A DESIGN PROJECT OF A REMOTELY OPERATED UNDERWATER VEHICLE

A Thesis Submitted to the Faculty of Engineering of İzmir Institute of Technology in Partial Fulfillment of the Requirements for Degree of

BACHELOR OF SCIENCE

in Mechanical Engineering

by

Group 7

Serdar ÖZDEMİR 160203013
Selim ŞAHİN 160203032
Mert Bartu IŞIK 160203040
Mustafa Harun YAKUT 160203007
Seyfi GİRGİN 160203041
Özgün ARI 150203006

June, 2013
İZMİR

ACKNOWLEDGEMENTS

We would like to thank the advisors, Assistant Professor M. İ. Can DEDE and Assistant Professor Ünver ÖZKOL for their help while studying on this project. Also, we appreciate the help of the Civil Engineer Mehmet CENGİZ for funding, Efe Lazer A.Ş. and Nehir EREN for Drybox manufacturing, Kastaş A.Ş. for sealing solutions, İYTE workshop staff Murat MİRZA, Şerafettin ÇAVDAR, Arif TOSUN and Mert Bartu IŞIK's father for transportation.

ABSTRACT

A DESIGN PROJECT OF A REMOTELY OPERATED UNDERWATER VEHICLE

Underwater ROVs' have very large field of operation and help many people such as scientists, explorers or other different industrial users. Operators generally use these vehicles to eliminate the risks of the underwater environment. Under 50 meters divers need more oxygen and after the operation they may need to be treated in pressurized rooms. The purpose of that study is to generate a simple solution for the divers and underwater surveillance operations. This report includes design and manufacture process of a small scale ROV which can be operational at maximum depth of 50 m underwater and it provides the user a camera view and an object scaling system.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1
INTRODUCTION

As a brief introduction, this project focuses on a design of an ROV, that's why short information about the ROV will be useful. First of all, ROV stands for remotely operated vehicle. An ROV is a type of machine or robotic system which allows people to explore the underwater environment or people can work at underwater structures via ROV's. These machines use propellers for thrust. And most of them are equipped with at least one camera for surveillance. They can be controlled through a cable connection or a wireless system. In this project the main subject is designing a small scale unmanned ROV which can dive under 50 meters and accomplish specific tasks that are predefined by the instructions. [1]

1.1. Purpose of the Project

When we consider this underwater ROV project, the main goal is to design and manufacture a prototype which can be a solution for surveillance problems encountered underwater operations. While designing the project secondary aim is to use our knowledge on design process and project management areas. In addition to these elements, to get some engineering experience that contains engineering design and calculations. Then meeting the end user and the other engineers who are working active in the field is another key element of conducting that project.

While developing this project, the point is that we have been trying to design a system which satisfies the design requirements and criteria. These requirements are given the section below.

Since the ROV can be operated 50 meters under the sea level, it can be a practical solution for many end users. With the help of the additional task, the object scaling with camera, this ROV especially focuses on the surveillance operations. So the end users can use it while underwater pipe or cable inspection and determine the length of cracks on the pipes or it can be used for ship hull inspections or to observe some underwater living creatures.

CHAPTER 2

PROJECT MANAGEMENT STUDIES

2.1. Linear Responsibility Chart

This Linear Responsibility Chart (LRC) shows the distribution of the responsibilities of tasks within the project. Every team member has primary and secondary responsibilities according to the complexity or simplicity of the given tasks. The table below shows how and which responsibilities are given to the members.

Table 1. Linear Responsibility Chart

	Serdar Özdemir	Selim Şahin	Seyfi girgin	Harun Yakut	Özgün Arı	Mert Bartu Işık
Thruster Design	3	1	2	2	3	2
Drybox Design	3	2	-	-	1	-
User interface	3	-	1	1	-	-
Communication	1	3	-	-	-	2
Control of the system	3	2	1	1	-	-
Stabilization	3	-	2	2	-	1
Power	3	1	-	-	2	2
Tethering	1	3	-	-	2	3
Frame	3	2	-	-	1	2
Purchasing of the products	2	3	-	-	2	1
Prototype	2	3	-	-	1	2
Manufacturing	1	2	3	3	2	2
Assembly and testing	3	1	2	2	3	3
Documentation	3	2	2	2	2	1
Legend: 1- Primary Responsible, 2-Support/work, 3-Must be consulted						

2.2. Gantt Chart

Gantt chart can be seen in the appendix section, it is not shown under that topic, because of its large dimensions. The Gantt chart includes the time line of the design project.

2.3. Work Breakdown Structure

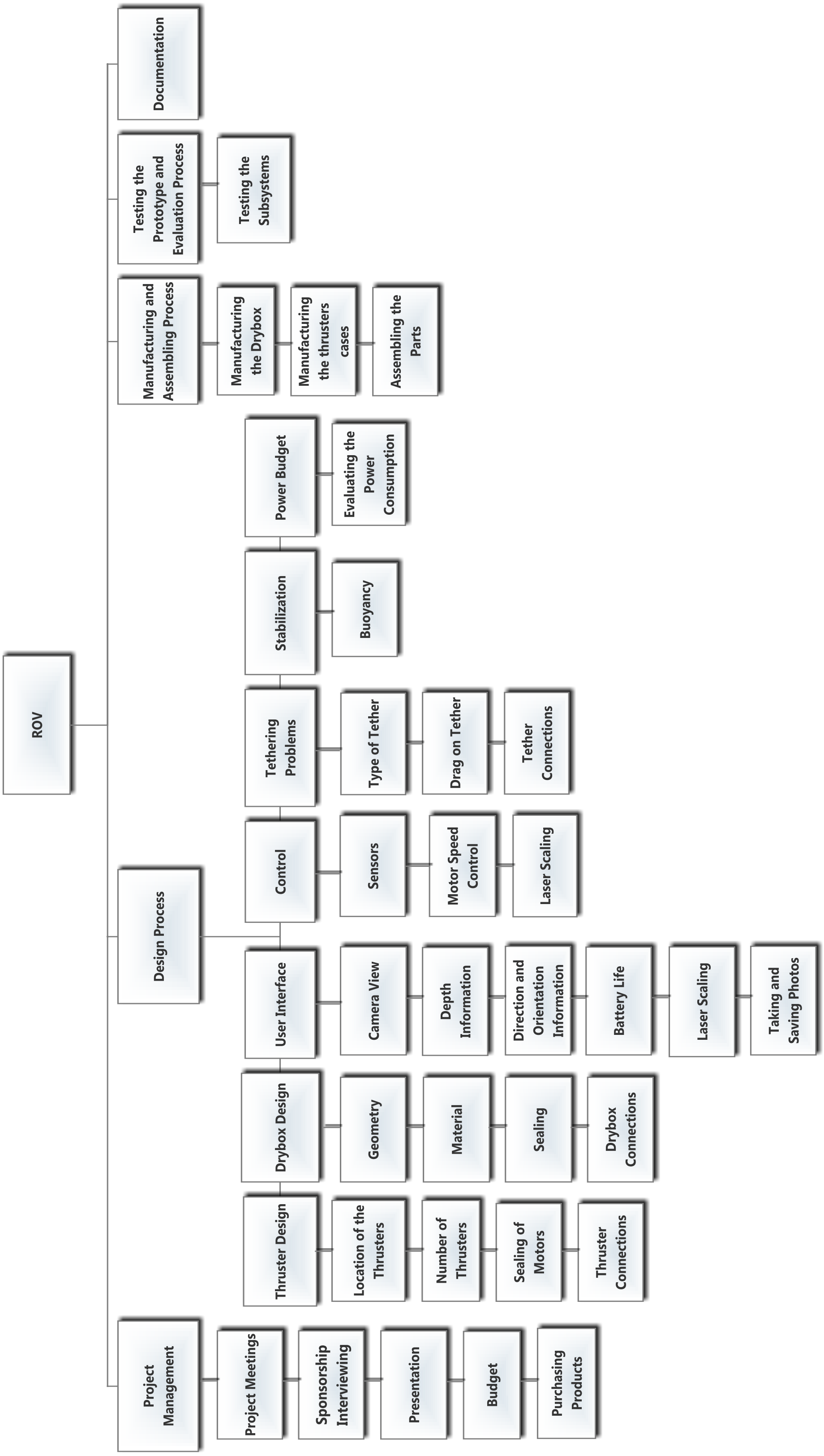

Figure 1. Work Breakdown Structure

CHAPTER 3
DESIGN REQUIREMENTS AND CONSTRAINTS

3.1. Problem Statement

The starting point of that project is that how can we keep humans away from risky environment while making underwater surveillance work. These risks can be indicated as; higher hydrostatic pressure, lack of oxygen, risk of decompression sickness that's why as a group, we tried to find a solution to eliminate these risks and any possible injuries.

3.2. Design Requirements

Before starting that project in order to specify a design target, design requirements are needed and this section contains these requirements and the desired features of the ROV.

- Will be operated at the depth of 50 meters
- At least one hour battery life for operation
- With an onboard camera that can be rotated ± 80º in two axis
- Can be controlled remotely by an operator on a boat
- Will dive and move on the plane of desired depth;
  - Able to turn right or left while moving in desired direction
  - Able to rotate around the vertical axis that passes through the center of mass.
- Will be controlled with at least one joystick
- Have a user interface which provides;
  - Depth information
  - Orientation and direction information
  - Interface to capture and save photographs from camera view
  - Object scaling interface
- Able to approach sea-floor without muddying.

3.3. Design Constraints

These are the design constraints which we encountered if the design requirements are considered.

- **Economic**

Our budget is approximately 2000 TL. We have managed to receive some fund for the project and that amount should not exceed. The cost is the most important value in evaluating design alternatives.

- **Environmental**

Environment is another concern while designing the project. To protect the nature, the paint on the body and other components should be friendly for environment. The thruster casings will be filled with oil and the oil discharge to the sea is an undesired result.

- **Health and Safety**

Due to the ROV runs on electrical power that's why any short circuits or electrical leaks could be dangerous for operator or other sea inhabitants. In addition to that, all of the sharp objects and edges on the system are unwanted.

- **Manufacturability**

Our budget is limited so the design alternatives that can be easy produced should be preferred. Besides the limited budget, the production facilities are limited and the design can be changed as a result of the tests, so ease of the manufacture is desired.

CHAPTER 4
DESIGN AND PROTOTYPING OF SUBSYSTEMS

4.1. Thruster Design

Thrust is the reaction force that is created by propulsion system by accelerating a mass of fluid and it is a vector quantity having both a magnitude and a direction. Thruster is a device that creates force to move any object. In this project, we have determined to use propeller-shaft-motor system as thruster. The main purpose of ROV is to dive and running 50m underwater. This is the hardest design constrains that we have to solve. The ROV must work at 6 bar pressure.

4.1.1. Sealing of Thrusters

The most conservative solution of sealing is to use sealing elements as O Ring or rod sealing elements. We could not manufacture the parts where the sealing elements are used. So we arranged a meeting with Kastaş A.Ş to design and produce the dynamic sealing parts. They design the thruster part and produce the new rod sealing elements for our project. We manufactured the static sealing part in our workshop at lathe.

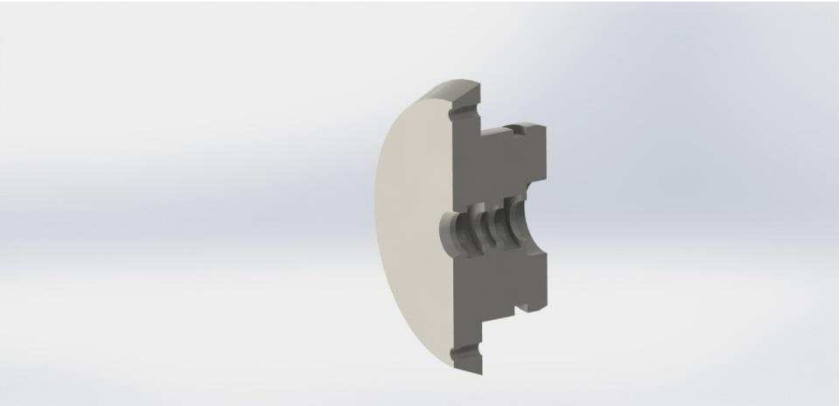

Figure 2. Section of Dynamic Sealing Part Manufactured by KASTAŞ A.Ş.

Figure 3. Section of Static Sealing Part Manufactured in İYTE Workshop

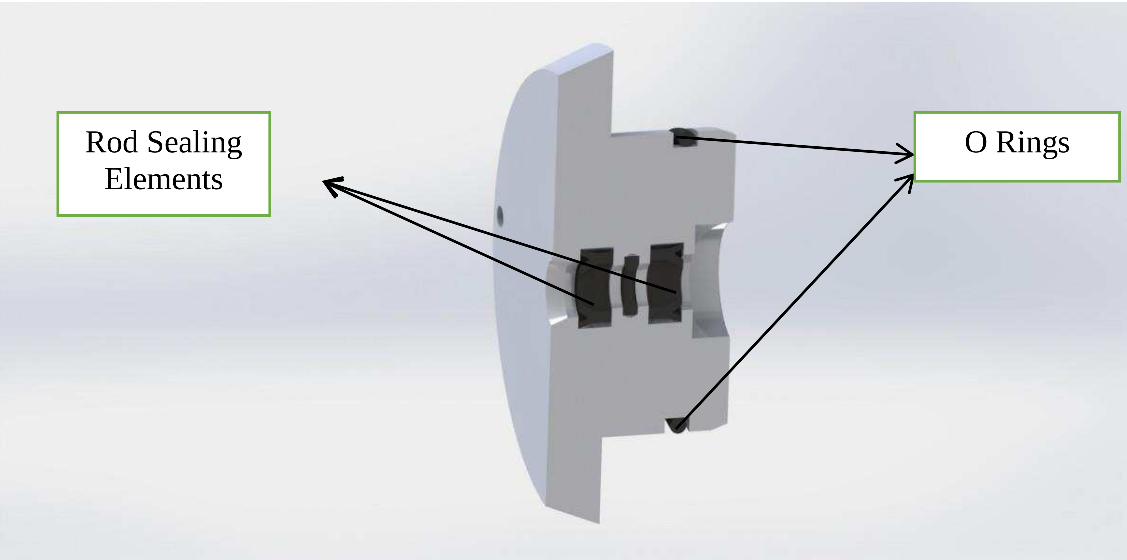

Figure 4. Dynamic Sealing Part with Sealing Elements

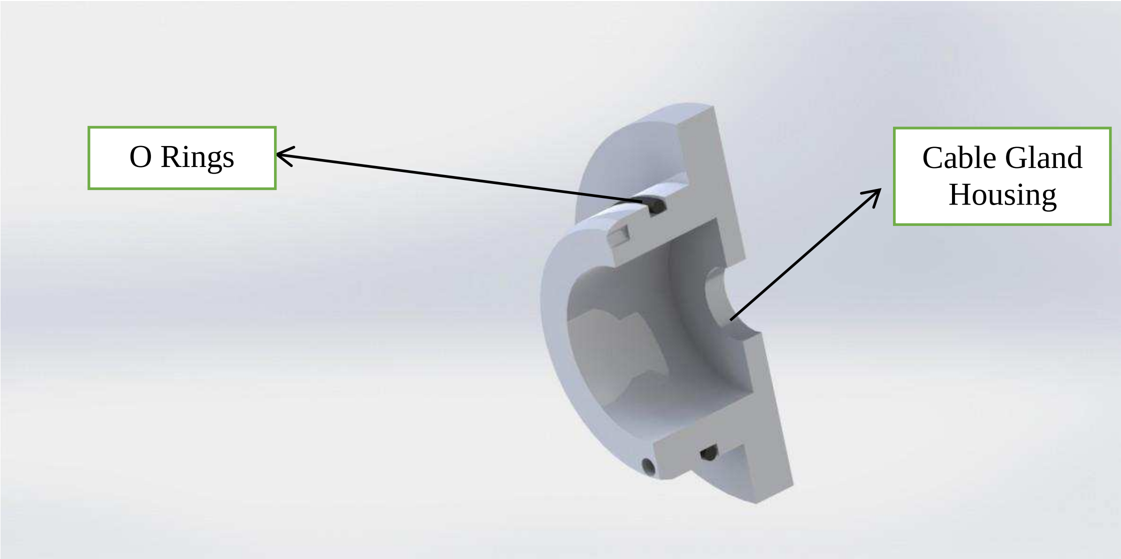

Figure 5. Static Sealing Parts with Sealing Elements

In addition to this we used cable glands and Teflon tape for thruster connection.


Figure 6. Cable Gland [2] (Source: http://www.cable-glands-brass.com/brass-metric-strain-relief/brass-cable-glands.gif)

On the other hand, sealing elements, (O Rings and rod sealing elements) were not enough for sealing. In order to solve sealing problem, we use a method from S.U.T.A (Sualtı Teknolojileri Araştırma Enstitüsü/Bodrum). SUTA has advised us to use dielectric oil for sealing. We have drilled the thruster case and placed a hose pipe. The principle is that when the outside pressure is increasing, elastic hose pipe will be compressed so inner pressure is increasing because of the deformation. Therefore there will be no mass transfer in thruster because of the equality of pressure.

