3 power. For cables, it is the diameter of the cable in inches divided by 12 times the length perpendicular to the flow. For ships, it is the wetted surface.

The vehicle drag is only one part of the equation as the tether usually dominates the vehicle-tether combination. This can be best illustrated by the following equation 2 [4].

$$Drag = 1/2 \times s \times Av \times V2 \times Cdv + \frac{1}{2} \times s \times Au \times Vu2 \times Cdu \quad (2)$$

The formula above consists of two different parts. The first part is the drag that appears on the vehicle and the second one is due to the cable drag.

Where v is for the vehicle, and u is for the umbilical (cable).

Another important formula that gives the power absorbed is given in the below equation 3 [4].

$$\text{Power} = (\text{Drag} \times V) / 550 \quad (3)$$

Where 550 is a constant, which converts meters/kilos/seconds to horsepower. Thus the power is proportional to the velocity cubed.

2.5 Cable Design:

One of the most important part of the ROV are the cables used for the communication of the ROV with the outside world. Some ROVs can go up to six kilometres of depth, so it is important that the ROV will be properly powered and can also transfer different measurements and data that it may take. The pressure that the cables must withstand is enormous. Vehicle size, weight, temperature, duration of the operation, and operating depth, as well as the vehicles motors, subsystems, and payloads, all combine to determine the ROVs cable design. There are two different categories for the cable used, umbilical and tether. The umbilical and tether are essentially the same item. The cable linking the surface to the cage or TMS is termed the "umbilical," while the cable from the TMS to the submersible is termed the "tether". In order to design an ideal ca-ble for an ROV, designer must consider the power, signal and strength needed for the specific application that will be used.

.2.5.1 Power Requirements

The cable must be able to withstand the power that is about to be transferred. The power is translated into amperes. It is necessary that the cable must have enough material to conduct this power to the far end. An important calculation that the designer must take into account is that the cable has resistance to electrical energy flow, which creates a voltage drop. For that reason copper is used, since is well known for its low resistance.

Another consideration is the insulation of the conductors in order to contain the electrical energy.

The most common material used for insulating the conductors is thermoplastic materials such as TEFLON™. However, because thermoplastics soften or melt with heat, it is important to know both the operating environment and the current requirements. The operating voltage in another consideration in the cable design. Limitation of voltage stress on the insulation is an important factor. If the voltage across the cable is too high it can cause failure to the insulator, and the electrical energy can exit the conductor before reaching its objective. To avoid a hazardous condition in case the insulator fails, a separate conductors are used as an emergency ground.

2.5.2 Signal Requirements:

The most important factor in signal requirements is the attenuation losses. The signal, whether electrical or optical, is attenuated through both the conductor and the insulator. The amount of attenuation varies and is directly connected with the frequency of the signal.

The signal transmission can vary, depending on the type of the signals the cables car-ry. Signals can be analog, digital, electrical or optical. Shielded cables are used in this case, so that the signals are protected from electromagnetic and radio frequency interferences. In addition cables that are carrying signals are separated from the cables that are carrying power. Other parameters that a cable designer must take into account are the impedance and capacitance of the cable and also signal's frequency.

Finally, for the transmission of a signal optical fibers can be used. In this case parameters to be considered are the attenuation, the bandwidth and the wavelength of the signal.

2.5.3 Strength Requirements:

Another important factor in cable's design is the strength requirements. The strength-member is a steel armor wire that provides the mechanical link to the ROV. It will also support the cable weight, the ROV and any additional payload. The cable size can in-fluence the load on the cable due to the drag.

The most common strength member material used for umbilical cables is steel. The steel is made with carbon and has galvanized coating on the outside to protect the car-bon steel from corrosion. Another material used for the strength member of the cable is synthetic fibres, such as KEVLAR. KEVLAR is a strong material that can handle enormous forces. It is also used for its light weight.

The price difference between those two different materials is remarkable. The designer must choose the correct material depending on ROV's needs. For ultra-deep systems, synthetic fibers are used, in order to get to the necessary depth.

Finally, the design of the ROV's cable tether is critical to the successful operation of the ROV. However, the technology has advanced to the point that is indeed a design problem and excellent cables are available for virtually any application

2.6 Special features

2.6.1 Laser Line Scanner

Laser line scanner, shortly abbreviated as LLS, is a device that works exceptionally well from a towed or moving platform for underwater search or surveys. LLS in its simplest form is a sensor that takes advantage of a laser to concentrate intense light over a small area, illuminating distant targets and extend underwater imagery. A series of spots on the seafloor consist an optical image, each sequentially illuminated by a pencil sized diameter laser beam that scans the bottom. The data gathered is displayed as a continuous image that can be recorded on a standard video cassette recorder. The optical sensor consists of subassemblies for the imbedded sensor control electronics, the laser, a scanner and a detector. All four subassemblies are integrated into a single unit, installed inside watertight pressure housing in order to remain waterproof. The Figure 1 below shows a laser line scanner.

