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BACHELOR OF SCIENCE
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MECHANICAL ENGINEERING

Remotely Operated Underwater Vehicle (ROV)

100% Report

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This B.S. thesis is written in partial fulfillment of the requirements in EML 4905. The contents represent the opinion of the authors and not the Department of Mechanical and Materials Engineering.

Ethics Statement and Signatures

The work submitted in this B.S. thesis is solely prepared by a team consisting of Gabriel Martos, Ashley Abreu, and Sahivy Gonzalez and it is original. Excerpts from others' work have been clearly identified, their work acknowledged within the text and listed in the list of references. All of the engineering drawings, computer programs, formulations, design work, prototype development and testing reported in this document are also original and prepared by the same team of students.

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Abstract

Remotely operated underwater vehicles (ROVs) are remote control underwater robots driven by an individual on the surface. These robots are tethered by a series of wires that send signals between the operator and the ROV. All ROVs are equipped with a video camera, propulsion system, and lights. Other equipment is added depending on the specifications required. These include a manipulator arm, water sampler, instruments that measure clarity, light penetration, temperature, and depth. Team Aquabot was determined to recreate such an ROV in order to fulfill a specific mission involving four separate tasks.

Introduction

Problem Statement

The purpose of this project is to design and build an ROV to be entered in the Marine Advanced Technological Education (MATE) ROV competition. This competition is divided into 3 categories, and the ROV is to be entered into the “Explorer” category, which is the most advanced. Our group researched various design criteria and material selection. The various requirements of the competition were taken into consideration to design the most efficient ROV for the tasks at hand.

The ROV will be following the criteria established by the Marine Advanced Technological Education (MATE) Competition. It must complete a number of tasks within a certain time frame divided in the following way:

I. 5 minutes to set up system and start submerging.

II. 15 minutes to complete tasks:

  - Task #1: Complete a primary node and install a secondary node on the seafloor.
  - Task #2: Design, construct, and install a transmissometer to measure turbidity over time.
  - Task #3: Replace an Acoustic Doppler Current Profiler (ADCP) on a mid-water column-mooring platform.
  - Task #4: Remove bio-fouling from structures and instruments within the observatory.

III. 5 minutes to demobilize the system.

We expect that the ROV will not only accomplish these given tasks, but also be able to carry out multiple other tasks, in addition to being able to reach a depth of 100 feet.

Motivation

Florida International University has seen many senior design projects, but very few (if any) Remotely Operated Underwater Vehicles have been presented as a proposed project. With that in mind, Team Aquabot was happy to be the first to take on the challenge and was able to complete a working prototype by November 2013.

Literature Survey

There is not enough information as to say who invented the first ROV. Regardless of that, there are two who deserve a lot of credit to the upbringing of this technology. The Programmed Underwater Vehicle (PUV) was a torpedo developed by Luppis-Whitehead Automobile in Austria in 1864, however, the first tethered ROV, named POODLE, was developed by Dimitri Rebikoff in 1953.

The U.S.A. NAVY has been recognized for advancing the technology to levels of operation that could fit into recovering of objects lost during at-sea tests. In 1966 ROVs became famous when US Navy Cable Controlled Underwater Recovery Vehicle (CURV) systems recovered an atomic bomb lost off Palomares, Spain in an aircraft accident. Shortly after in 1973, the Pisces III saved the pilots of a sunken submersible off Cork, Ireland with only minutes of air remaining. [2]

After the NAVY did its work, commercial firms that saw a promising future in this technology to be used in offshore oil operations brought the technology even further. Two of the first ROVs developed for offshore work were the RCV-225 and the RCV-150. These ROVs were developed by Hydro-Products in the U.S.A. Many other firms developed a similar line of small inspection vehicles. Nowadays, the search for oil has taken us into deeper regions of the oceans. ROVs have become an essential part of such work.