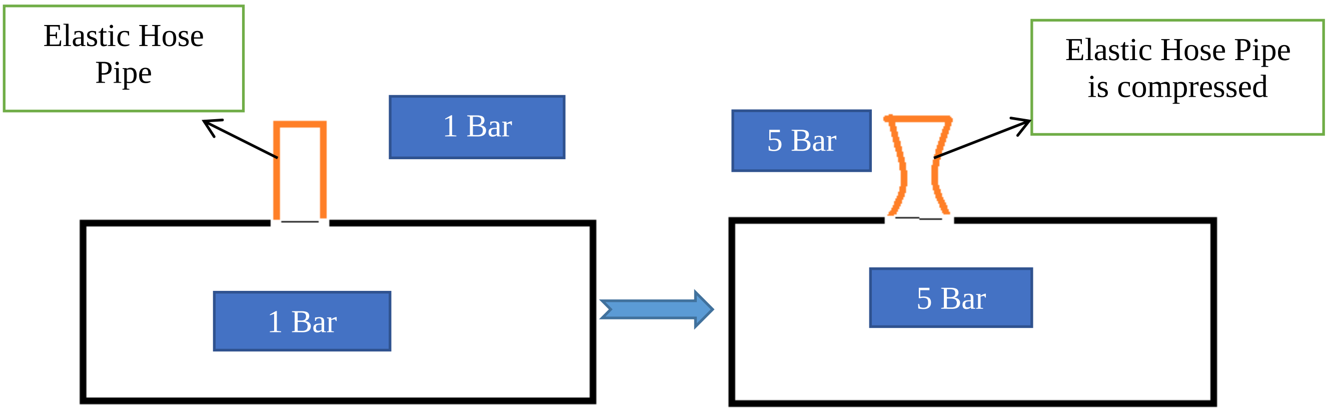

Figure 7. The Behavior of the Hose Pipe under Pressure

4.1.2. DC-Motors

In thruster design, a DC Motor with reductor is used. The reason is to decrease RPM and current and to increase torque.

- Technical Properties of DC Motor [3]

Running Voltage: 12 V

Revolution per minute: 750 rpm

Unload Current: 240mA

Load Current: 4APower: 48W

Torque: 6 kg/cm

Motor diameter: 36mm

Reductor diameter: 42mm

Shaft: 7mm shaft

Shaft length: 17mm

Motor length: 86mm

Weight: 234 gr

Figure 8. DC Motor [3] (Source: http://www.robotistan.com/12V-750Rpm-Reduktorlu-DC-Motor,PR-785.html)

4.1.3. Shaft

The material of shaft is Ti-35A (Annealed) and for propeller assembling screw on to shaft is threaded. Besides we have completed the fatigue calculation of shaft.

4.1.3.1. Fatigue Calculations

Shaft diameter= 8 mm

Material = Ti-35 A   Annealed

Yield Strength, S_y = 210 Mpa

Tensile Strength, S_{ut} = 275 Mpa

$m_{propeller}$ = 0.030 kg

$F_{propeller}$ = 0.2943 N

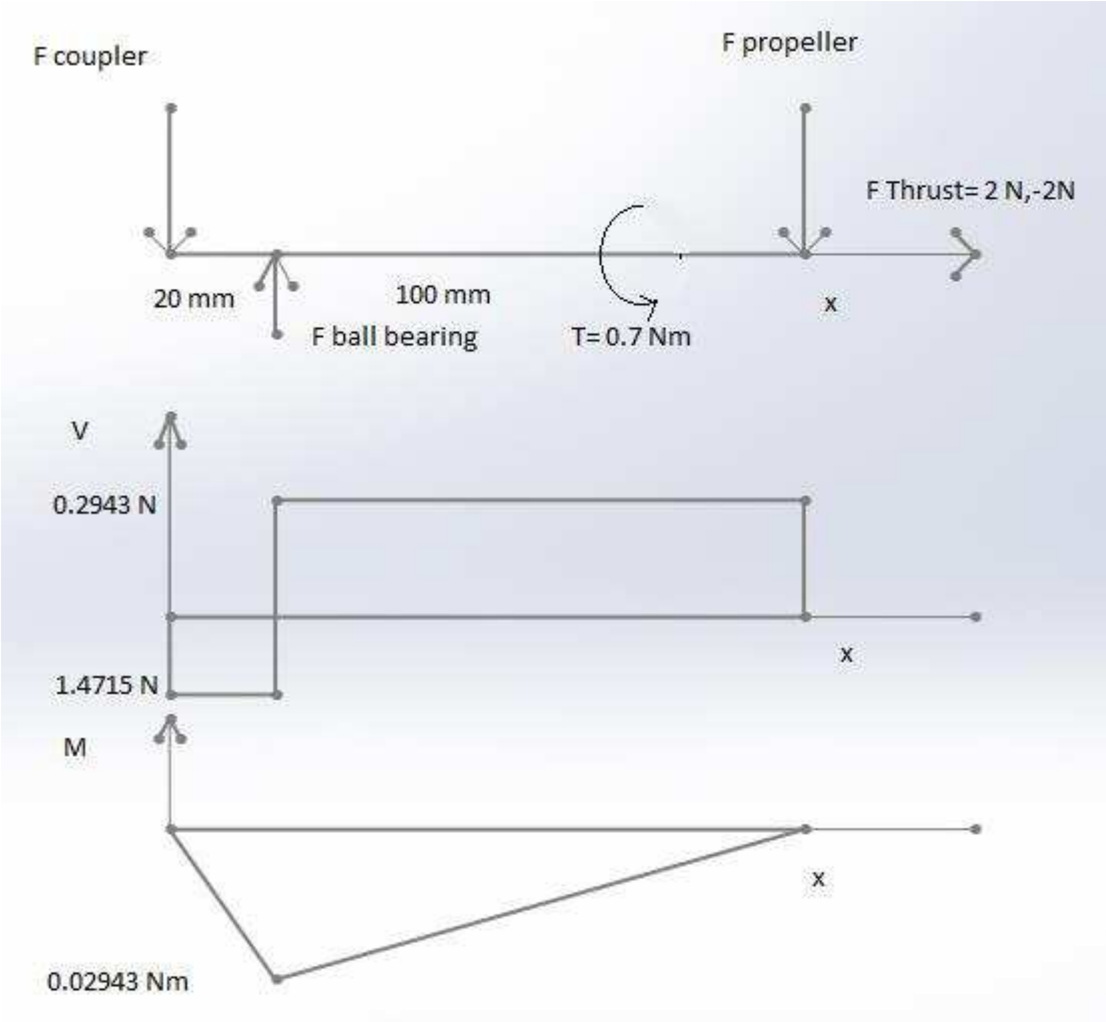

Figure 9. Fatigue Calculation Diagrams

- $\mathbf{S_e = k_a.k_b.k_c.k_d.k_e.k_f..S_e^{'}}$

$S_e^{'} = 0.5\ S_{ut} = 137.5$ MPa

- **Surface Factor, k_a**

$k_a = a*S_{ut}^{b}$ *Surface finish, hot rolled*

a = 57.7

b = -0.718

$k_a = 1.022668$

- **Size Factor, k_b**

$k_b = 1.24.d^{-0.107}$

$k_b = 0.9926$

- **Loading Factor, k_c**

k_c = 1 For combined loading

- **Temperature Factor, k_d**

At 50℃ k_d = 1.010

- **Reliability Factor, k_e**

k_e = 1

- **Miscellaneous-Effects Factor, k_f**

k_f = 1

- **Characterizing Fluctuating Stresses**

$F_m = (F_{max} + F_{min}) /2$ $F_a = (F_{max} - F_{min})/2$

$\sigma_m = (\sigma_{max} + \sigma_{min})/ 2$ $\sigma_a = (\sigma_{max} + \sigma_{min}) / 2$

$\sigma_{bending} = M.c / I$ $\sigma_{normal} = P/A$ $\tau_{Torsion} = T.r /J$

Where ;

$\sigma_{bending}$ = Bending Stress

M = Moment

c = distance to neutral axis

I = Moment of Inertia

T = Torque

r = Radius

J = Polar Moment of Inertia

A = Area

P = 2 N and -2 N

M= 0.02943 Nm

r= 0.004

$I= (\pi * r^4)/4 = 2.010619298e\text{-}10\ m^4$

$J=(\pi * r^4)/2= 4.021238597e\text{-}10\ m^4$

$\sigma_{bending}$ = M.c / I = 0.585 MPa

σ_{normal} = P/A   = 0.039 Mpa and -0.039 Mpa

$\tau_{Torsion}$ = T.r /J   =6.963 Mpa

- **The Distortion Energy theory**

$\sigma = [(\sigma_{bending} + \sigma_{normal})^2 + 3*\tau_{Torsion}^2]^{½}$

σ_{max} = 12.076 Mpa

σ_{min} = 12.072 Mpa

σ_m = 12.074 Mpa

σ_a = 0.002 Mpa

- **Soderberg**

$(\sigma_a / S_e) + (\sigma_m / S_y) = 1 / n$

$S_e = k_a.k_b.k_c.k_d.k_e.k_f.S_e'$

S_e = 140.972 MPa

n = Safety Factor

(0.002/140.972) + (12.074/210) = 1/n

n= 17.338

4.1.4. Coupling and Ball Bearing

We have 22 mm outer diameter, 8 mm inner diameter and 7 mm thickness ball bearing. We have used Chloraethyl to assembly for shaft and bearing. To extend shaft we use coupling that has 7 mm and 8 mm inner dia. The maximum allowable torque of shaft is 7 Nm.


Figure 10. Coupling (Right) and Ball Bearing (Left)

4.1.5. Propellers

Propeller selection is the hardest process for thruster system. Because if we designed propeller that gives us desired thrust, we could not manufacture it. So we had to try different type's propeller.

The Criteria of Selection

- Weightless

It has to be light because of the torque of motor and shaft.

- Material

Material is important for corrosion.

- Dimensions

The maximum diameter has to be 150 mm.

- Cost

We had to test each propeller to reach desired thrust. For this process our budged was limited.

- Pair

The propeller that we selected must be two-way. According to these criteria we have selected two propellers for vertical and horizontal directions.

4.1.5.1. 13mm Propellers

Used for vertical motion and they are taken from previous year's project.

Figure 11. 13mm Propeller

4.1.5.2. 8mm Propellers

Used for horizontal motion and this propeller manufactured by Özgür Özzeybek and it was reproduced at Has Çelikler.


Figure 12. 8mm Propeller

4.1.6. Test Results of Thrusters

We have manufactured a test device to measure net thrust force with respect to voltage and current. In test we used seed oil as dielectric oil.


Figure 13. Thruster Test Setup

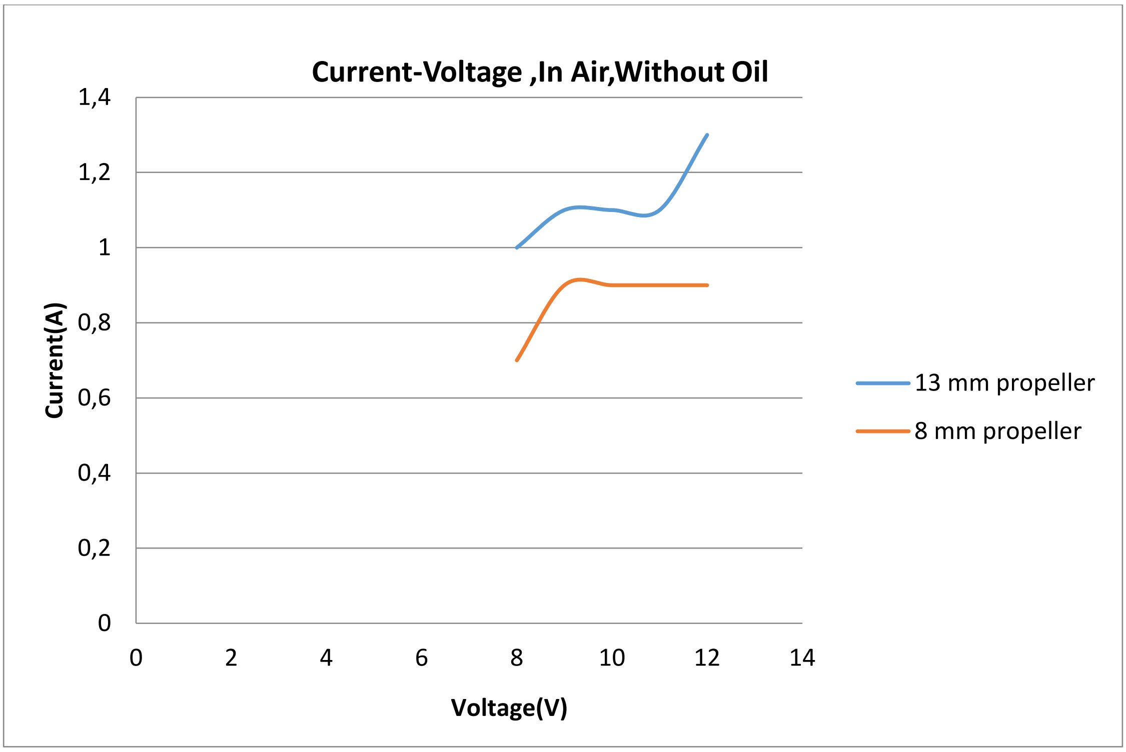

Figure 14. Graph of Current versus Voltage (Without Oil)

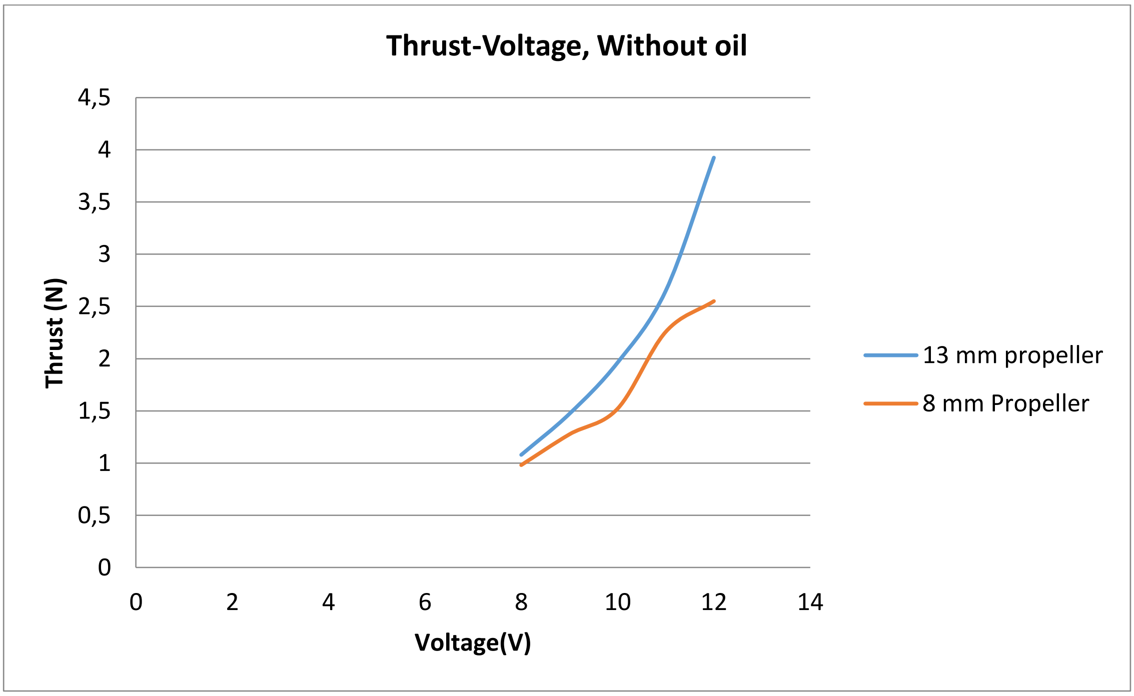

Figure 15. Graph of Thrust versus Voltage (Without Oil)

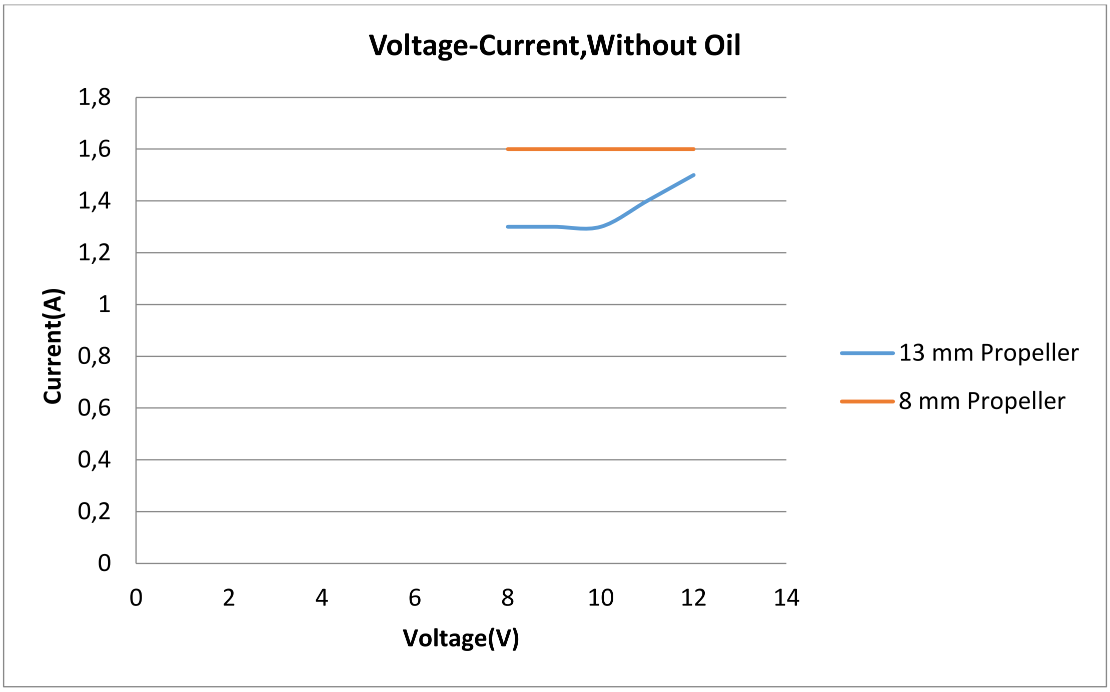

Figure 16. Graph of Current versus Voltage (Without Oil)