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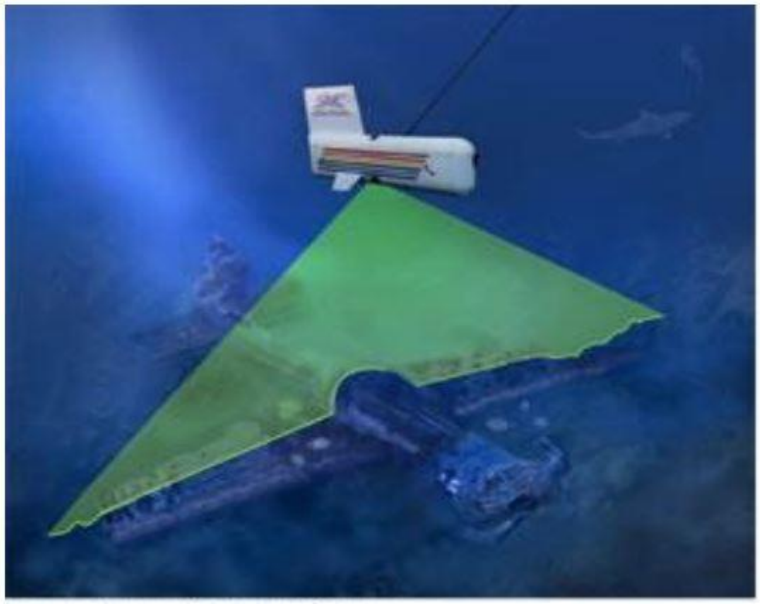

Figure 1 Laser line scanner

The laser line scanner can be attached to the ROV or be as an individual device. In case that it is attached on the ROV the best possible place is between the sidescan sonar and the camera. Typical size of a LLS system is about 35 cm in diameter and 1.6m long. The price tag for LLS can be up to 550000 euros. Most tools that a ROV uses have also their drawbacks. In case of the LLS system the scanner requires motion in order to capture and generate images. This means that the LLS should be moving all the time across the sea and close to the seafloor.

2.6.2 Sonar

In underwater environment light is absorbed over very short distances. Working under-water the lack of long range vision is a major limiting factor. Earlier, when divers did the underwater work such as repair and maintenance, the vision of the objects was difficult and moving from one place to the other was slow. As robotics and instrumental intervention arrived at the worksite, the need of extended vision became more vital.

For this reason engineers have turned away from the visible light spectrum and moved to another form of transmittable energy underwater: sound. Sound attenuates in dense water as light, but not over a short distance as light. Devices that use sound propagation to communicate or detect objects under the surface of water, are called sonars.

There are two different types of sonars, passive and active. Passive is essentially used for listening the sound made by vessels. Active sonars emit pulses of sounds and are used for listening echoes. In case of the ROVs, active sonars are used. In the past few decades those instruments have become more sophisticated and accurate.

Underwater sound transmission has also its limitations. The frequency used by the sonar affects the range capable of gathering the data. Sonars that are using high frequencies are effective in short distances (up to 1 Km), they have great imaging. On the other hand, sonars that use low frequencies have longer operational distance (many kilometres), but the image is not as good as in high frequency sonar. A typical frequency for imaging sonar is around 300 KHz. Nowadays, sonars used by ROVs have many other applications as well, such as mapping and collision avoidance.

2.6.3: Manipulators:

Another feature that all work class ROVs have are the manipulators. Manipulators are mechanical arms that are able to perform various jobs underwater. Because the underwater environment is intrinsically inhospitable to humans, using remotely manipulated mechanical arms is a natural way to perform subsea work. The remote manipulation is also called teleoperation. It allows human operators working from the surface to manipulate underwater objects. ROV manipulators, unlike the industrial ones, are equivalent of human arms and hands. Manipulation of the objects happens in real time by the ROV operators. The usual place for the manipulators is the front side of the ROV.

A wide variety of manipulator types evolved during years to cover a very board range of subsea applications. Tasks that manipulators can work with can be easy, such as grasping a lift line, or more complex ones, such as plugging and unplugging electrical and hydraulic connectors. The Figure 2 shows a manipulator arm.

Figure 2Manipulator Arm[6]

The vehicle designer should consider the following when designing manipulators: num-ber and types required, their location, required control type, lift, maximum and minimum reach and finally the camera locations.