Design Alternatives

Design Alternative 1

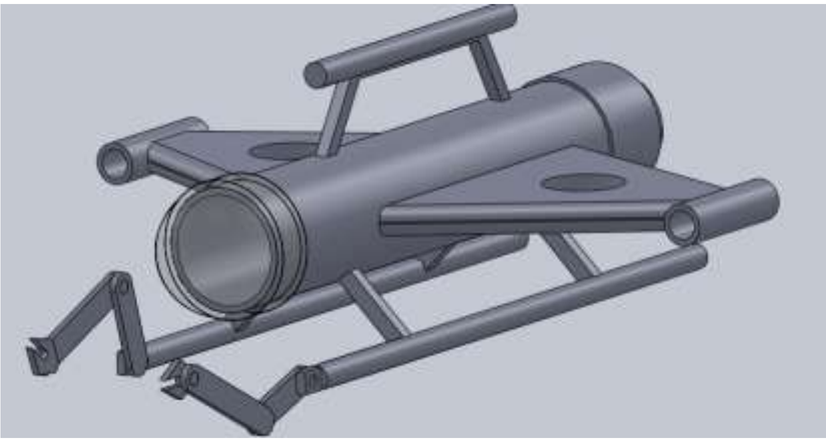

Figure 1. Design Alternative 1 Model

The first design that was observed is shown above in Figure 1. This design employs the usage of 2 legs at the bottom of the ROV that serve several purposes. The ability to insert lead rods into the legs, and apply positively buoyant material at the top will always ensure that the ROV will remain upright. Another purpose is that if the unit is operating on the ocean floor, it will be able to rest on the ground while performing the predetermined duties. The last advantage would be to mount the claws on these legs, which would be aligned right in front of the camera.

This design also utilizes the implementation of four thrusters. The two mounted horizontally in the wing will provide the ascent and descent, while the other two mounted at the end of the wings will provide the maneuverability in the horizontal plane.

The main body material was not chosen for this alternative, but there were a few materials that were considered. The first one was aluminum. Although aluminum is not relatively expensive, machining all the parts would be. The other material was PVC.

This material was highly likely to be chosen due to the very low cost, and ease of availability. Not to mention that it comes in many diameters with all types of fittings. Since the competition will take place in a pool, the hydrostatic pressure will not cause failure since a schedule 80 4” PVC pipe is rated to withstand 194 psi. [1]

Design Alternative 2

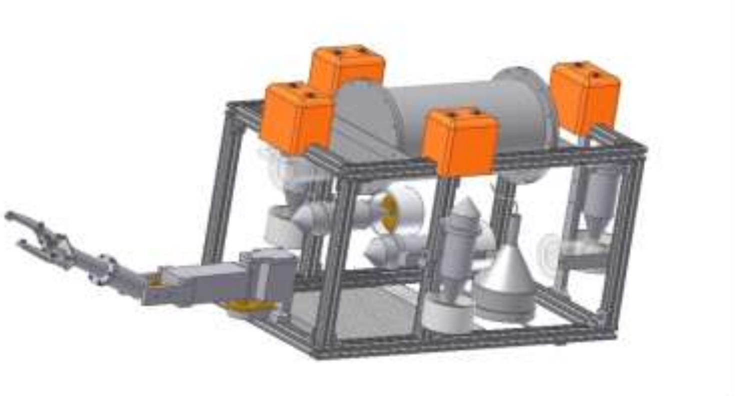

Figure 2. Design Alternative 2 Model

The second alternative of the design was to make it in the shape of a box. This setup follows the traditional design of ROVs. The whole system would be enclosed in a cage with foam on the top, weights on the bottom and all the electronics in the middle of the ROV such as Figure 2. Having a box setup allows the components to be fixed on the cage, which makes it easier to construct and increases stability.

The robotic arm and weights would be placed on a plate at the bottom of the cage followed by dividing the foam into four sections and placing them in specific locations above the whole ROV to achieve the desired buoyancy. The camera together with the four thrusters would be placed around the outside of the cage to balance each other out (the camera is located directly above the robotic arm). All electrical components would be at the center, housed in a cylindrical body for their protection. The materials considered to this design are the same as Design Alternative 1.

ROVs constructed in this fashion are not as hydrodynamic as the Design Alternative 1, due to their cage-like structure. Also this structure is considerably bigger than an ROV without the cage. On the other hand, having the cage permits the addition of parts even after the ROV has been built and used compared to an un-caged setup where the ROV can only carry the instruments it was designed to.