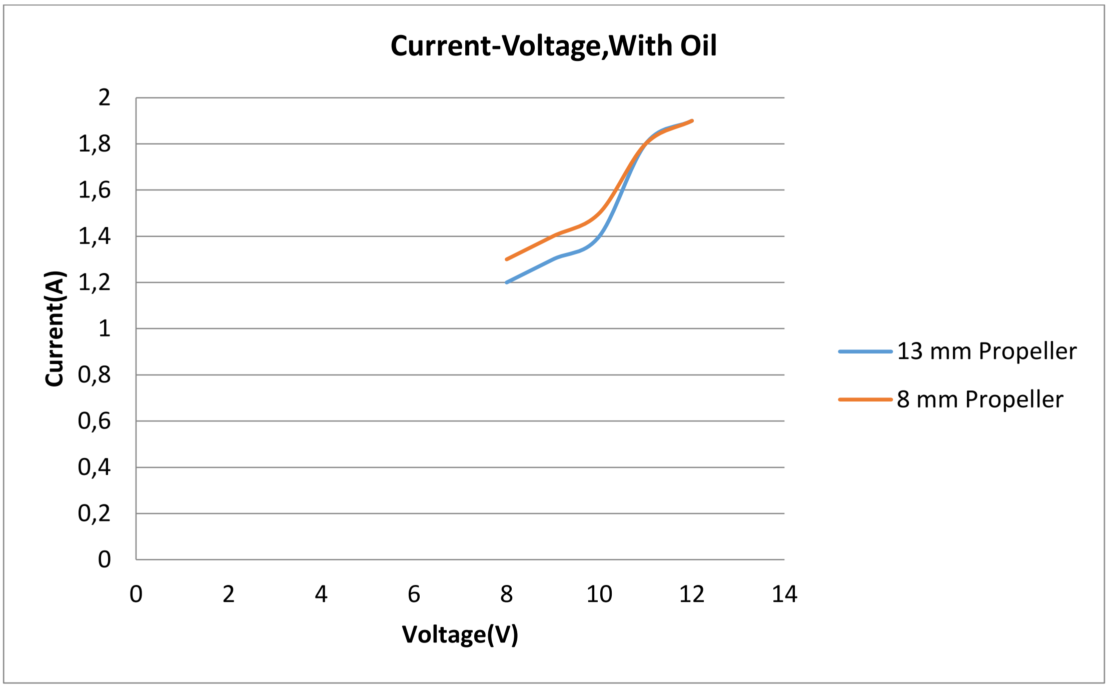

Figure 17. Graph of Current versus Voltage (With Oil)

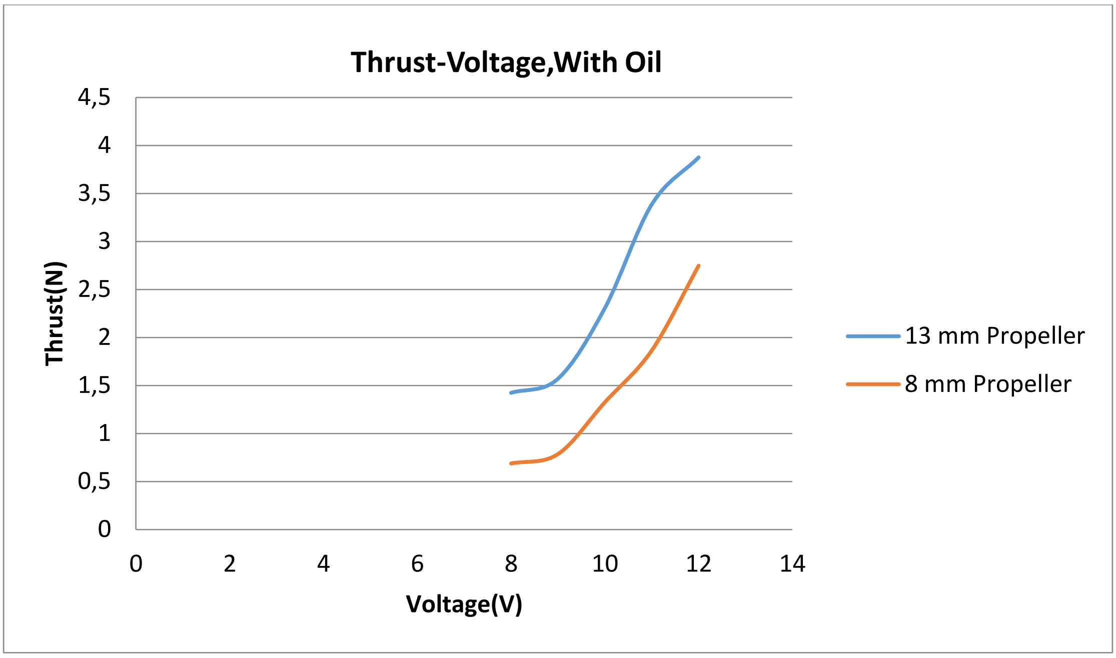

Figure 18. Graph of Thrust versus Voltage (With Oil)

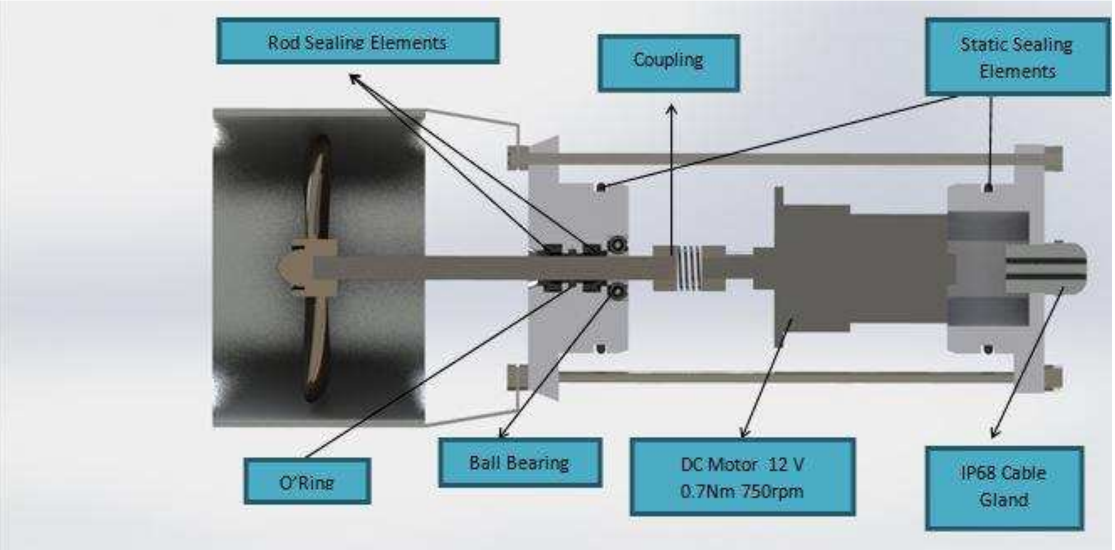

Figure 19. Cross Section of Thruster Assembly

Figure 20. Assembly of Inner Components of Thruster

4.2. Drybox and Frame

For that work package, we separate it into five different sections to get better results and understanding. These subsections are geometry, sealing, cable connectors and mechanical analysis of the drybox and the semispherical Plexiglas dome.

4.2.1. Geometry

In order to have an advantageous and strong structure design for under hydrostatic pressure, a cylindrical geometry was selected. Besides that criterion we tried to keep the design simple and tried to have a symmetrical shape for increased stability. We started with a cylindrical pipe which has a diameter of 140 mm and 380 mm in length. The thickness of the pipe is 3 mm. Then two 5 mm thick flanges are welded to the front and rear ends. These will help us to fasten the rear plate and front semi spherical Plexiglas dome. Flanges and the end caps are fixed to the main body by 6 bolts and nuts (M8) through the M8 holes. The material of the body and the frame is AISI316 stainless steel to create a sufficiently strong structure which can withstand the forces due to the hydrostatic pressure of 0,6 MPa, and it is selected from a stainless material to prevent the corrosion effects of seawater.

On the other hand the drybox bod and the frame are designed together to get a monocoque structure. While designing the frame component, the general ideas are again the symmetry and the positions of the thrusters for better stability. In order to deal with any possible problems the orientation of the thrusters are kept on the same plane by the center of mass. The geometry of the body can be seen the figure below.

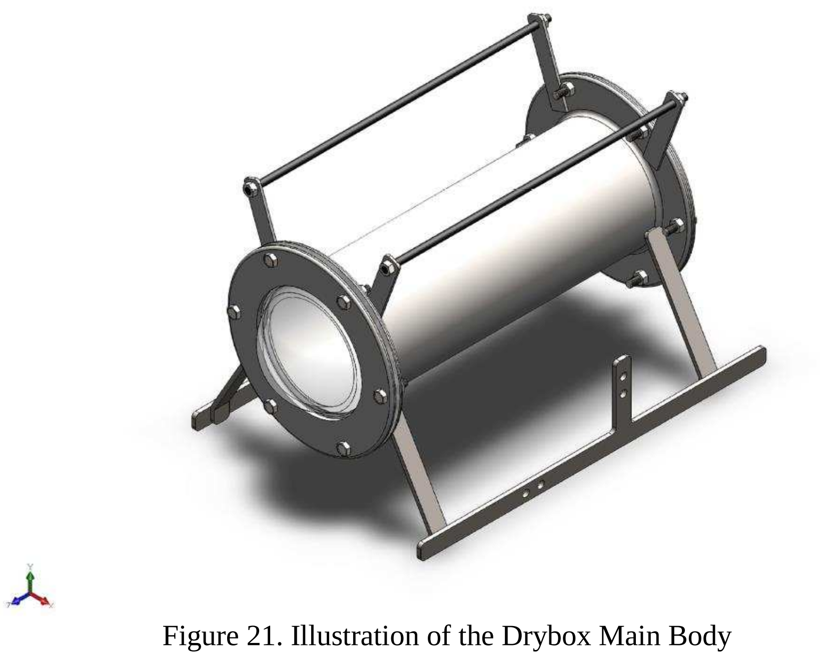

Figure 21. Illustration of the Drybox Main Body

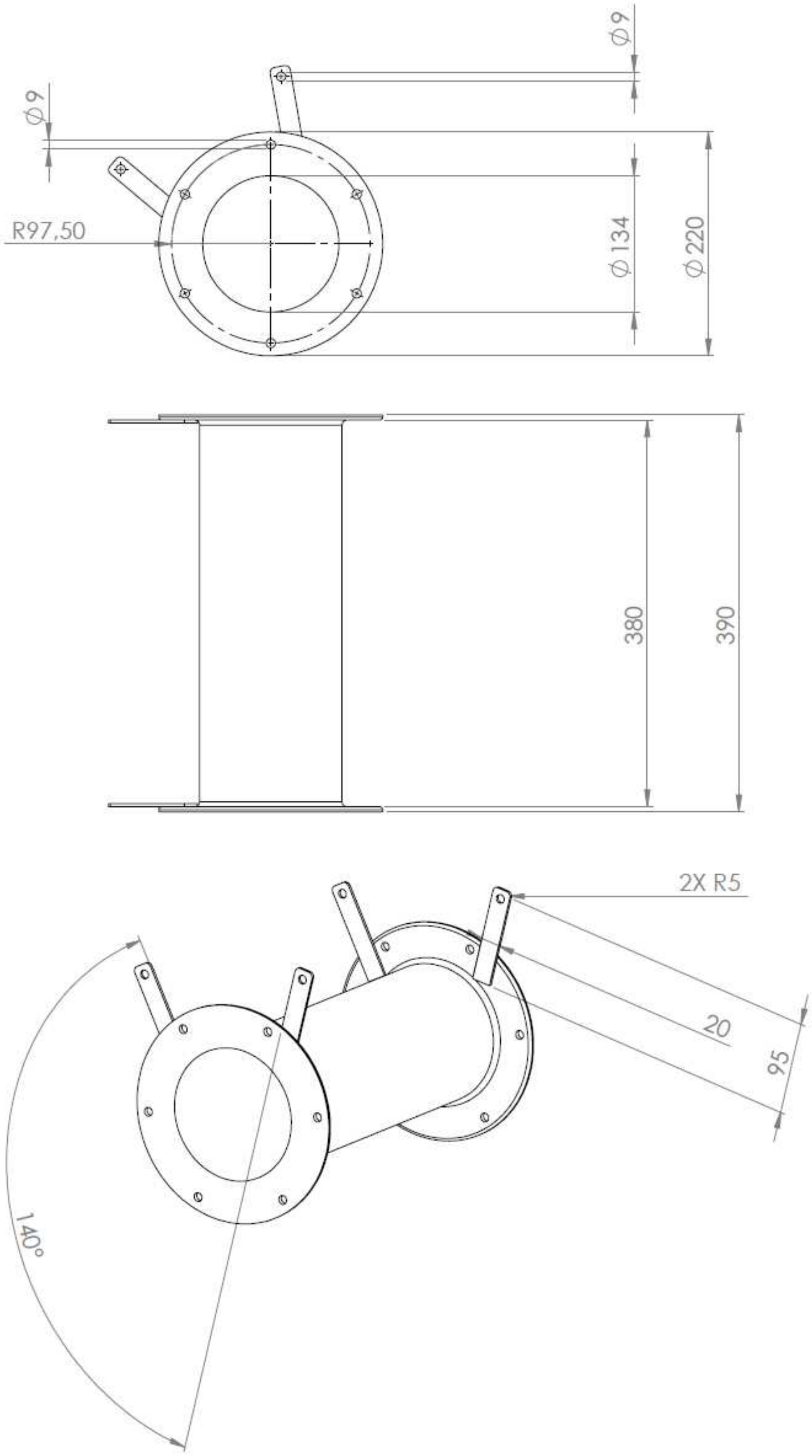

Figure 22. Technical Drawings of Drybox Main Body

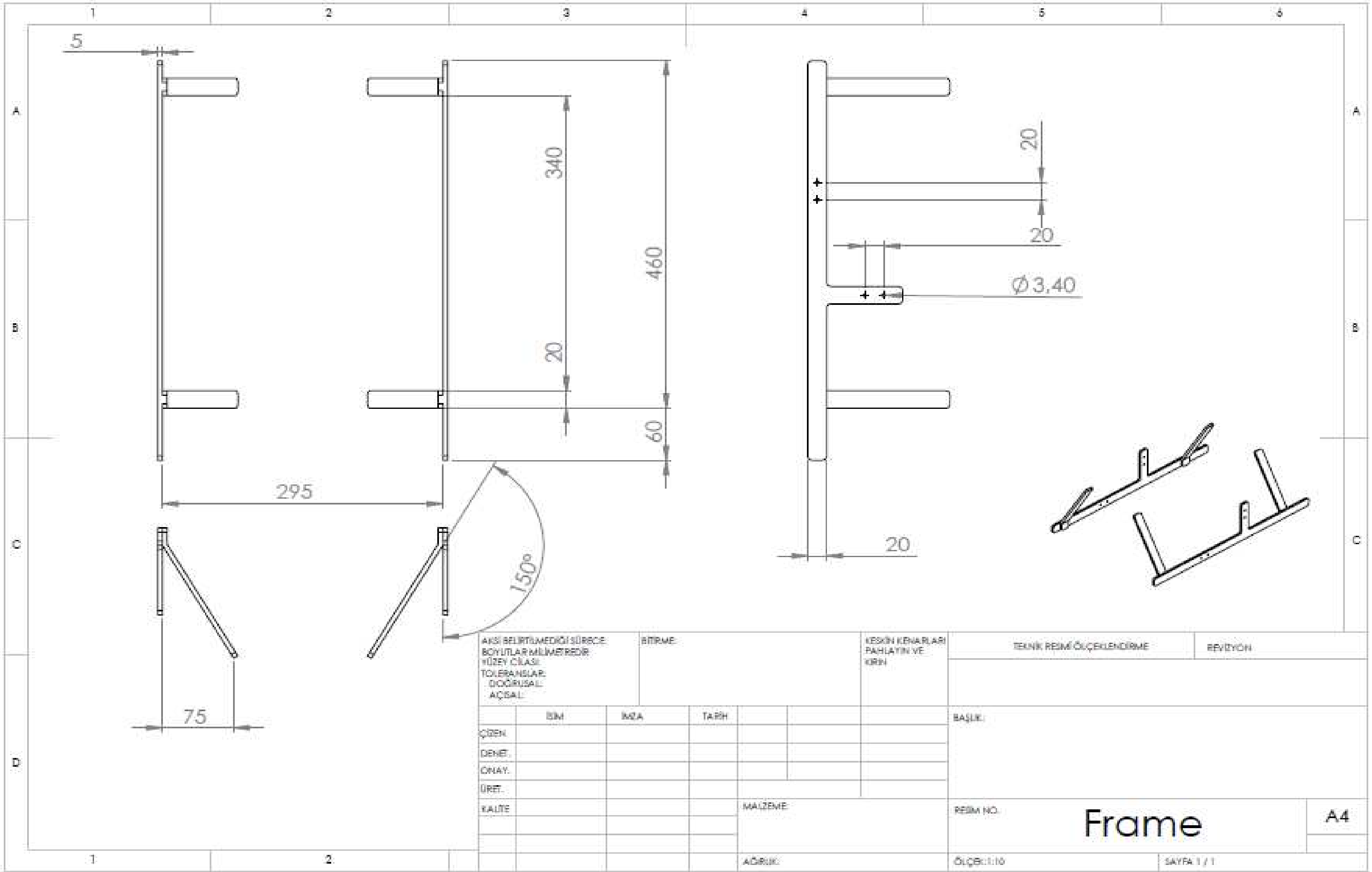

Figure 23. Technical Drawings of Frame (in mm)

4.2.2. Sealing of the Drybox

As the result of the design we need to use O-rings to prevent water leaks into the drybox and keep the electronic components away from sea water. The selected O-rings (KO 1488035) with an inside diameter of 148.8 mm and thickness diameter of 3.52 mm are supplied by the KASTAŞ. To place the O-rings the specific O-ring grooves are machined on the flanges and the technical drawings of flange and O-ring assembly can be seen from the figure below.