Finally, future manipulators will be able to detect potential collisions, move the slave arm directly to an object or along a pre-defined curve, and record manipulator move-ment paths for later review or feedback.

2.7 ROV Pilots:

Nowadays the subsea industry is getting busier all the time. Companies that are working with subsea projects invest a lot money and effort for development and expansion in their companies. This has been particularly noticeable in the area of remotely operated vehicles. As the demand for ROVs increases, so does the need for qualified ROV pilot technicians. The number of projects completed with the help of a ROV have at least doubled since the beginning of this century. Therefore companies using the ROV technology have been exceptionally interested in improving their employee’s skills and knowledge. The technical features of ROVs are continuously getting more and more specific and fine. This has led to the need of highly trained professional ROV pilots [7].

3.Electronic Speed Controller (ESC):

The Electronic Speed Controller (ESC) is an electronic circuit that is responsible for driving motors, adjusting motors speed and direction. It can act as a dynamic brake as well. From now on the term “Electronic Speed Controller” will be referred as ESC. ESCs are mainly used by almost all radio controlled models such as RC airplanes, helicopters, drones and cars. Besides radio controlled models, ESCs are also used on electric cars, electric bicycles and electric aircrafts. There are two different types of ECSs, brushless and brushed.

An important feature that the new ESCs have is the “Battery Eliminator Circuit”, also referred as BEC. The BEC is responsible for providing the power to the receiver and servos from the motor battery. This circuit eliminates the weight of a receiver battery needed.

3.1 Brushless ESCs:

Brushless ESCs are mostly used in brushless motors. They provide a three phase electric power low voltage source of energy for the motor. The output of a brushless ESC is trapezoidal wave. ESCs produce three separate waves, one for each wire of the motor. Each wave has a 120° phase difference. The speed of the motor is achieved by changing the wave length (frequency) of the trapezoidal wave on the three phases, and it is not related with the voltage or current supplied. By increasing the frequency, the speed of the motor increases as well. Decreasing the frequency causes the speed of the motor to decrease. The Figure 3 below shows a brushless EMAX 4 in 1 ESC. This is mostly used in drones. It is capable to drive four brushless motors with maxi-mum of 25A current on each motor.

Figure 3 :4in 1 ESC[8]

Almost all new ESCs are programmable. This way the user is able to change the ESC's options, such as setting low voltage cut-off limits, timing, acceleration, braking and the direction of the rotation. These ESCs are controlled by an advanced micropro-cessor. Programming an ESC can be achieved either from an ESC programming card, or straight from the RF transmitter. The Figure 4 below shows a programming card.

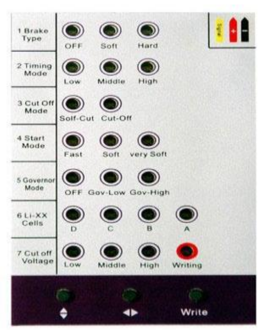

Figure 4 Emax programming Card[9]

Programming an ESC with the card mentioned above is much easier compared to pro-gramming with the RF transmitter. By connecting the signal wire of the ESC and the power supply, user is able to see which settings are used at the moment. By pressing the buttons on the card, user is able to change the settings in any way wanted.

3.2 Brushed ESCs:

Brushed ESC working principle is different from the brushless ESC. In order to in-crease the speed of the motor, the ESC must provide more voltage than before. By increasing the output current of the ESC, user can achieve higher torque values. The Figure 5 below shows a brushed ESC.

Figure 5: Turnigi Brushed ESC [10]

Brushed ESCs have two cables for the power (Positive and Negative), a signal wire for adjusting the speed and two wires for feeding the brushed motor. Another feature brushed ESCs have is that user is able to change the direction of the motor by inversing the polarity.

4. Construction of The ROV

4.1 Main Frame:

In order to make the frame for the ROV, white PVC pipes were used. The diameter for each PVC pipe was 32mm (3.2cm). The pipes were glued together in every connection with PVC transparent glue. In order to make sure that the frame will be waterproof glass silicone was used. The overall size of the ROV is 86.5cmx42cmx20cm (L x W x H). On the main frame four brushless motors where mounted with the help of stainless steel adjustable rings. The motors are used for the movement of the ROV.