Proposed Design

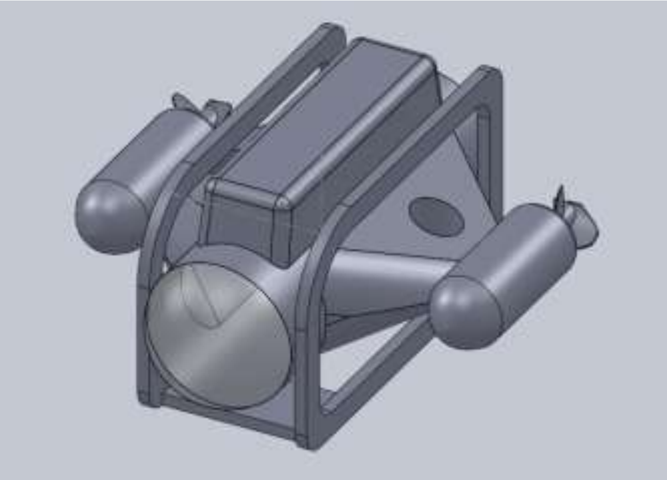

Figure 3. Proposed Design Model

For the proposed design shown above, the team decided to combine both design alternatives. The goal is to be as hydrodynamic as possible, but keeping the stability of the system and ability to add components. This design would be compact meaning all the parts would be placed as close as possible while leaving space for specific additions. A smaller ROV increases the maneuverability of the system under water.

The model will have a cylindrical body with a transparent dome in the front where the camera will be located, a foam top and everything surrounded by a small, tight cage.

The four thrusters would be placed on the wing-like structures (two on each one, facing two axes) for movement. Components such as the robotic arm would be placed on the cage with the ability to be removed if needed.

For this design, the team plans to try the same type materials as the alternatives but would like to experiment also with a fiberglass body. The idea is to calculate the buoyancy of the ROV only by the components it will by carrying without considering the body.

Actual Design

Figure 4. Actual Design Outcome

The actual design is a culmination of the first design alternative and the proposed design. The main difference was that there was no cage-like structure and the thrusters were mounted inside smaller diameter PVC pipes that were molded into the body. This was done to help protect the thrusters from damage if the ROV gets too close to a wall or encounters any objects or debris.

Analytical Analysis

Material Options

There are numerous variables that were looked into, for example safety factor, material, thickness, length, and diameter. Due to this there was a spreadsheet made with the capacity to enter all these parameters, and calculate the maximum depth with the corresponding cost. The unmanned submersible will make out of a barrel lodging all the wires, circuits, and cameras. The failure analysis will be dependent upon this cylinder's behavior as the depth increases. The joined spreadsheet utilizes the comparisons for hoop stress, longitudinal stress, and axial stress to verify the principle stresses. It then connects the principle stress to the Von Mises comparison to confirm the factor of safety. The previous equations are recorded below.

$$\sigma_H = \frac{p * r}{t}$$

$$\sigma_L = \frac{p * r}{2t}$$

$$\sigma_{1,2} = \frac{\sigma_x + \sigma_y}{2} \pm \sqrt{\frac{\sigma_x - {\sigma_y}^2}{2} + {\tau_{x,y}}^2}$$

$$\sigma_{vm} = [\frac{(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2}{2}]^{0.5}$$

$$SF = \frac{Yield\ strength}{\sigma_{vm}}$$

The upcoming analysis depends on a couple of presumptions. For example, the cylinder will act as a pressurized vessel with a negative internal pressure value. An alternate assumption is that the atmospheric pressure will be 101.325 kilopascals. The water that the submersible will be worked in is ocean water, which has a thickness of 1027 kg/m^3. Some materials will be acknowledged for the submersible so correlations could be made when referencing cost versus depth. The materials acknowledged are broadly accessible and cost anywhere from $11.27 to almost $4,000. The list below incorporates all the materials acknowledged.

- 316 Stainless Steel (36X96 Sheet - Unpolished)
- 7075 Aluminum (48x72 Sheet)
- Titanium Grade 2 (24X36 Sheets - Ground Finish)
- Titanium Grade 5 (24X36 Sheets - Ground Finish)
- PVC Schedule 40
- PVC Schedule 80

There are a considerable amount of parameters to these calculations, and some were made consistent for the simplicity of the material correlation. The variables that might be altered for optimization while staying inside a factor of safety are diameter, length, thickness, and depth. This permits the ability to observe which of the six materials will withstand the desired depth while staying inside the factor of safety demands. This also allows the option to implement different size combinations to see how it affects the outcome.