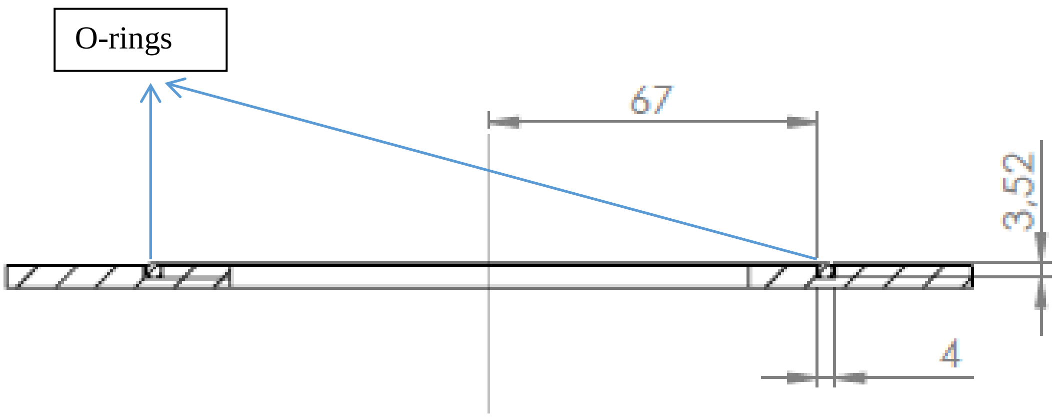

Figure 24. Technical Drawing of O-ring, Flange Assembly Cross Sectional View (in mm)

4.2.3. Cable Connections (Cable Glands)

The drybox has 5 separate cable connections for 4 thrusters and the main control cable, to provide a waterproof solution custom made cable glands are used. They are designed after the suggestions from the ROV producers, SUTA (Sualtı Teknolojileri Araştırma), in Bodrum. They are machined from a hexagonal brass rod. The inner components are an O-Ring and a conical shaped pressure ring. The figure below shows the assembled and disassembled cable glands.

4.2.4. Strength Analysis of Drybox

Drybox structure was analyzed by using Ansys 14.0 according to maximum hydrostatic pressure of 0.6 MPa. The material is AISI316 Stainless Steel and mechanical properties are given the table below.

Table 2. Mechanical Properties of AISI316 Stainless Steel [4]

MECHANICAL PROPERTIES	
Density ($\times 1000$ kg/m^3)	8
Poisson's Ratio	0.27-0.3
Elastic Modulus (GPa)	193
Tensile Strength (Mpa)	515
Yield Strength (Mpa)	205
Elongation (%)	40
Reduction in Area (%)	50
Hardness (HRB)	95

According to the results the maximum equivalent stress is 17.717 MPa. Therefore the safety factor is 11 for compressive yield strength point of 207 MPa.

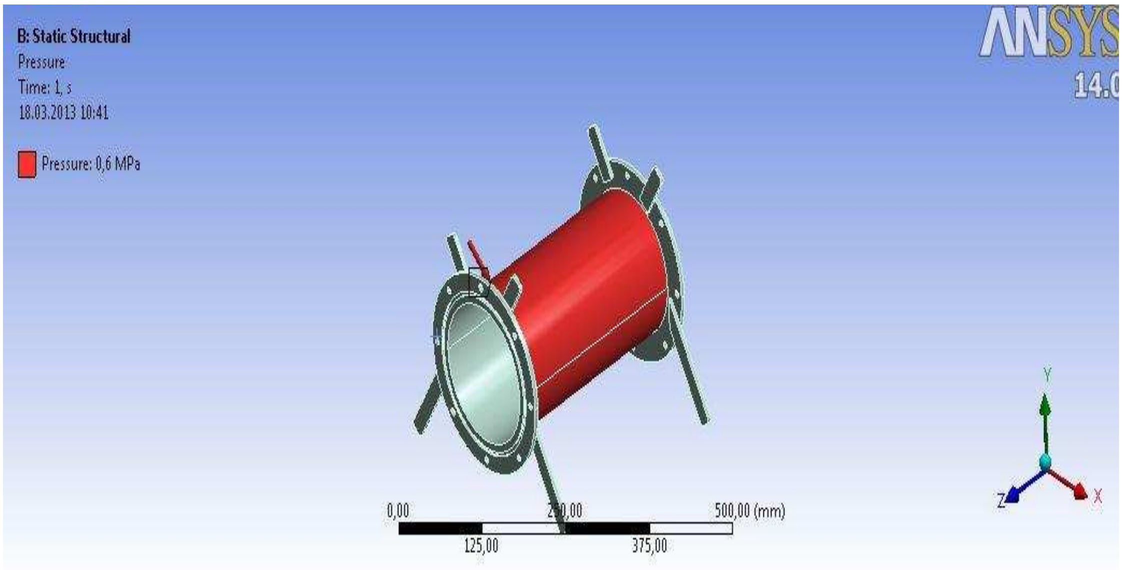

Figure 25. Pressure Acting to the Surface

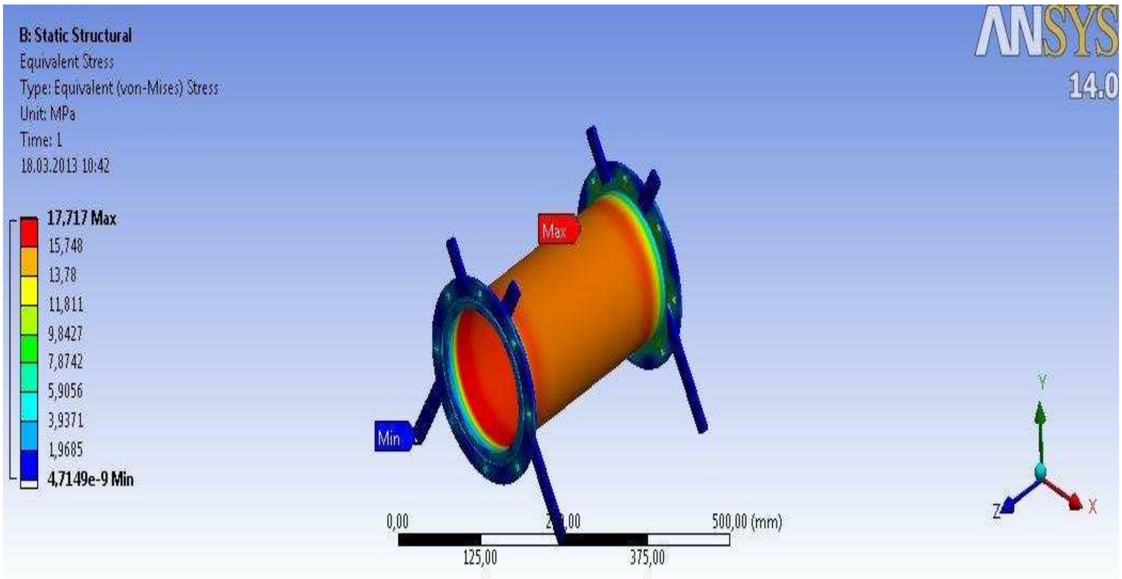

Figure 26. Result of Equivalent Stress

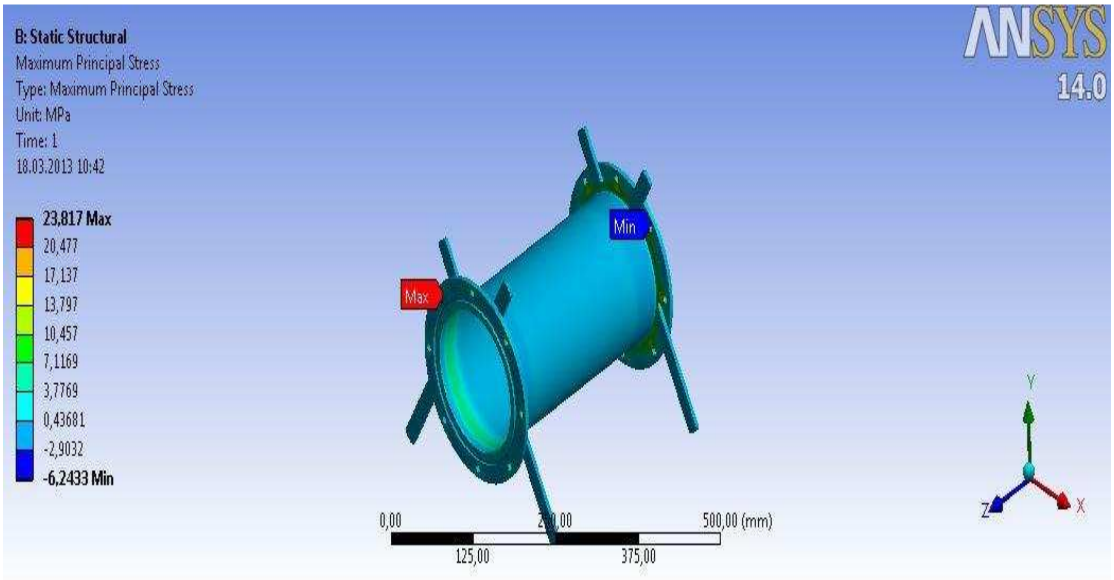

Figure 27. Maximum Principle Stress

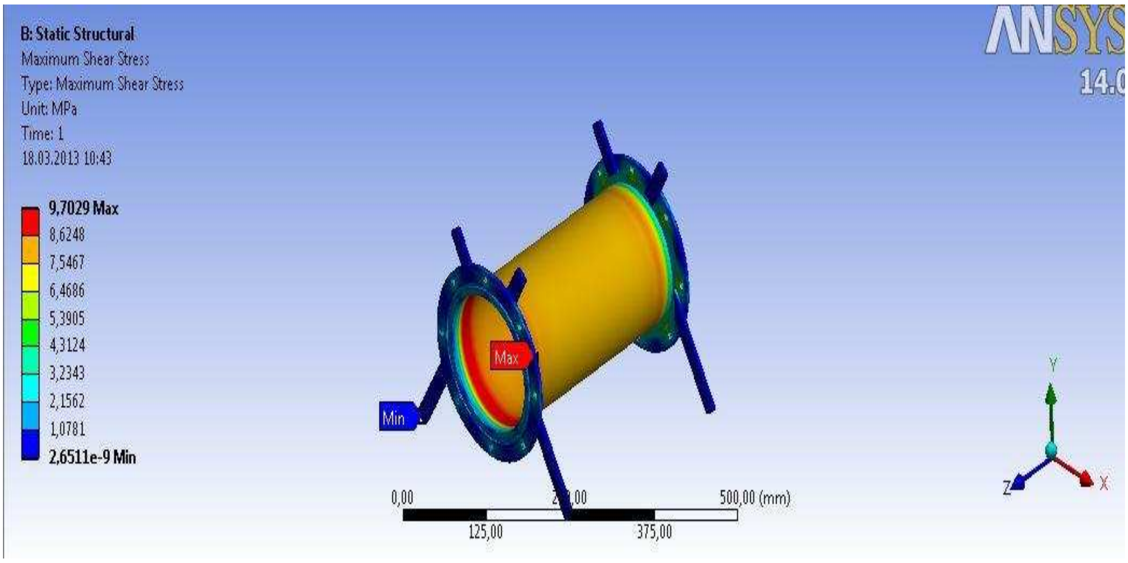

Figure 28. The Maximum Shear Stress

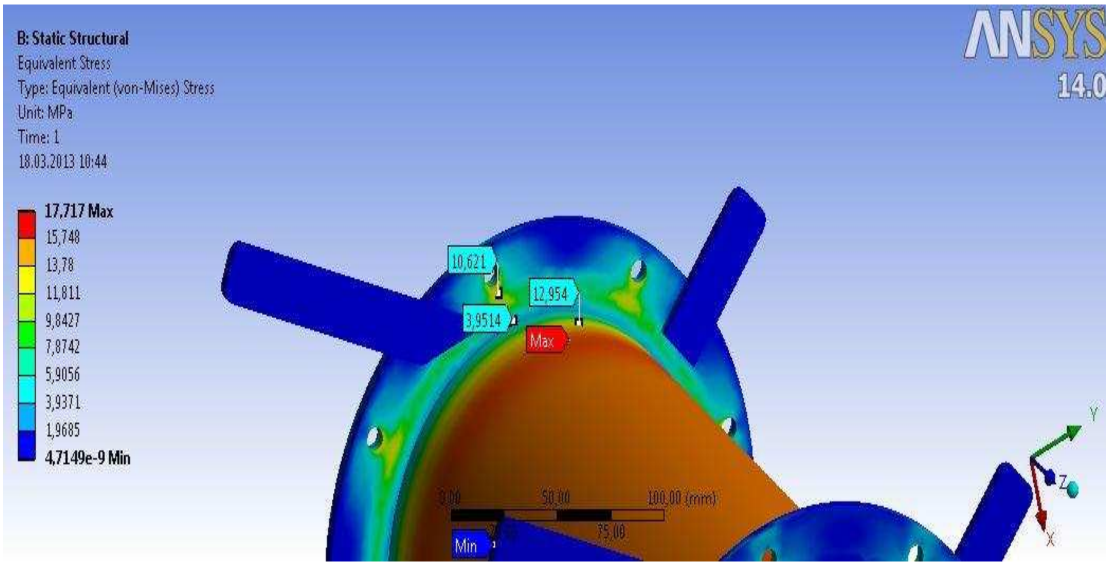

Figure 29. The Equivalent Stress

Because of the lack of sufficient space, we the full page figures of analysis are not placed in this section. However you can find more them detailed figures in the appendix section.

Table 3. Results of Stresses

TYPE	Total Deformation	Equivalent (von-Mises) Stress	Maximum Principal Stress	Maximum Shear Stress	Normal Stress
Minimum	0, mm	4,7149e-009 MPa	-6,2433 MPa	2,6511e-009 MPa	-17,62 MPa
Maximum	1,0228e-002 mm	17,717 MPa	23,817 MPa	9,7029 MPa	20,787 MPa

Type	Shear Stress	Maximum Principal Elastic Strain	Equivalent Elastic Strain	Maximum Shear Elastic Strain
Minimum	-8,3835 MPa	1,8121e-014 mm/mm	1,2138e-013 mm/mm	3,5989e-014 mm/mm
Maximum	8,3832 MPa	9,6535e-005 mm/mm	9,181e-005 mm/mm	1,3172e-004 mm/mm

4.2.5. Strength Analysis of Plexiglas

The semispherical front dome was produced from Plexiglas material and its properties are given the table.

Table 4. Mechanical Properties of Plexiglas [5]

Density / ISO 1183 / 1.19 g/cm3
Tensile strength / ISO 527-2/1B/5 / 80 MPa
Elongation at break / ISO 527-2/1B/5 / 5.5%
Modulus of elasticity / ISO 527-2/1B/1 / 3300 MPa
Flexural strength / ISO 178 / 115 MPa
Compressive yield stress / ISO 604 / 110 MPa
Shear modulus / ISO 537 / 1700 MPa
Impact strength / ISO 179/1fu / 15 kJ/m²
Notched impact strength / ISO 180/1 A / 1.6 kJ/m²
Minimum cold-bending radius / - / 330 x sheet thickness
Admissible material stress / - / 5 - 10 MPa
Poisson’s ratio / ISO 527-1 / 0.37
Ball indentation hardness / ISO 2039-1 / 175 MPa
Scratch resistance / ISO 9352 / 20 - 30% haze