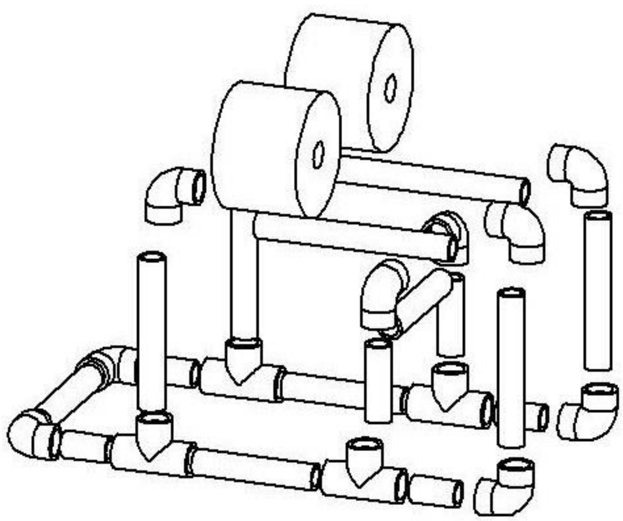

Figure 6 Initial Frame Assembly

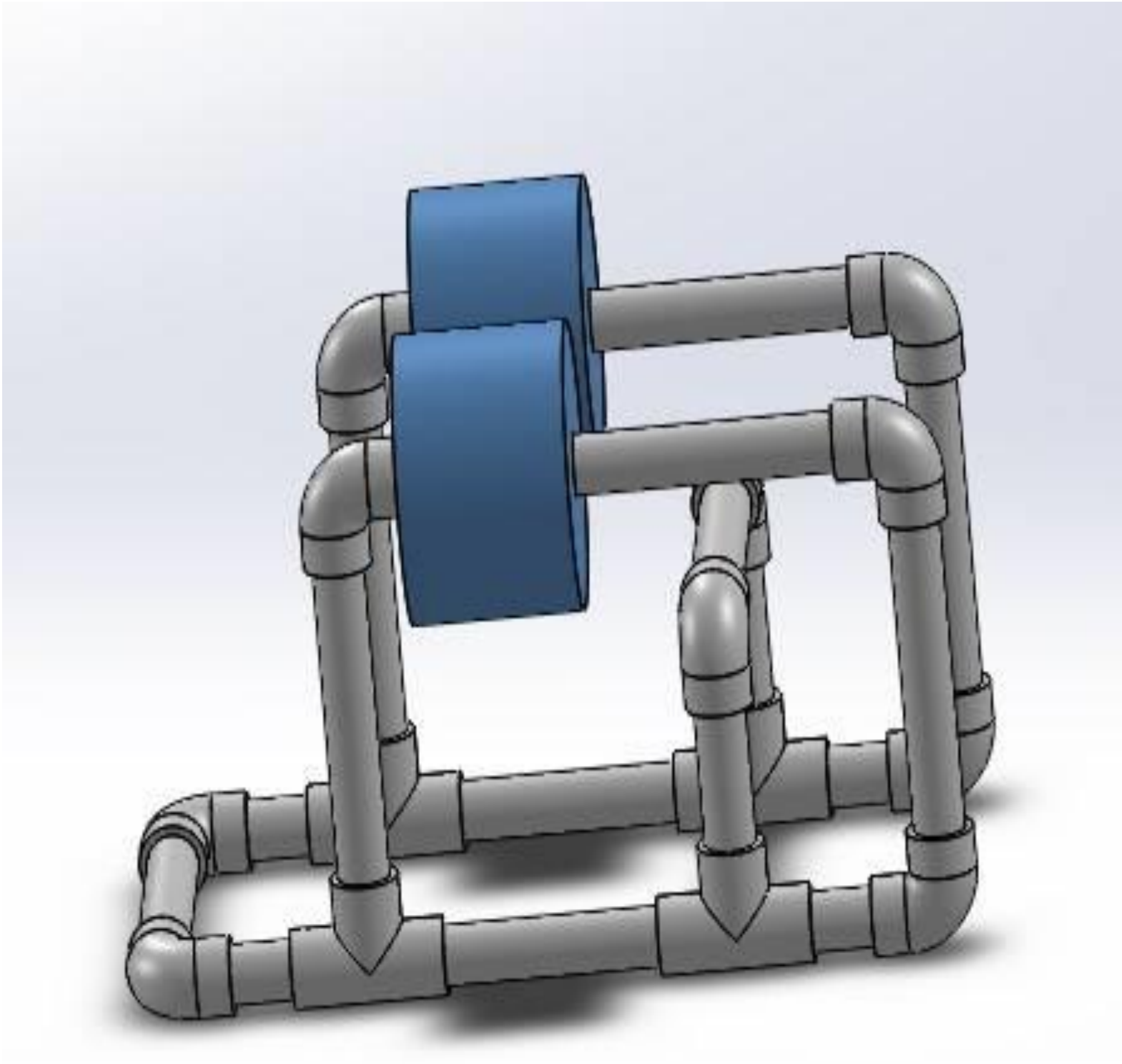

Figure 7 Frame with Floats

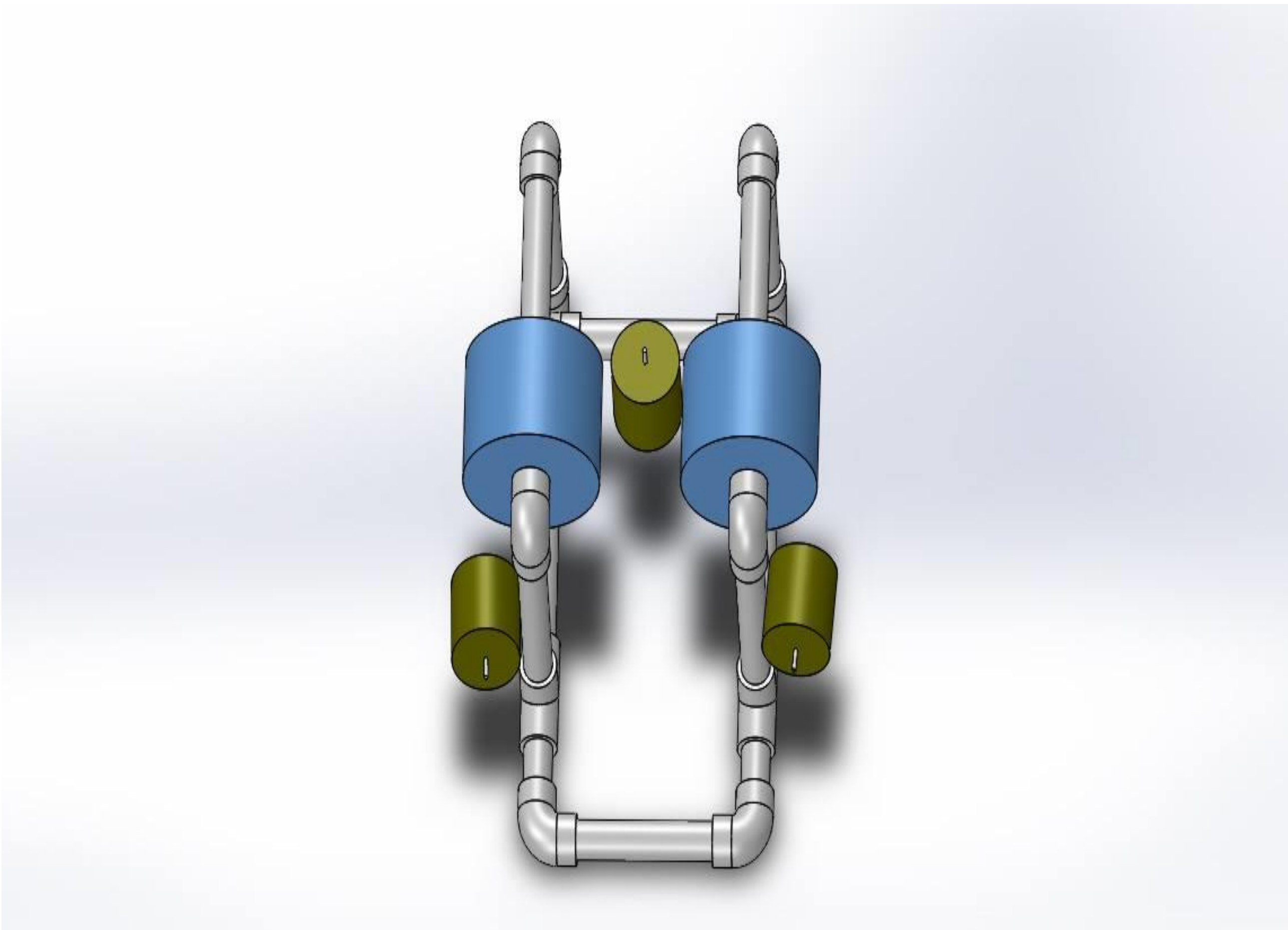

Figure 8: Frame with Thruster

Another important factor that had to be taken into account was adjusting the ROVs buoyancy. Buoyancy is the upward force exerted by a fluid that opposes the weight of an immersed object [10]. The optimum buoyancy for a ROV is slightly positive. One of the main reasons why ROVs have slightly positive buoyance is to ensure that they will return to the surface in case a power failure occurs. Another reason for using slightly positive buoyance is the obviation of need for continual thrust reversal. This allows a near-bottom maneuvering without the need of thrusting up.