Analysis of Results

The task was to determine how deep into ocean the Remotely Operated Underwater Vehicle (the pressure vessel) can dive while maintaining a safety factor of 1.5, and additionally figure out which material would allow us to achieve this goal with the best cost. The different materials will be tested according to the size of the pressure vessel. It is to be noted that this is a simplified version of the actual model, which will be used as a preliminary test in order to understand the effects of hydrostatic pressures on an object under water. The model being tested has a cylindrical body that is hollow inside. This will assimilate the body of the actual ROV without the two wing-like components of the model.

The pressure vessel has a length of 0.4752 meters (1 foot and 5 inches) and a diameter of 0.1524 meters (6 inches) consistent with the real model. These measurements were kept the same for all the materials being tested and the only measurement that was changed was the thickness due to the fact that each material is sold with a certain thickness. The materials tested were PVC Schedule 40, PVC Schedule 80, Aluminum 7075, Stainless Steel 316, Titanium (Grade 2) and Titanium (Grade 5). The yield strength, tensile strength, and cost for each material were collected for the analysis. In order to measure the factor of safety of the pressure vessel to ensure that the material will not fail, the following values we calculated depending on the depth at which the pressure vessel is located: Tangential stresses, Axial stresses, Principles stresses and Von Misses stresses.

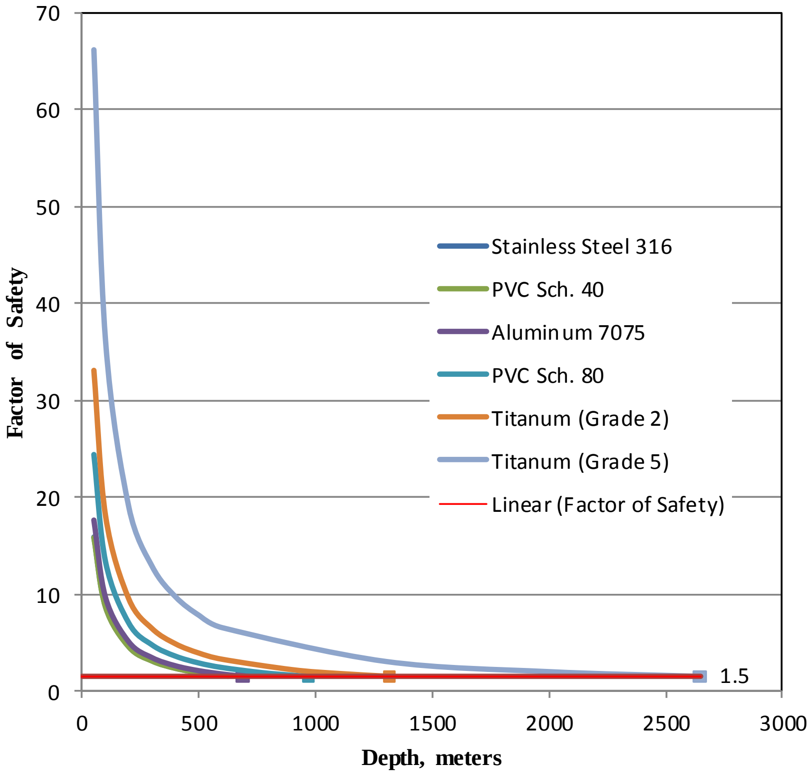

Figure 5. Factor of Safety in Comparison to Depth

With the factor of safety calculations done, the attention was turned to the cost analysis. Due to the fact that each material is sold with a certain diameter, the cost of the material depends on solely its length. Keeping in mind that all models accounted for have the same length, it can be said that price will not change with the depth at which the specimen is sent. The prices were placed side by side with the maximum depth each material reached. In doing this, the material that went the deepest for the least amount of the cost would be the one selected. Of course there are some obvious assumptions that could be made, for example Titanium (Grade 5) would go deeper than any other material but its cost would to be high and PVC Schedule 40 is the cheapest but it will not go very deep. These assumptions cannot influence the selection of the material because the material of the lowest cost would prevail.