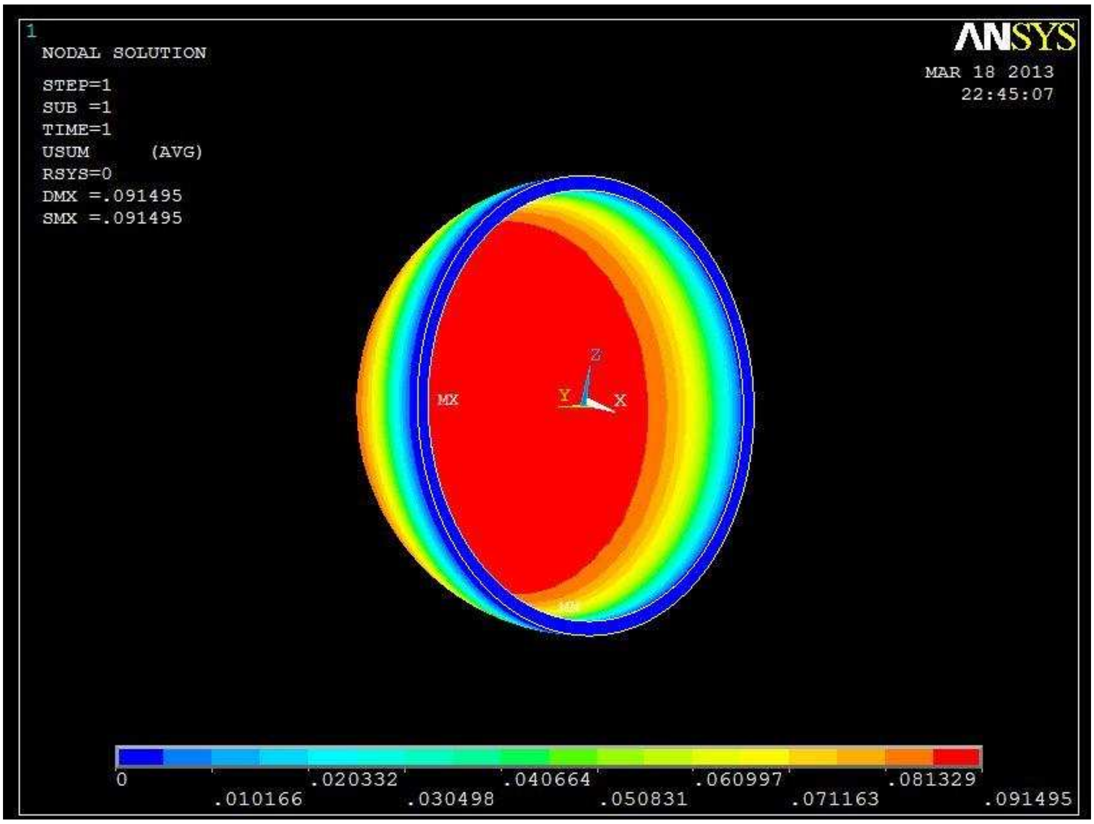

Figure 30. Total Displacement in mm

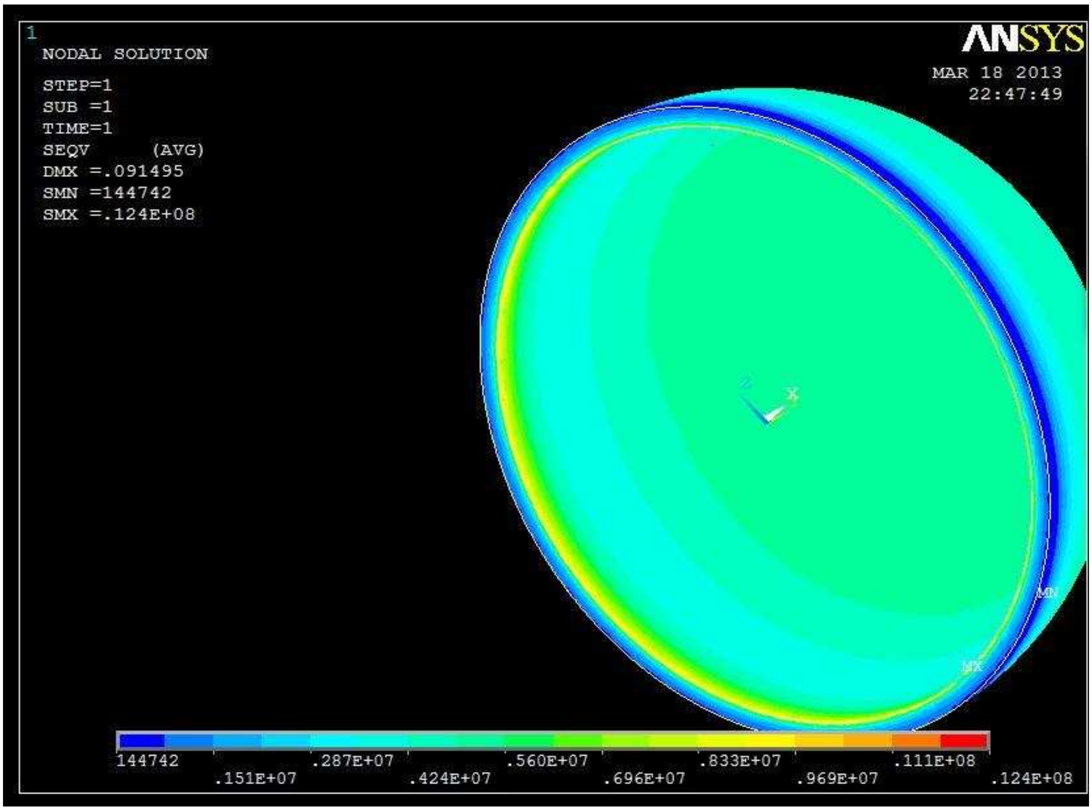

Figure 31. Equivalent Stress in Pa

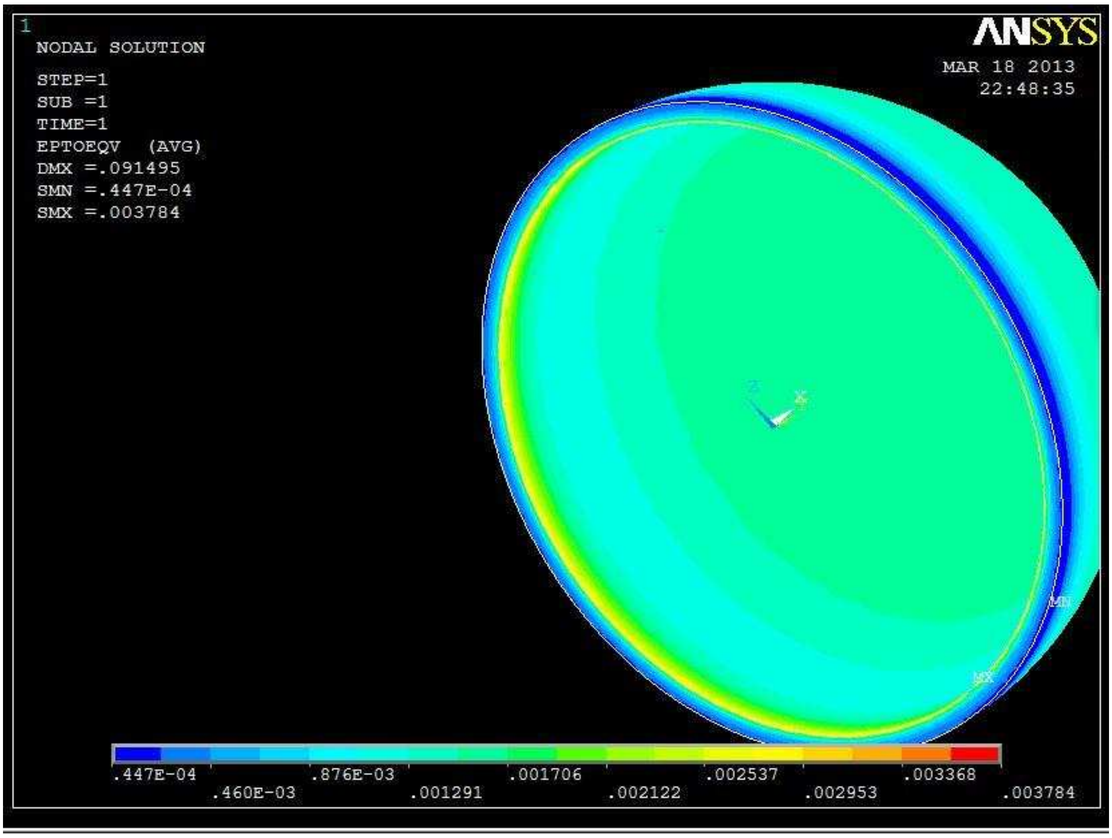

Figure 32. Equivalent Strain

According to the results and the compressive yield stress point, the safety factor of Plexiglas is 8.870. After the strength calculation we have verified that our ROV can dive to the 60 m depth without any trouble and it can even go deeper within safety limits.

4.3. Control

4.3.1. Electronic Components

We have used a lot of different electronic devices to achieve the control of the ROV. These are can be listed mainly as microprocessors, motors, motor driver units, batteries, and communication shields and so on.

4.3.1.1. Arduino and Arduino Ethernet Shield

We are using Arduino Mega 2560 as our microcontroller. It is chosen since its open source coded microcontroller and great utility in the robotics applications. Also it has quite enough inputs and outputs on its board, which is needed for our ROV due to having a lot of sub component to be attached.

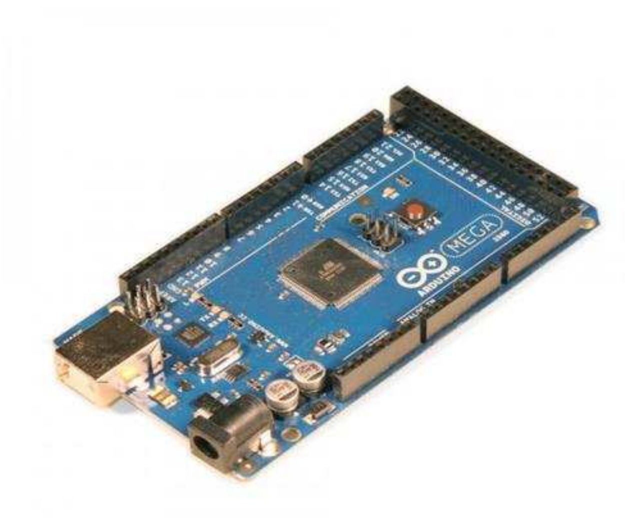

Figure 33. Arduino Mega 2560 [6] (Source: http://arduino.cc/en/Main/arduinoBoardMega)

Arduino Mega has USB connection port but we couldn't make use of it since our robot will function at 50 meters depth, meaning we have to use at least 70-75 meters long cable for tethering. Since we know that after 7-8 meters, USB communication will be impossible and huge amount of data loss will be encountered, we had to find another communication way between the Arduino mega placed in ROV with the User placed in surface. So we figure the communication problem out by using Ethernet cable and an Ethernet shield placed on the Arduino Mega. In our research we have learned that data loss up to 100 meters is not a problem via Ethernet cable. Cat-6 type Ethernet cable will be used for the communication between the Ethernet shield and PC.

We also made some tests to see the reliability of the Ethernet communication before we use it for the ROV. In our tests, we have confirmed the same results.

Figure 34. Arduino Ethernet Shield [7] (Source: http://arduino.cc/en/Main/ArduinoEthernetShield)

4.3.1.2. Motor Driver Cards

We have searched through the internet but we couldn’t find any proper dc motor control unit for our purpose. So we ourselves produced our dc motor control units. We have manufactured it via printed circuit board method. It enables us to drive every motor forward and backwards. It has great current drawn capability, it supports up to 50A normal current and 60A peak current for 10seconds.

Figure 35. Motor Driver Cards (Front View)

4.3.1.3. Batteries

We are asked to operate our ROV for 1 hour, at least. So we have made our calculations to reach the desired operation time. We decided to use Li-Po batteries since they are powerful, and lighter than the other battery options. Additionally, they are re-chargeable and we can use them again and again. We are using 9.500mAh Li-Po batteries in total.

4.3.1.4. Pressure Sensor

One of our aims is to obtain the pressure and depth information while on operation. We are using Gems pressure sensor that transmits pressure up to 6 bars. We can directly obtain pressure values from that sensor. However, we had to write some algorithm to obtain depth information since we can't directly obtain it. So we have written a code, which transforms pressure into depth and then shows us on the control panel.

Figure 36. Pressure Sensor

4.3.1.5. Camera

Acquiring subsea view is one of our main tasks. In order to do that, we are using IP camera attached to the Arduino. Thanks to Ethernet communication we have no data loss is seen during transmission.

4.3.1.6. Router

We are attached a router into our system, in order to link the ethernet shield and IP camera to the main computer located in the surface.

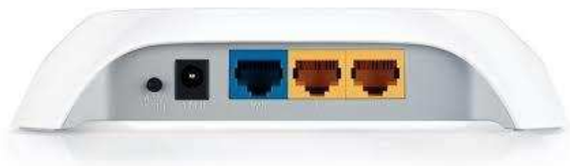

Figure 37. TP Link WR 720N Router Rear View (Source: http://www.tp-link.com/en/products/details/?model=TL-WR720N) [8]

Router wirelessly connects the IP camera. Ethernet shield is wired to the router and the tether comes from the surface. We have selected TP-LINK WR 720N type, since it’s small and sufficient for our requirements.

4.3.1.7. Electronic Circuits

After the coding part, hardware part comes in. We connected the electronic equipment, which are electronic motor controllers, Arduino Mega & Arduino ethernet shield, router, ip camera, and power control circuit needs to be linked all over. The hard part of this process is fitting all the electronic devices into the ROV. After connecting all the electronic parts, all the system looked like this:

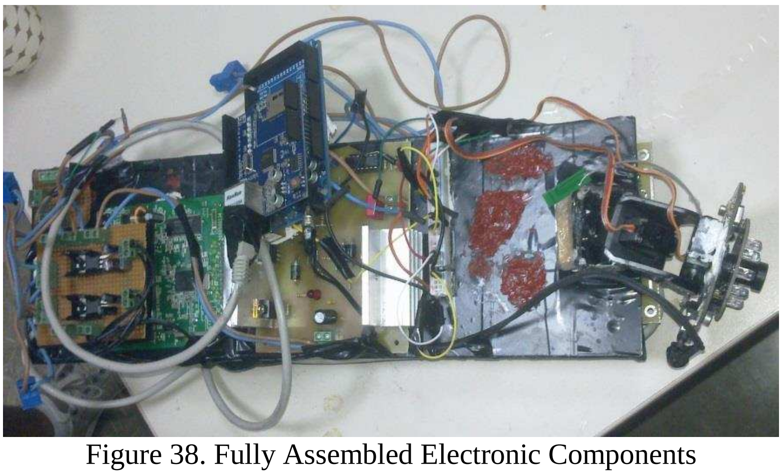

Figure 38. Fully Assembled Electronic Components

4.4. Buoyancy and Stabilization

The ability of an object to float or sink relates to relation of buoyant force (B) and weight (W). If B is greater than W, the object floats. Put other way, if B is smaller than W, the object sinks. If they are equal to each other, the object remains where it is. Based on the basic information, we have designed that, the density of our ROV is less than the density of seawater. Thus, if any failure in mechanical or electronic systems of our ROV occurs under water, it will provide a big benefit which is to rise automatically to water surface by itself.

For stability design of ROV, it is the most important rule to put center of buoyancy to the top and center of gravity to the bottom on same vertical axis. Therefore, these two centers should be as far as possible from each other for more stable. In order to increase distance between center of gravity and center of buoyancy, stand on the bottom side of ROV and apparatus on the upper side of ROV for buoyant materials have been designed. This technique provides easily stability on the pitch and roll axis.

4.4.1. Center of Buoyancy

Table 5. Center of Buoyancy

Center of Buoyancy				
Σ (volume*distance) / Σ (Volume)				
Part Name	Volume m^3	Unit	x	y
Vertical Thrusters	0,0004241	2	172	50
Horizontal Thrusters	0,0004241	2	364	80
Front Buoy	0,004	1	160	349
Rear Buoy	0,004	2	349	134
Drybox	0,0062	1	257	174
Center of Buoyancy (mm)				
x axis	275,42848			
y axis	183,805412			

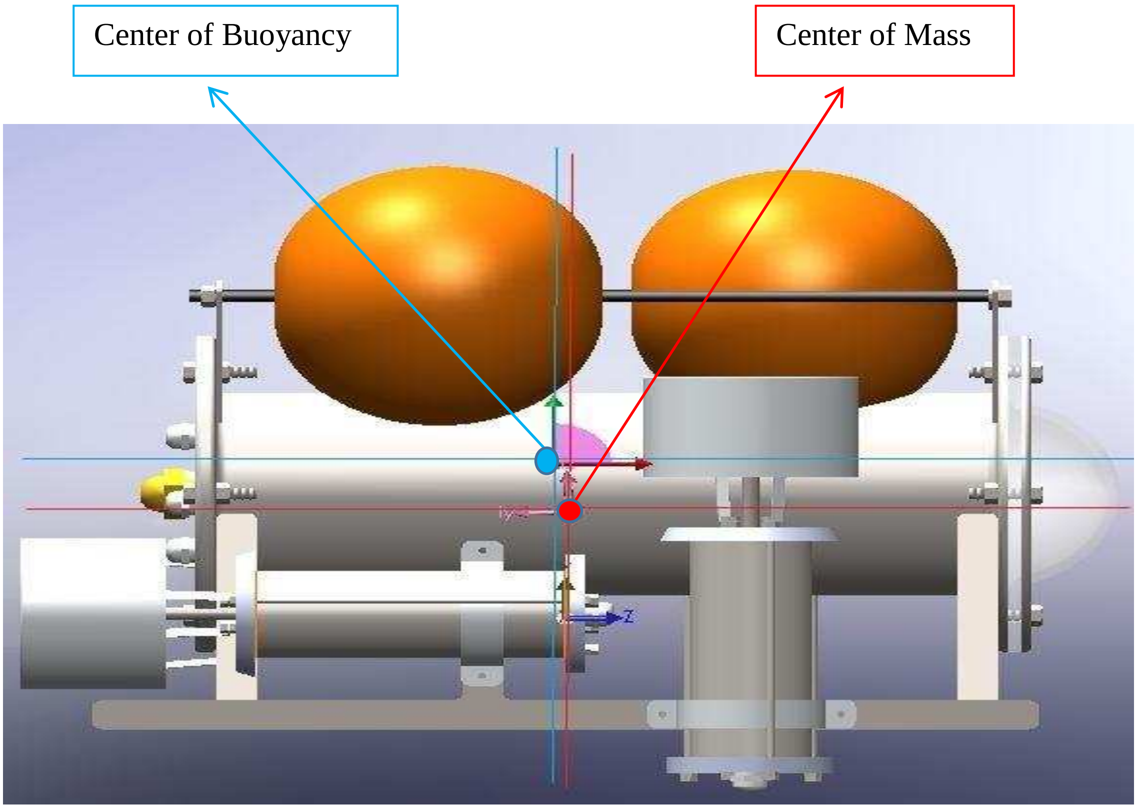

Figure 39. Center of Buoyancy and Mass

4.4.2. Buoyancy Calculations

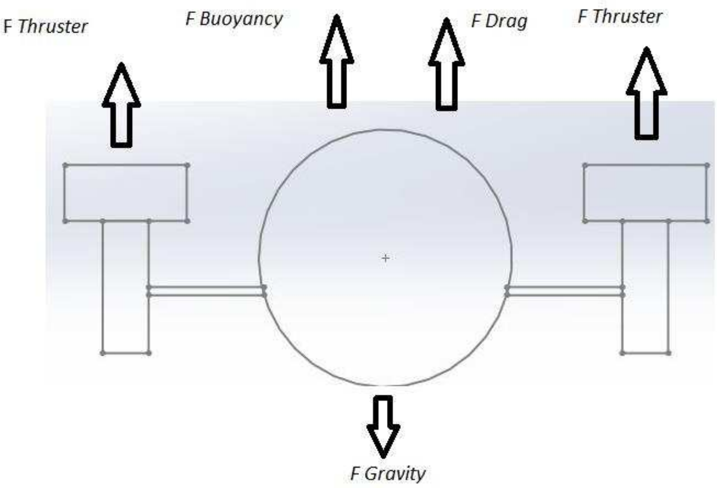

Figure 40. Diagram of the Forces Acting on the Body

Table 6. Buoyancy Calculations

	Unit Mass	Number of Material	Total Mass of Materials	Unit
$m_{all.case}$	16,85	1	16,85	kg
$m_{all.electronics}$	2	1	2	kg
$m_{oil\ for\ thruster}$	0,26	4	1,04	kg
$m_{buoyant\ material}$	0,825	3	2,475	kg
Total Mass of ROV			22,365	kg
Total Weight of ROV			219,40065	N
Desired Buoyancy Force			220,40065	N

Table 7. Calculations for Needed Free Volume

	Volume	Unit
Required Free Volume	0,021918963	m^3
Free Volume of Drybox	0,006157522	m^3
Free Volume of Thrusters	0,001182244	m^3
Total Volume of Materials	0,003050854	m^3
Needed Free Volume	0,011528343	m^3
	11,52834344	lt
Free Volume of the Buoyant Material	12 Lt	

4.5. Object Scaling System

For this object scaling system, we aimed that the operator can get information about the dimensions of objects which are seen on the user interface which are supplied by camera view. By using that system, the user can get estimated values only, because the interface will be availabe only for making estimations by the operator.