The Figure 9 below shows the forces applied on an object being in the water.

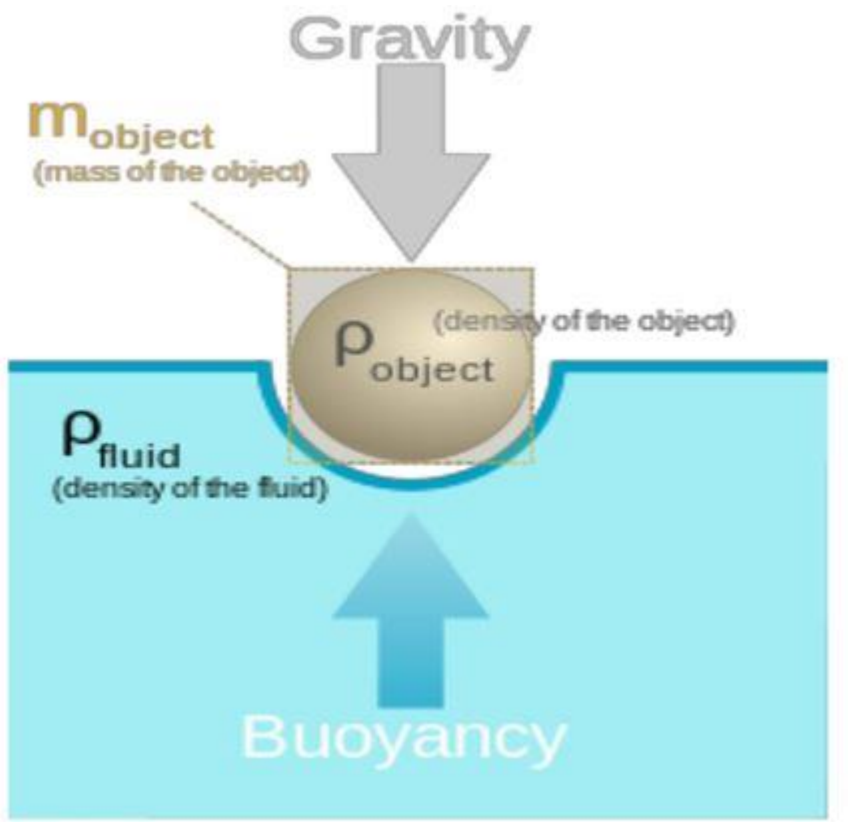

Figure 9 Buoyance force[11]

To achieve that, iron rods were attached on the bottom side of the frame. The amount of iron rods and the weight of them were selected by trying different weights and length while the ROV was in the water.

4.2 Main Tube:

The most important part of the ROV is the main tube. The main tube is made from a hard type PVC pipe with 120mm of diameter. On both ends of this pipe, round trans-parent Plexiglas (150mm diameter) is attached and secured from one end to the other with long screws; in order to assure that the tube will be remain waterproof.

In the main tube a CCD color camera is mounted and placed close to the transparent Plexiglas in order to have the best possible view of the underwater target. The camera also works by giving the best possible view for the correct movement of the ROV. An-other important electronic component that is placed in the waterproof tube is the ESC (Electronic Speed Controller) that is responsible for driving the four brushless motors. In addition, a 3 cell LIPO battery with the capacity of 8000maH will be used for powering the ESC and finally the motors. Finally, a PCB (Printed Circuit Board) with Ethernet connection will be responsible for the tethering with the controllers side.

4.3 Motors:

To assure the proper movement of the ROV inside the water four powerful brushless motors were used. The main reason why brushless motors were used is that they can work inside the water without any problem and they do not have to be waterproofed. Brushless motors are suitable for working underwater since they do not have contacts, and they are powered by the stationary coils. The stationary coils are powered by an AC signal to spin the casing containing the magnets. So there is nothing for the water to interfere with electrically speaking (assuming the wiring is all insulated). The Figure 10 below shows the brushless motor used.

Figure 10 Emax Brushless Motor[12]

All brushless motors are rated in KVs. KV is the amount of RPM that the motor can spin per volt. The motor mentioned above is rated at 980KV. That means that the maximum RPM for that motor, assuming that it will work with a 3 cell battery, (11.1Volts) is 980KV x 11.1V= 10878 RPM/min. The maximum RPM of the motor is also directly linked with the size of the propeller that is mounted on the motor. Longer propeller can give more thrust but less RPM, and vice versa.

In order to reduce thrust losses, motors were mounted on a cylindrical PVC pipe with 6cm of diameter. This type of setup is called EDF which stands for Electric Ducted Fan. This kind of setup is widely used in electric RC jets for their high performance and minimal thrust losses.

Typical corner rack connectors used for mounting the motors on them and later on the corner rack connectors were screwed on the 60mm PVC pipe. The propellers used have 57mm of diameter. The mount of the propellers on the motor was achieved with a common propeller mount that came with the motors.

4.4 Electronic Speed Controller:.

As mentioned before, in order to drive the four brushless motors, the need of an ESC is necessary. For that reason, knowing that space is limited in the main tube, a 4 in 1 ESC was selected for this purpose. The Figure 11 below shows the ESC used for driving the brushless motors.

Figure 11 : 4 in 1 ESC[7]

The main advantage of this ESC is the space that it requires. The dimension of the ESC is 65mm x 66.5 mm x 17.5mm (L mm x W mm x H mm). The ESC has four signal inputs, one for each motor, the power supply that is fed from the 3 cell battery. Also the Figure 13 above shows M1, M2, M3, and M4 with 3 pins each one, where the motors are connected. The signal inputs S1, S2, S3 and S4 were connected with the micro-controller

4.5 Camera:

For monitoring the direction of the ROV a color CCD camera was used. The maximum resolution of the camera can reach up to 700TV Lines. The lens of the camera is 2.1mm and the viewing angle is 140 degrees. The Figure 12 below shows the camera used in order to monitor the movement of the ROV, and also the underwater life.

Figure 12 CMOS Camera

The camera has 2 cables. The red cable is for powering up the camera and the second wire is used as signal wire. The power supply needed to power up the camera is 9-12V and will use the same battery as the motors are using (3 cells, 9000 mAH capacity). The signal wire of the camera will be connected on the PCB and after then with the Ethernet wire to the controller's side that will be the 7" inch color monitor.

4.6 TFT Monitor:

The TFT monitor used is a 7" inch HD color screen monitor with resolution of 800x480 pixels. The display format of the monitor is 16:9 and it has an auto switch on the color encoding system

(PAL/NTSC). The dimensions of the monitor are 174x113x19 mm and the power supply needed is 9-35V. The Figure 13 below shows the TFT Monitor used for observing the ROV.

Figure 13 TFT Monitor

The TFT monitor is power through a 3 cell Lipo battery with a capacity of 3000 mAH and it can run up to 15 hours continuously.

4.7 Connectors:

Two connectors were screwed and waterproofed with silicone on the bottom end of the main tube. The connectors were attached on the 6mm thickness transparent Plexiglas. These connectors are so called “Electric Deck Aviation Connectors” and they are waterproof. The main usage of these connectors is the line connections between electrical equipment, various instruments and meters. They have good sealing performance, they are light weight and they have high resistance against corrosion. Also high conductivity and dielectric strength was one of the main reasons why these connectors were chosen. The Figure 14 below shows the actual connector used

.

Figure 14 Electric Deck Aviation connector[13]

The size of the each connector is 35x80mm. Each connector has 20 pins, therefore enough pins for the projects needs plus for any future improvements on the functionality of the ROV. One of the two connectors will be used as a communication channel between the outside world with the inside and the second connector vice versa. The left connector is used as the connection between the motors that are placed on the main frame with the ESC that is placed inside the main tube. The right hand side connector was used for the communication of the ESC with the controller side.

4.8 Controller

The ROV is controlled by a controller based on a microcontroller and two joysticks used for ROVs movement. The microcontroller used for this purpose is an Arduino Mega 2560.

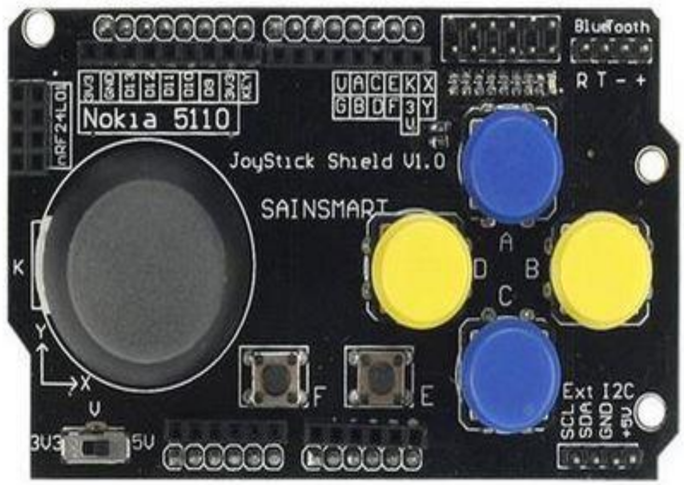

Figure 15 Controller of ROV

Each joystick has two potentiometers, one for each axis (vertical and horizontal). Arduino Nano is able to read the values of each joystick through the analog input of the microcontroller. The readings of the potentiometer can be from 0 to 1023. The brush-less motors are acting as servo motors, and for that reason scaling potentiometer's readings is necessary (0-1024, 0-180). The controller is powered by a normal 9 V battery.