The hardware parts that are used by the system are the web-cam for image acquisition and two red laser pointers for fixing the refence points. As software equipment, there is a scale, which is very similar with a simple ruler, will be placed horizontal and the vertical axis the camera view screen on the user interface.

The working principle can be explained as, two red pointer will be used for determinig a specific distance which can be useful st the point of scaling. We decide the distance between the first pointer and the second single red dot. Then the dimension of the objects can be estimated by scaling the known distance to the one edge of the object.

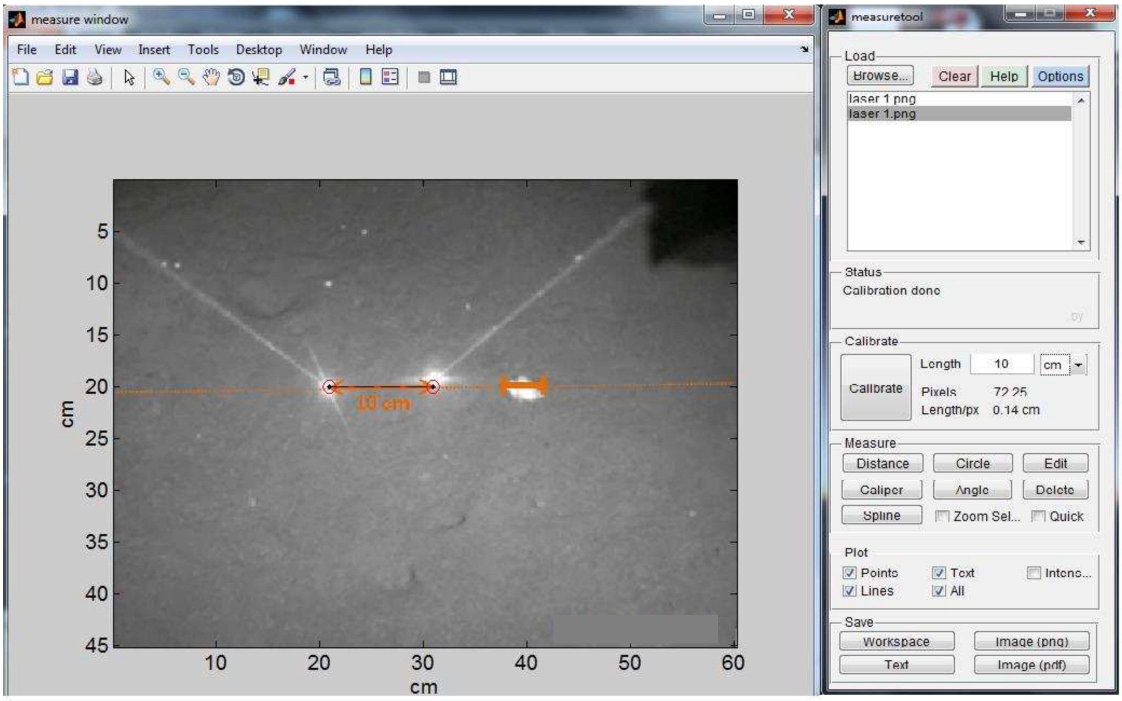

Figure 41. User Interface of Scaling System

4.6. Communication and Tethering

The easiest way to communicate with the ROVs is to have no communication at all. Direct cable connection can be used in the vehicles which are on board a support ship and mission may be pre-programmed in the vehicle. Although this way is inexpensive and simple, it limits flexibility in operation. It depends on the mission may not be changed in response to what happens.

For the communication with the operator; ROVs use a tether, high-bandwidth communication. With the electrical or fiber optic tethers we can transfer high-definition video, but a tether between the operator and vehicle can be a problem. The vehicle must be operated close to shore, or support vessel must be moved with the ROV. Only relatively shallow depths may be reached, because the drag force on the tether becomes prohibitive at some point. The perfect ROV should have the following features;

- Minimum tether diameter.
- Powered from the surface to increase working-endurance limit.
- Very small in size.
- Have an enough data pipeline for sensors. [9]

When we considered these reasons, a CAT6 type of cable connection was selected for communication between the ROV and computer. Also there is a safety rope and buoyant materials attached to the tether cable.

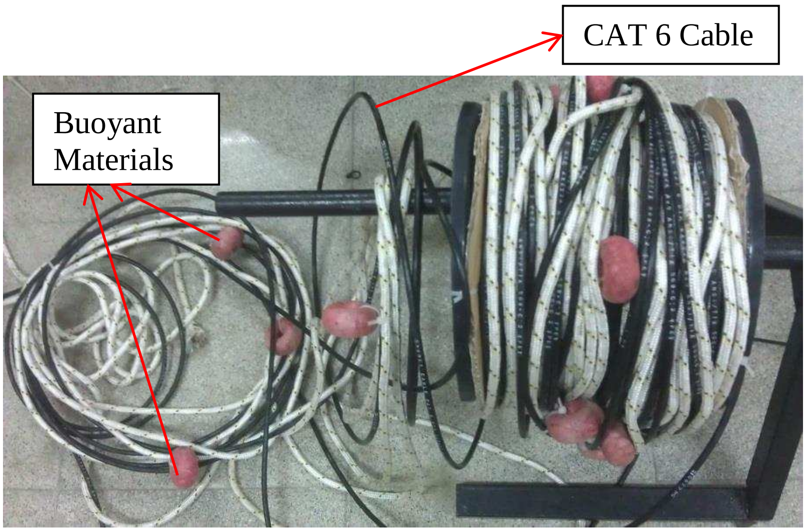

Figure 42. Tether Cable

4.7. User Interface

Control of the ROV consists of two part. First one is the coding part which is done by Arduino compiler & Viusal Basic 6.0. The other part is the hardware part, and composing of the required equipment and fitting them into the Nautilus.

First task is done with the help of Ali Vala kavuncu & Yiğit Gürsoytrak. These guys handled with the coding part of the system. What they do is relating the joystick with the needed movement inputs. Also we have constructed user interface within visual basic. The figure of the user interface can be seen as follows:

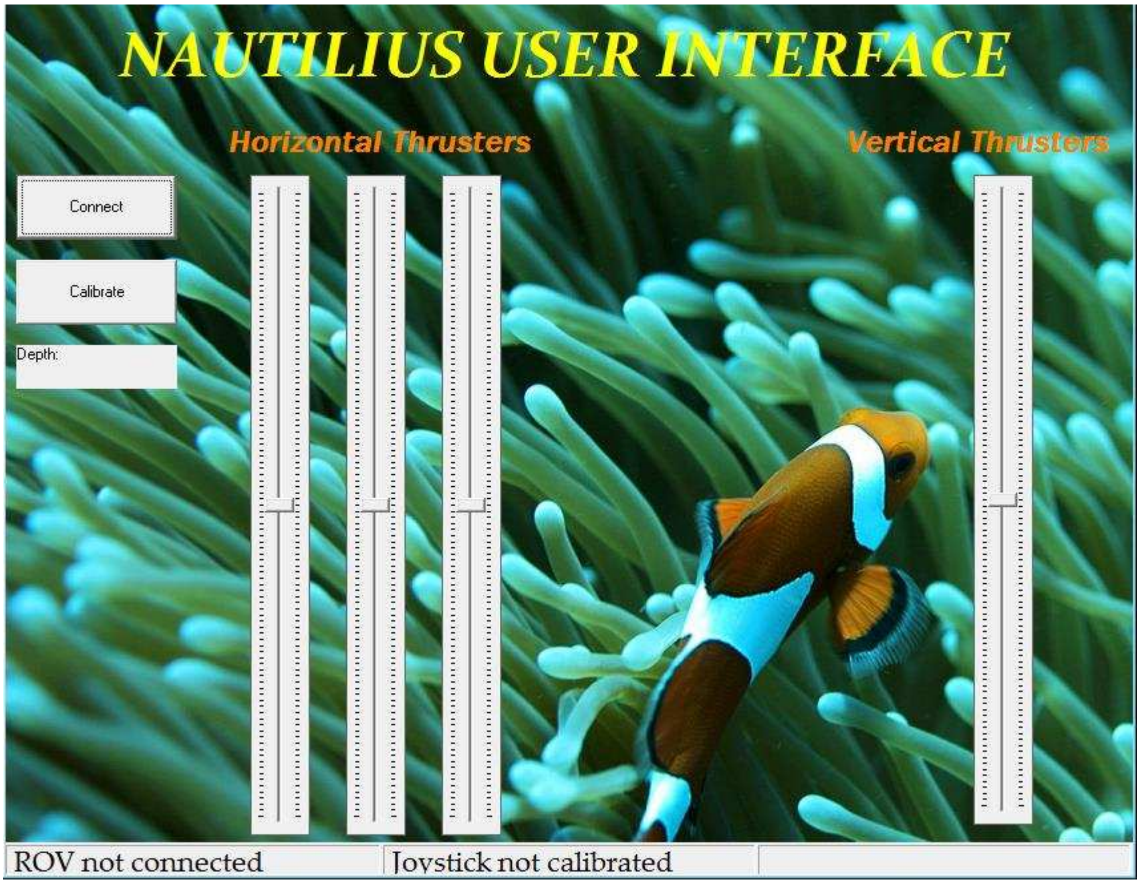

Figure 43. User Interface

4.8. Manufacturing and Assembly

4.8.1. Manufacturing of Drybox

Production of drybox is made in Bursa by Efe Lazer. Thanks to this company we got all our materials and laser cut is completed. All of our materials are stainless steel. We used a cylindrical pipe as a body with 140 mm in diameter and 380 mm in length and thickness is 3mm. Flanges with 5 mm thickness are cut in laser with 6 holes (M8) in one side. After that, flanges went to the turning machine to open O-ring channels and welded by TIG welding. Two legs with 5mm thickness were welded under the body to tie thruster on the drybox. We bought a flat plate Plexiglas and put it on de body to see how Plexiglas behaves between two flanges.

Figure 44. Unwelded Parts of Body

Figure 45. TIG Welding Process

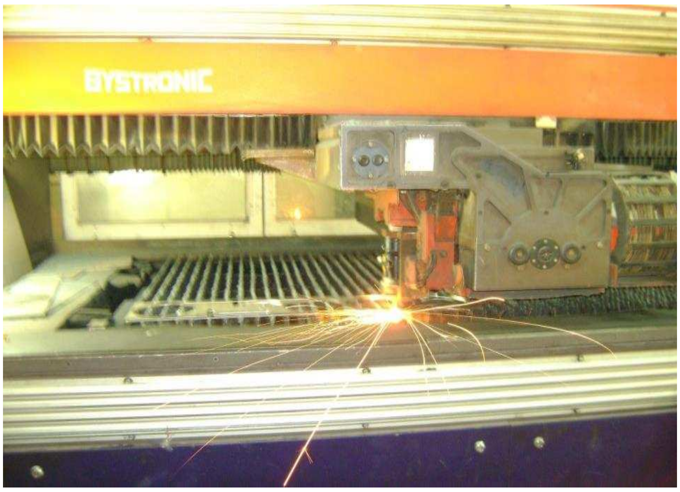

Figure 46. Laser Cutting Process

Figure 47. Cylindrical Pipe (AISI316 Stainless Steel)

Figure 48. Flanges

4.8.2. Production of Thruster Casings

In the production of thruster casings again stainless steel cylindrical pipe is used with 150mm length and 2mm thickness. On the front side, thanks to KASTAŞ Company, we have delrin parts which have 2 seals and one O-ring in the shaft exit. In the pipe delrin is used to put motor inside the casing. All the delrin materials were manufactured in the IYTE’s workshop by us. Inner radius of 8mm bearing is used to help the external shaft. On the back side of the casings, we used again delrin and we tied them with two studs which are shown in figure below. Both sides of the delrin parts, we used O-rings to get the waterproofing. IP68 Cable glands are used for cable exit. We used them because, we don’t concern about the pressure difference in the casing with the help of transformer oil inside the casing and the hose. Coupling with spring is used to extend the shaft of the motor. Finally; we assembled all the materials and thrusters are ready to test.


Figure 49. Casing Front Cap


Figure 50. Inside of a Casing

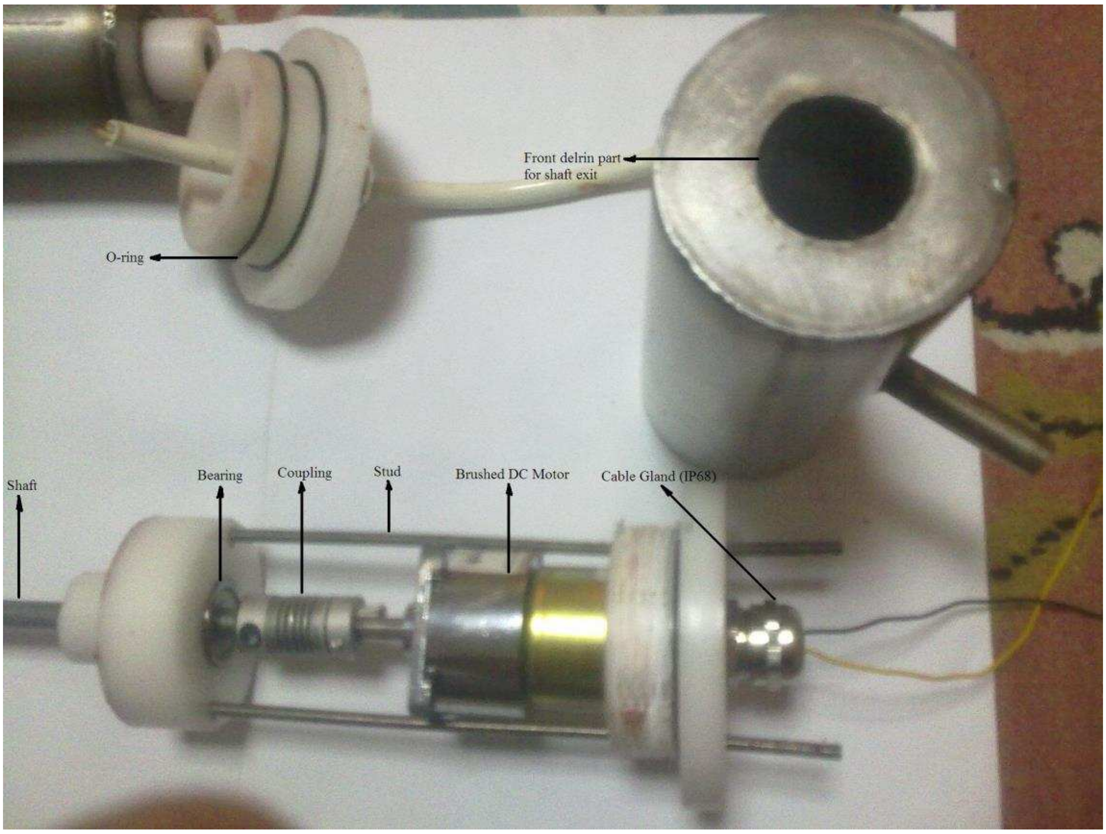

Figure 51. Inner Components Assembly of a Thruster

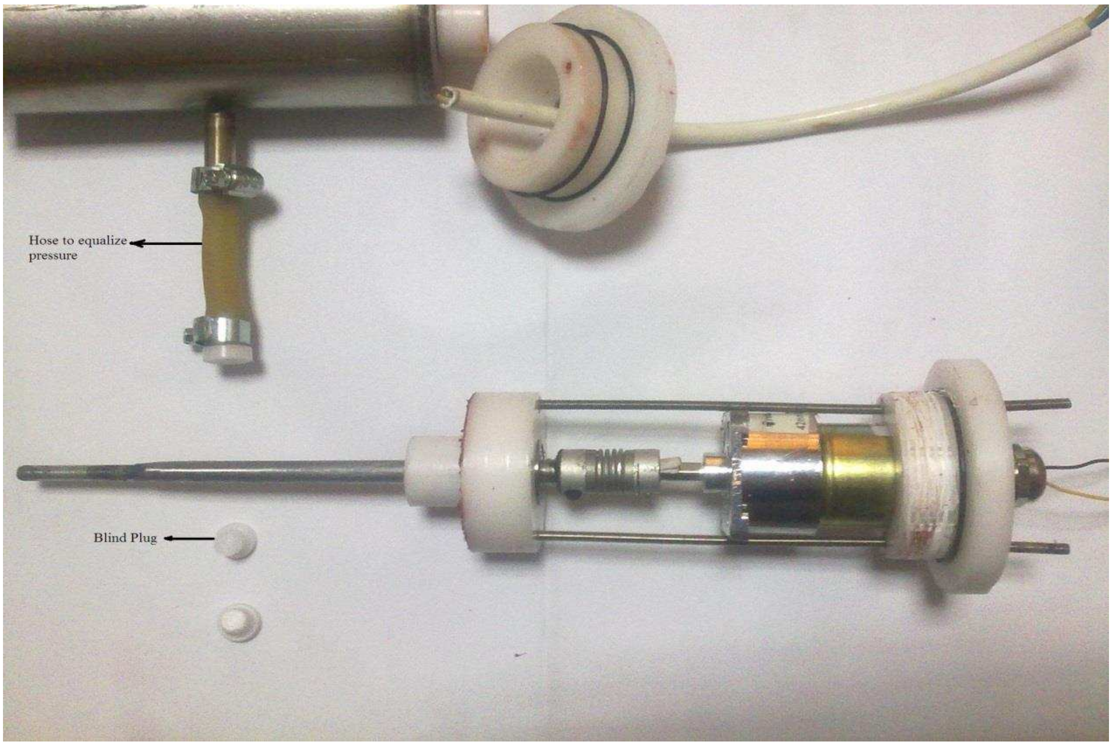

Figure 52. Hose, Blind Plug and Motor, Coupling and Shaft Assembly

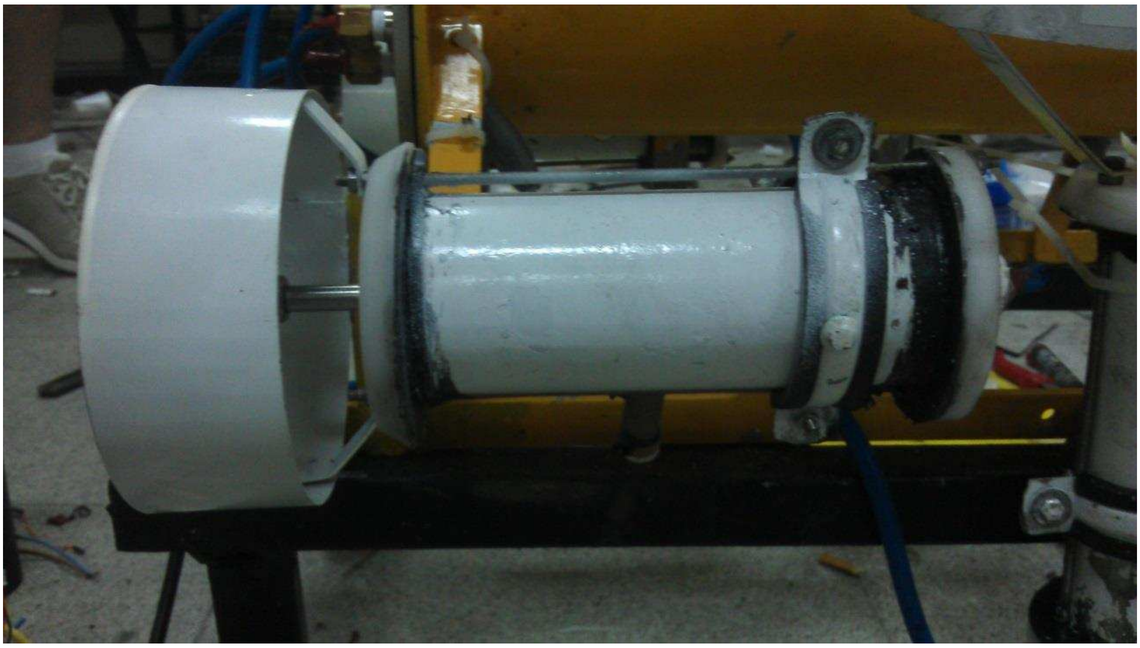

Figure 53. Fully Assembled Thruster

4.8.3. Production of Cable Glands

Production of cable glands were done in the IYTE's workshop as well. At first we used steel material to test the manufacturing process. Then, we manufactured our own cable gland with brass material and one O-ring for cable. These cable glands are used in the back side of the drybox.