4.9: Software

Arduino IDE 1.0.6 is the software used for programming the Atmel microcontroller of the Arduino Nano. Brushless motors and servos are both controlled with the same principle: Pulse Width Modulation, shortened as PWM. Therefore Servo library was used. Servo function creates the objects to be controlled. Four objects were created since four brushless motors were used in this project. Attach function was used for attaching the four objects on the PWM outputs of the microcontroller. Analogread function was used for reading the values of the two joysticks.

Arduino Code:

```
#include "NrfLibrary.h"
#include <SPI.h>
void setup()
{////////////////////////////////motor controller 1
pinMode(22,OUTPUT);//ind
pinMode(24,OUTPUT);//inc
pinMode(26,OUTPUT);//inb
pinMode(28,OUTPUT); //ina
pinMode(3,OUTPUT);  ////for motor1
pinMode(4,OUTPUT);   ///for motor2
pinMode(A0,INPUT);////input speed from pot1
pinMode(A1,INPUT);////input speed from pot2
//////////////////////////////motor controller 2
pinMode(30,OUTPUT);//ind
pinMode(32,OUTPUT);//inc
pinMode(34,OUTPUT);//inb
pinMode(36,OUTPUT); //ina
```

```
        pinMode(6,OUTPUT);  ////for motor1 ena

        pinMode(5,OUTPUT);   ///for motor2  enb

void pot1(int speedmotor1)

{

speedmotor1=analogRead(A0);

}

void pot2(int speedmotor2)

{

      speedmotor2=analogRead(A1);

} void motor1(int INc,int INd,int speed){

        digitalWrite(24,INc);

        digitalWrite(22,INd);

        analogWrite(3,speed);

};

void motor2(int INa,int INb,int speed){

        digitalWrite(28,INa);
```

```
        digitalWrite(26,INb);

        analogWrite(4,speed);

void brakeMotor1(int INc,int INd,int speed)

{

      digitalWrite(24,INc);

        digitalWrite(22,INd);

        analogWrite(3,speed);

        }

void brakeMotor2(int INa,int INb,int speed)

{

        digitalWrite(28,INa);

        digitalWrite(26,INb);

        analogWrite(4,speed);

        }

void loop()

{
```

```
motor1(0,1,245);

        delay(4000);

brakeMotor1(0,0,255);

        delay(1000);

        motor1(1,0,245);

        delay(4000);

        brakeMotor1(0,0,255);

        delay(1000);

motor2(0,1,245);

        delay(4000);

        brakeMotor2(0,0,255);

        delay(1000);

        motor2(1,0,245);

        delay(4000);

        brakeMotor2(0,0,255);

        delay(1000);
```

}

5. Testing

This chapter will explain the testing that should be carried out during the whole process of the ROV's construction.

After the completion of ROV's main frame and main tube, the need of putting it into water was important for the acquisition of first impressions. After running this test, verification of the floatation of the frame cam be achieved.

Another important factor that had to be found through the testing process, is to verify that the main tube could stay waterproof after diving into the water. The result after this testing should be positive, since the main tube stayed waterproof for one day into 10 meters of depth without the water entering it. This test is the most important since the main tube had all the important electronics and power needed for the ROV.

Another important factor that had to be tested was the proper movement of the ROV from the four brushless motors. Configuring them and testing their limits by using the joysticks..

Finally, the most important test should be putting the whole construction into its environment. After running this test verification of the main scope of movements can be achieved such as moving forward , backward , turning left and right.

6. Conclusion:

The aim of this project was to design and construct a small scale ROV from the start. In order for the project to be successful, all the right parts and components had to be found and put together properly. This is one of the parts during the whole process and took most the time and effort. That's why the project couldn't be completed.

During this project, some problems appeared. Most of them were solved, but not all of them. Therefore the project has a lot of space for further improvements. Even though the ROV does not have the intended features implemented, the system is functional at this point. Therefore, the main goal, constructing and controlling a small scale ROV, isn't accomplished completely , yet the result is satisfactory as the design of the control system is complete and ready for further implementation.

As further improvements, the ROV could have a temperature sensor that provide the temperature that is inside the water, and compass sensor that shows the direction of the ROV. Finally, another feature that may be added on the ROV is a small manipulator arm that is controlled through two or more waterproof servos.

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