Figure 54. Cable Gland Figure 55. Cable Gland (Disassembled)

4.8.4. Production of Semispherical Plexiglas

We ordered our Plexiglas to the Özer Pleksi thanks to the Group 5. Serhat Kerimoğlu has contact with the producer and we met with producer. According to our body’s size Plexiglas manufactured in spherical shape.

Figure 56. Semispherical Plexiglas

4.8.5. Production of the Table for Rope (Pulley System)

We bought our rope with 70 m length and 8 mm in diameter and we needed to produce a pulley system for ROV. With the help of this pulley, we can release and collect our rope. This system manufactured in our workshop thanks to Şerafettin Çavdar.

Figure 57. Pulley System Left View

Figure 58. Pulley System Front View

CHAPTER 5

RESULTS

5.1. Vertical Motion

When the vertical thrusters start to run at 12 V, they create 7.75 N thrust. This value, buoyancy force and weight are constant. And Drag force is changing with respect to velocity. The correlation of these forces is:

$F_{Thrust} + Weight - F_{Buoyancy} - F_{Drag} = F_{acceleration}$

$F_{acceleration} = m \, . \, a$

$V_1 = V_0 + a.t$

Where;

a = Acceleration

m = Mass

V = Velocity

Velocity of ROV is increased by 0.01 m/s increment. When the $F_{acceleration}$ is zero, the velocity reaches maximum value. Data are given in Appendix B.

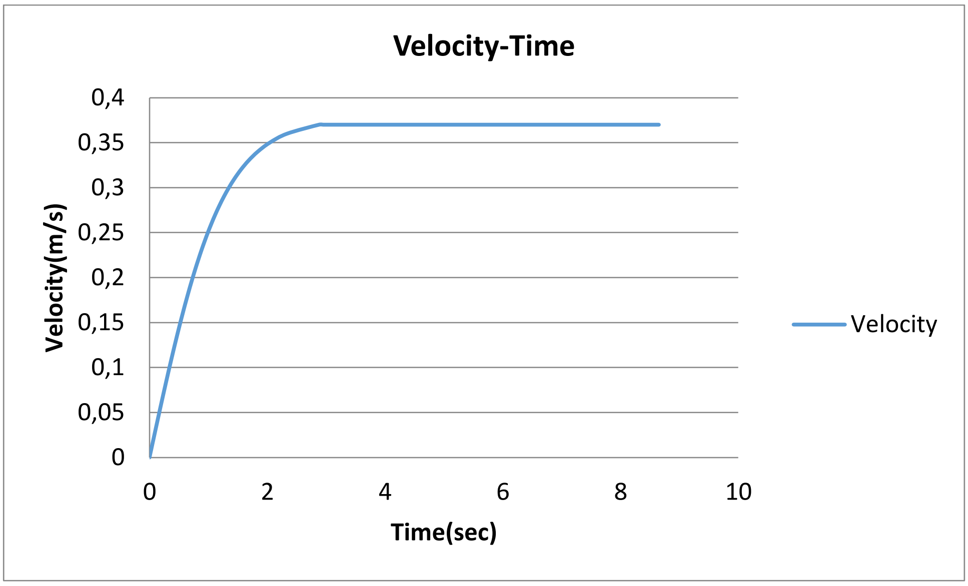

Figure 59. Vertical Motion Velocity – Time Graph

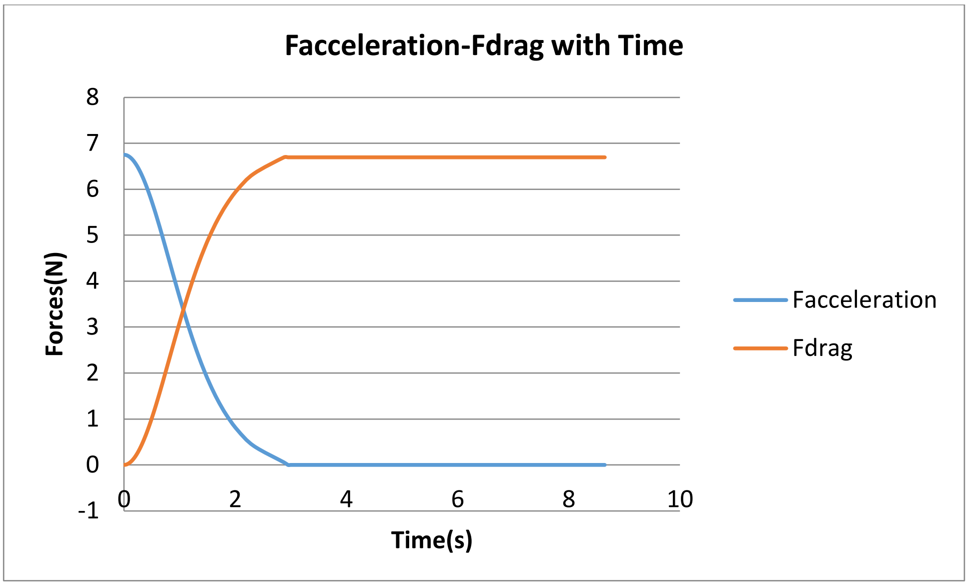

Figure 60. Vertical Motion $F_{acc} - F_{drag}$ versus Time Graph

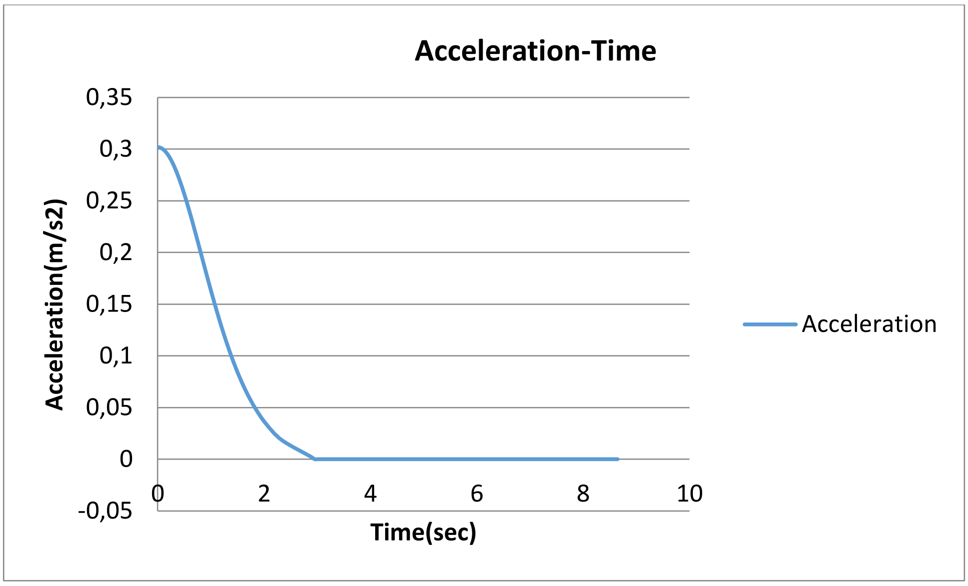

Figure 61. Vertical Motion Acceleration – Time Graph

This graph shows mechanical power and electric power with time.

Mechanical Power = $F_{Thrusters}$. Velocity

Electric Power = Voltage . Current

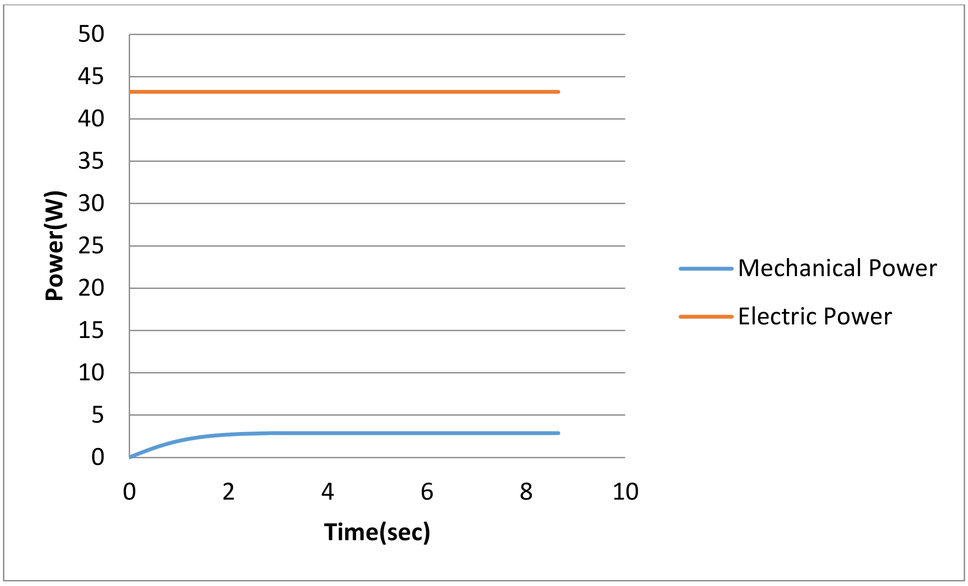

Figure 62. Vertical Motion Mechanical and Electrical Power

5.2. Horizontal Motion

Horizontal thrusters create 5.50 N thrust. And drag force is changing with respect to time. The velocity of ROV in horizontal direction is increased by 0.02 m/s increment. The correlation of forces is:

$F_{Thruster} - F_{Drag} = F_{acceleration}$

$F_{acceleration} = m.\ a$

$V_1 = V_0 + a.t$

Where;

a = Acceleration

m = Mass

V = Velocity

These graphs show the relationship between velocity, acceleration and forces with time. Data are given in Appendix B

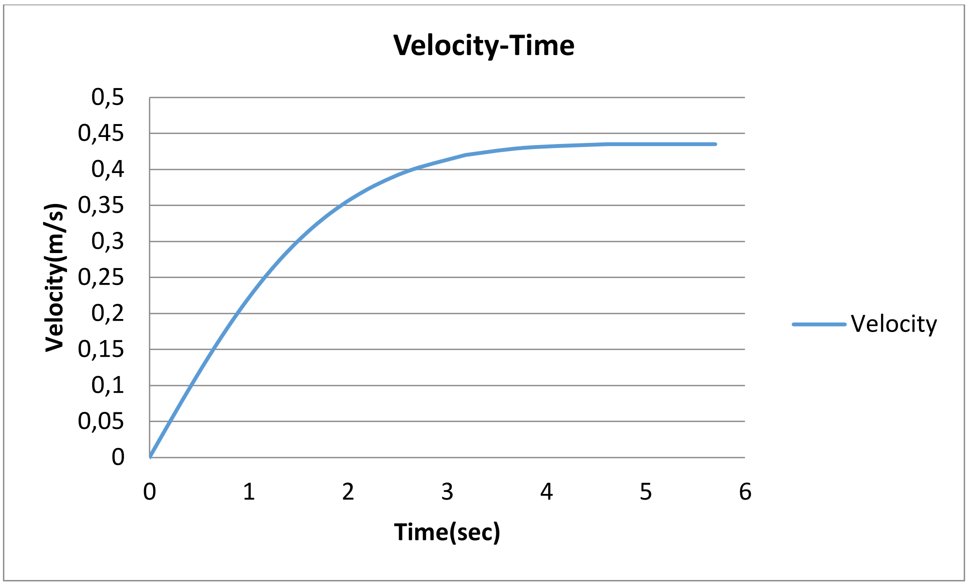

Figure 63. Horizontal Motion Velocity – Time Graph

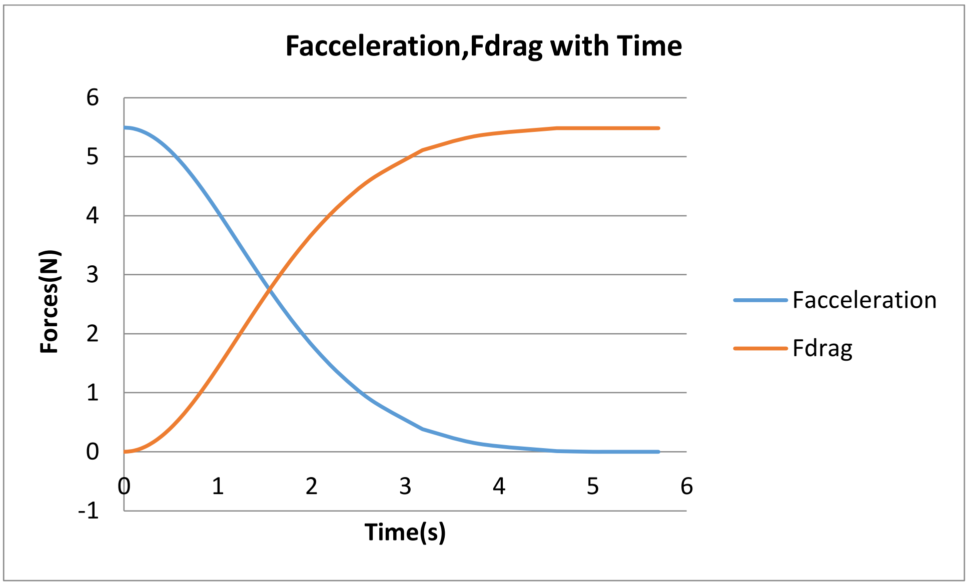

Figure 64. Horizontal Motion F_{acc} – F_{drag} – Time Graph

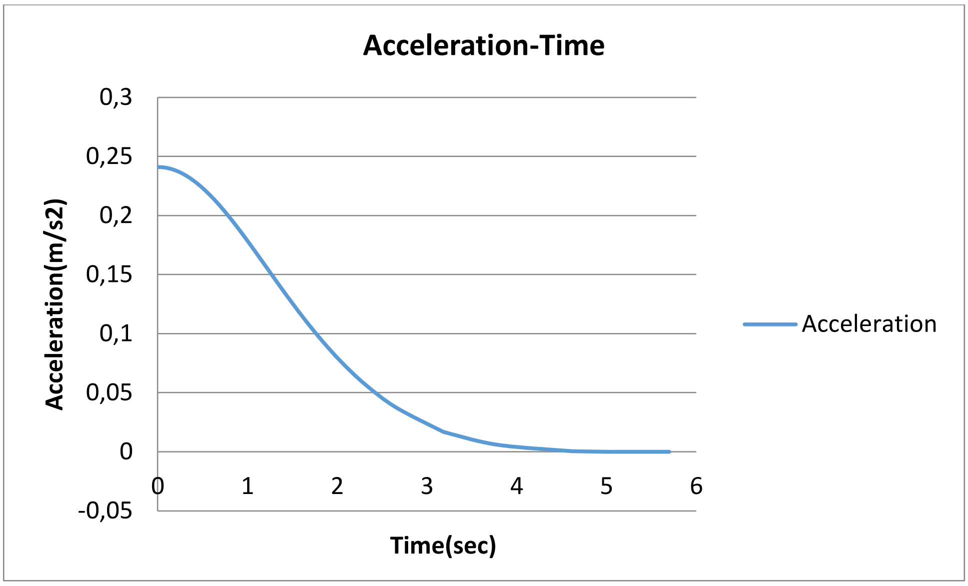

Figure 65. Horizontal Motion Acceleration – Time Graph

This graph shows mechanical power and electric power with time.

Mechanical Power = $F_{Thrusters}$. Velocity

Electric Power = Voltage . Current

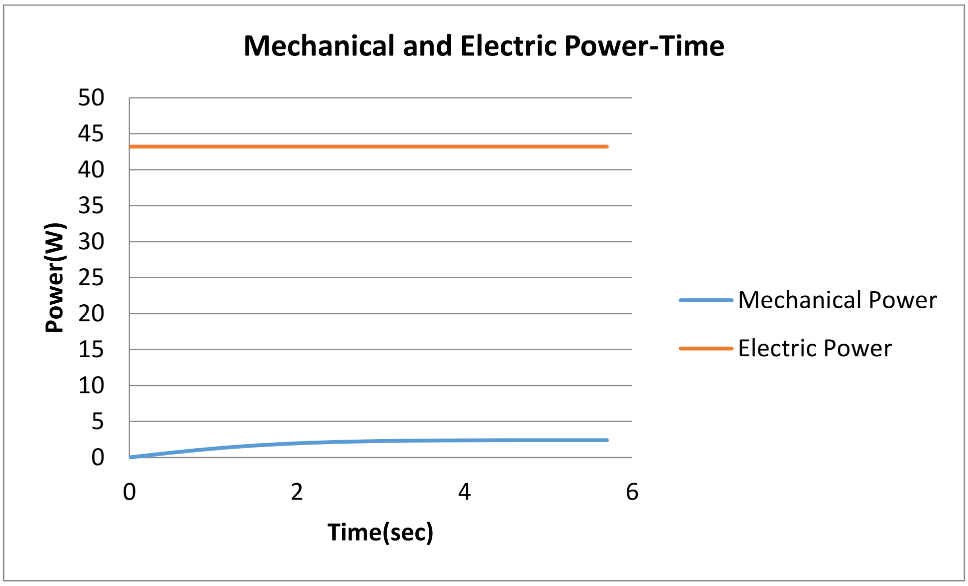

Figure 66. Horizontal Motion Mechanical and Electrical Power versus Time

5.3. Power Budget

We have 9500 mAh Li-Po batteries. When the all thrusters are running maximum power, there is no need battery up to about 60 minutes.

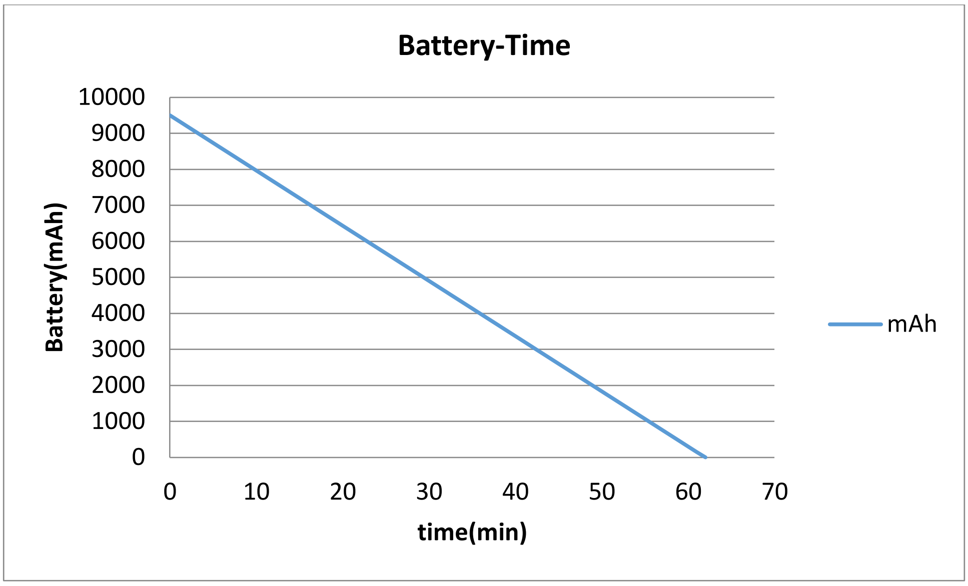

Figure 67. Maximum Power Consumption of the System

5.4. Total Cost

This project is funded by our sponsors and we defined a maximum budget of 2000 TL and tried not to exceed that limit. As can be seen from the table below the total expenses are about the maximum limit.

Table 8. Cost Analysis

Item	Cost
DC Motors (Including Burned Outs and Unused)	192
Production Costs	250
Ethernet Shield	135
Propellers	20
Shafts	40
Cable Glands	35
Cable	55
Plexiglas Dome	60
Li-Po (9500 mAh) Battery	75
Buoyants	75
Electronic Equipment	130
Camera Stand	38
Labour Cost	350
Fuel Cost	250
Rope	40
Paint	20
Delrin	90
Motor Driver Boards	50
Other Misc. Cost	150
TOTAL (TL)	2055

References

[1] Sea View, “What is a ROV?”
http://www.seaviewsystems.com/questions/what-is-an-rov/

[2] Cable Gland,
http://www.cable-glands-brass.com/brass-metric-strain-relief/brass-cable-glands.gif

[3] Robotistan, “12V 750 rpm Redüktörlü DC Motor”,
http://www.robotistan.com/12V-750Rpm-Reduktorlu-DC-Motor,PR-785.html

[4] Efunda.com, “Stainless Steel”,
http://www.efunda.com/Materials/alloys/stainless_steels/show_stainless.cfm?ID=AISI_Type_316&prop=all&Page_Title=AISI%20Type%20316, in 2013.

[5] Plexiglas.net, “Plexiglas Properties”,
http://www.plexiglas.net/product/plexiglas/en/about/faq/Pages/properties.aspx, in 2013.

[6] Arduino.cc, Arduino “Mega 2650”,
http://arduino.cc/en/Main/arduinoBoardMega

[7] Arduino.cc, Arduino Ethernet Shield,
http://arduino.cc/en/Main/ArduinoEthernetShield

[8] TP Link, “150 Mbps Wireless N Router”,
http://www.tp-link.com/en/products/details/?model=TL-WR720N

[9] OWENS, Dylan. DSpace@MIT. June 2009.
http://dspace.mit.edu/handle/1721.1/50267.

APPENDIX A

A1. Gantt Chart

The Gantt chart can be seen on the next page

APPENDIX B

B1. Vertical Motion Data

Table B1. Vertical Motion Calculation Data

Vertical Motion									
13 mm Propeller									
Fthruster	buoyancy force (N)	weight (N)	Fdrag (vertical) (N)	velocity (m/s)	Facceleration (m/s^2)	Time (s)	Acceleration (m/s^2)	Power (W)	Electric Power
7,75	220,40065	219,40065	0	0	6,75	0	0,301810865	0	43,2
7,75	220,40065	219,40065	0,00489008	0,01	6,74510992	0,033133333	0,301592216	0,0775	43,2
7,75	220,40065	219,40065	0,01956032	0,02	6,73043968	0,066290688	0,30093627	0,155	43,2
7,75	220,40065	219,40065	0,04401072	0,03	6,70598928	0,099520315	0,299843026	0,2325	43,2
7,75	220,40065	219,40065	0,078241279	0,04	6,671758721	0,132871099	0,298312485	0,31	43,2
7,75	220,40065	219,40065	0,122251999	0,05	6,627748001	0,166392994	0,296344646	0,3875	43,2
7,75	220,40065	219,40065	0,176042878	0,06	6,573957122	0,200137488	0,293939509	0,465	43,2
7,75	220,40065	219,40065	0,239613918	0,07	6,510386082	0,234158093	0,291097075	0,5425	43,2
7,75	220,40065	219,40065	0,312965117	0,08	6,437034883	0,268510895	0,287817343	0,62	43,2
7,75	220,40065	219,40065	0,396096476	0,09	6,353903524	0,303255152	0,284100314	0,6975	43,2
7,75	220,40065	219,40065	0,489007995	0,1	6,260992005	0,338453987	0,279945987	0,775	43,2
7,75	220,40065	219,40065	0,591699674	0,11	6,158300326	0,374175164	0,275354363	0,8525	43,2
7,75	220,40065	219,40065	0,704171513	0,12	6,045828487	0,410492002	0,270325441	0,93	43,2
7,75	220,40065	219,40065	0,826423511	0,13	5,923576489	0,447484451	0,264859221	1,0075	43,2
7,75	220,40065	219,40065	0,95845567	0,14	5,79154433	0,485240358	0,258955704	1,085	43,2
7,75	220,40065	219,40065	1,100267989	0,15	5,649732011	0,523857001	0,25261489	1,1625	43,2
7,75	220,40065	219,40065	1,251860467	0,16	5,498139533	0,563442949	0,245836778	1,24	43,2
7,75	220,40065	219,40065	1,413233105	0,17	5,336766895	0,604120345	0,238621368	1,3175	43,2
7,75	220,40065	219,40065	1,584385903	0,18	5,165614097	0,646027741	0,230968661	1,395	43,2
7,75	220,40065	219,40065	1,765318862	0,19	4,984681138	0,689323658	0,222878656	1,4725	43,2
7,75	220,40065	219,40065	1,95603198	0,2	4,79396802	0,734191121	0,214351353	1,55	43,2
7,75	220,40065	219,40065	2,156525258	0,21	4,593474742	0,780843498	0,205386754	1,6275	43,2
7,75	220,40065	219,40065	2,366798695	0,22	4,383201305	0,829532129	0,195984856	1,705	43,2
7,75	220,40065	219,40065	2,586852293	0,23	4,163147707	0,88055648	0,186145661	1,7825	43,2
7,75	220,40065	219,40065	2,816686051	0,24	3,933313949	0,93427785	0,175869168	1,86	43,2
7,75	220,40065	219,40065	3,056299968	0,25	3,693700032	0,9911383	0,165155378	1,9375	43,2
7,75	220,40065	219,40065	3,305694046	0,26	3,444305954	1,051687342	0,15400429	2,015	43,2
7,75	220,40065	219,40065	3,564868283	0,27	3,185131717	1,116620598	0,142415905	2,0925	43,2
7,75	220,40065	219,40065	3,83382268	0,28	2,91617732	1,186837475	0,130390222	2,17	43,2
7,75	220,40065	219,40065	4,112557237	0,29	2,637442763	1,263530342	0,117927242	2,2475	43,2
7,75	220,40065	219,40065	4,401071954	0,3	2,348928046	1,348328391	0,105026964	2,325	43,2
7,75	220,40065	219,40065	4,699366831	0,31	2,050633169	1,443542035	0,091689388	2,4025	43,2
7,75	220,40065	219,40065	5,007441868	0,32	1,742558132	1,55260591	0,077914515	2,48	43,2
7,75	220,40065	219,40065	5,325297064	0,33	1,424702936	1,6809517	0,063702345	2,5575	43,2
7,75	220,40065	219,40065	5,652932421	0,34	1,097067579	1,837931794	0,049052876	2,635	43,2
7,75	220,40065	219,40065	5,990347938	0,35	0,759652062	2,041793438	0,033966111	2,7125	43,2
7,75	220,40065	219,40065	6,337543614	0,36	0,412456386	2,336204539	0,018442047	2,79	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0,05548055	2,878443688	0,002480686	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	2,95	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	3	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	3,05	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	3,1	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	3,15	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	3,2	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	3,25	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	3,3	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	3,35	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	3,4	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	3,45	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	3,5	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	3,55	0	2,8675	43,2

7,75	220,40065	219,40065	6,69451945	0,37	0	3,6	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	3,65	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	3,7	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	3,75	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	3,8	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	3,85	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	3,9	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	3,95	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	4	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	4,05	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	4,1	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	4,15	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	4,2	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	4,25	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	4,3	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	4,35	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	4,4	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	4,45	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	4,5	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	4,55	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	4,6	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	4,65	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	4,7	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	4,75	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	4,8	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	4,85	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	4,9	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	4,95	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	5	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	5,05	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	5,1	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	5,15	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	5,2	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	5,25	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	5,3	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	5,35	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	5,4	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	5,45	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	5,5	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	5,55	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	5,6	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	5,65	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	5,7	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	5,75	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	5,8	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	5,85	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	5,9	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	5,95	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	6	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	6,05	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	6,1	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	6,15	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	6,2	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	6,25	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	6,3	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	6,35	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	6,4	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	6,45	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	6,5	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	6,55	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	6,6	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	6,65	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	6,7	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	6,75	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	6,8	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	6,85	0	2,8675	43,2

7,75	220,40065	219,40065	6,69451945	0,37	0	6,9	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	6,95	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	7	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	7,05	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	7,1	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	7,15	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	7,2	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	7,25	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	7,3	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	7,35	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	7,4	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	7,45	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	7,5	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	7,55	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	7,6	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	7,65	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	7,7	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	7,75	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	7,8	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	7,85	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	7,9	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	7,95	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	8	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	8,05	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	8,1	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	8,15	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	8,2	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	8,25	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	8,3	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	8,35	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	8,4	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	8,45	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	8,5	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	8,55	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	8,6	0	2,8675	43,2
7,75	220,40065	219,40065	6,69451945	0,37	0	8,65	0	2,8675	43,2

B2. Horizontal Motion Data

Table B2. Horizontal Motion Results Data

Facceleration (N)	Fthrusters (N)	Fdrag (N)	Velocity (m/s)	Acceleration (m/s2)	mass (kg)	time (sec)	Power(W)	Electrical Power
5,4936	5,4936	0	0	0,24104918	22,79037	0	0	43,2
5,4820106	5,4936	0,0115894	0,02	0,240540658		0,082971	0,109872	43,2
5,4472424	5,4936	0,0463576	0,04	0,239015093		0,166117	0,219744	43,2
5,3892954	5,4936	0,1043046	0,06	0,236472484		0,249793	0,329616	43,2
5,3081696	5,4936	0,1854304	0,08	0,232912831		0,33437	0,439488	43,2
5,203865	5,4936	0,289735	0,1	0,228336135		0,420239	0,54936	43,2
5,0763816	5,4936	0,4172184	0,12	0,222742395		0,507829	0,659232	43,2
4,9257194	5,4936	0,5678806	0,14	0,216131612		0,597619	0,769104	43,2
4,7518784	5,4936	0,7417216	0,16	0,208503785		0,690155	0,878976	43,2
4,5548586	5,4936	0,9387414	0,18	0,199858914		0,786077	0,988848	43,2
4,33466	5,4936	1,15894	0,2	0,190197		0,886147	1,09872	43,2
4,0912826	5,4936	1,4023174	0,22	0,179518042		0,991301	1,208592	43,2
3,8247264	5,4936	1,6688736	0,24	0,167822041		1,102711	1,318464	43,2
3,5349914	5,4936	1,9586086	0,26	0,155108996		1,221885	1,428336	43,2
3,2220776	5,4936	2,2715224	0,28	0,141378907		1,350826	1,538208	43,2
2,885985	5,4936	2,607615	0,3	0,126631775		1,49229	1,64808	43,2
2,5267136	5,4936	2,9668864	0,32	0,110867599		1,650228	1,757952	43,2
2,1442634	5,4936	3,3493366	0,34	0,094086379		1,830624	1,867824	43,2
1,7386344	5,4936	3,7549656	0,36	0,076288116		2,043194	1,977696	43,2
1,3098266	5,4936	4,1837734	0,38	0,05747281		2,305358	2,087568	43,2
0,85784	5,4936	4,63576	0,4	0,03764046		2,653349	2,19744	43,2
0,3826746	5,4936	5,1109254	0,42	0,016791066		3,184692	2,307312	43,2
0,3826746	5,4936	5,1109254	0,42	0,016791066		3,184692	2,307312	43,2
0,13639985	5,4936	5,3572002	0,43	0,005984977		3,780247	2,362248	43,2
0,01108946	5,4936	5,4825105	0,435	0,000486585		4,615672	2,389716	43,2
0,01108946	5,4936	5,4825105	0,435	0,000486585		4,615672	2,389716	43,2
0	5,4936	5,4825105	0,435	0		5	2,389716	43,2
0	5,4936	5,4825105	0,435	0		5,1	2,389716	43,2
0	5,4936	5,4825105	0,435	0		5,2	2,389716	43,2
0	5,4936	5,4825105	0,435	0		5,3	2,389716	43,2
0	5,4936	5,4825105	0,435	0		5,4	2,389716	43,2
0	5,4936	5,4825105	0,435	0		5,5	2,389716	43,2
0	5,4936	5,4825105	0,435	0		5,6	2,389716	43,2
0	5,4936	5,4825105	0,435	0		5,7	2,389716	43,2

ÖNERİLER

Sualtı gözlem aracı tasarlayacak olan takımlara teknik ve işleyiş hakkında, yaşadığımız tecrübelerden birkaç öneride bulunabiliriz. Bunun yanında dersin işlenişi ile ilgili de önerilerim olacak. Öncelikle proje işleyişi ile ilgili şunu kesinlikle söyleyebilirim ki, 6 kişilik bir grubu yönetmek kolay bir iş değil. Yapılmasının faydalı olacağını düşündüğüm şeyleri maddeler halinde yazacağım.

1. İlk olarak yapılması gereken herkesin boş günlerini göze alarak ortak bir toplantı zamanı belirlemek. Toplantılar bir projede koordinasyonu sağlama açısından çok önemlidir.

2. Proje tamamen öğrencilerin maddi kaynakları ile yapıldığından, birinci dönem sonunda bir sponsorluk dosyası hazırlayıp firmalara başvurmanız sizin için faydalı olacaktır.

3. Hazırlanan gantt çizelgesine göre hareket etmek, projenin zamanında bitmesini sağlayacaktır fakat çizelgeyi hazırlarken test sürelerini mümkün olduğunca uzun tutun çünkü beklenmedik aksilikler olabiliyor.

4. Dönem başında yapılan görev dağılımına bağlı kalın, yavaş giden işlerde sorumluyu en başından uyarın çünkü aksayan işler ileriki zamanlarda başınıza büyük dertler açabilir.

Dersin işlenişi hakkında;

1. Üç haftada bir yapılan sunumlar faydalı oluyor fakat verilen raporların geri dönüşü yapılırsa projeyi sürdüren grup eksik veya yanlış yaptığı yerleri görüp düzeltebilir.

2. Bizim projemizde en çok zorlandığımız kısım elektronik oldu. Bunun sebebi makine mühendisliği öğrencisi olmamızdır ve şahsi görüşüm şudur ki, bu tarz kontrolün dahil olduğu projelerde her gruba en az 2 elektronik veya bilgisayar mühendisliği öğrencisi dahil edilmelidir.

Projeyi yapacak arkadaşlara başarılar dilerim.

Serdar ÖZDEMİR