PVC Sch. 40		Stainless Steel 316		Aluminum 7075		PVC Sch. 80		Titanium (Grade 2)		Titanium (Grade 5)	
Depth	FoS	Depth	FoS	Depth	FoS	Depth	FoS	Depth	FoS	Depth	FoS
50m	15.817	50m	15.887	50m	17.634	50m	24.403	50m	33.093	50m	66.199
100m	8.636	100m	8.675	100m	9.628	100m	13.324	100m	18.069	100m	36.145
200m	4.526	200m	4.546	200m	5.046	200m	6.983	200m	9.47	200m	18.944
300m	3.067	300m	3.08	300m	3.419	300m	4.732	300m	6.416	300m	12.835
400m	2.319	400m	2.329	400m	2.586	400m	3.578	400m	4.852	400m	9.706
500m	1.864	500m	1.873	500m	2.079	500m	2.876	500m	3.901	500m	7.803
600m	1.559	600m	1.565	600m	1.738	600m	2.405	600m	3.261	600m	6.524
610m	1.534	610m	1.541	650m	1.606	770m	1.881	900m	2.186	1300m	3.038
620m	1.509	620m	1.516	690m	1.515	900m	1.612	1100m	1.793	2000m	1.98
624m	1.499	627m	1.499	697m	1.499	969m	1.499	1317m	1.499	2644m	1.499

Table 1. Factor of Safety at each Depth

Finally, with everything taken into consideration, the material that used the lowest cost and with the best Depth to Cost Ratio was selected. Taking the lowest depth achieved and dividing it by the price of the material calculate this Depth to Cost Ratio. Of course, the higher the ratio the better the selection was. PVC Schedule 80, although having a price that was slightly higher than that of PVC Schedule 40, had a better Depth to Cost Ratio. This means PVC Schedule 80 reached a depth of 969 meters, while PVC Schedule 40 only reached 624 meters. All the other materials had a low depth to cost ratio and used much more of the money than the two PVC tubes. In conclusion, the best material was the PVC Schedule 40, further testing will be done but this material seems to be the best choice to house the body of the ROV.

Cost Analysis	Percent of Budget	Depth to Cost Ratio
PVC Sch. 40	0.56%	55.4
Stainless Steel 316	3.64%	8.6
Aluminum 7075	4.82%	7.2
PVC Sch. 80	0.74%	65.2
Titanium (Grade 2)	17.07%	3.9
Titanium (Grade 5)	47.15%	2.8

Table 2. Depth to Cost Analysis

Solidworks Analysis

Solid works also offered us another alternative to determining the behavior of the material under pressure. Since the only closed body of the ROV is the 4” section of PVC with the clear acrylic dome, this would be the only area experiencing hydrostatic pressure. The area under analysis is shown in the figure below

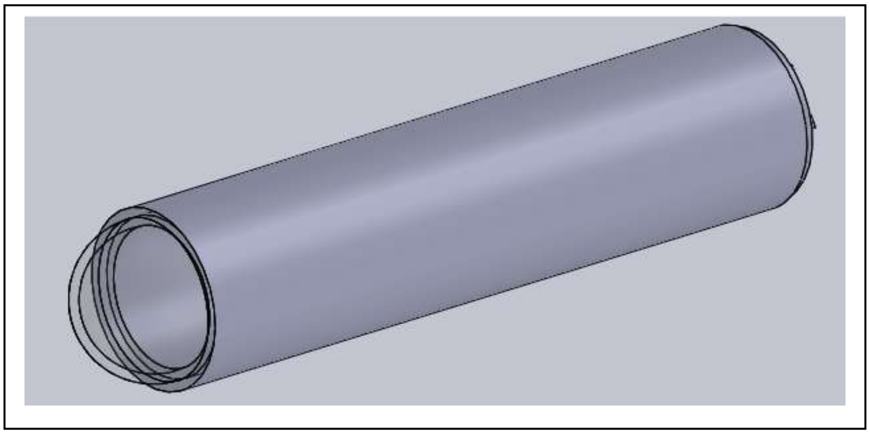

Figure 6. Solid works sample analysis

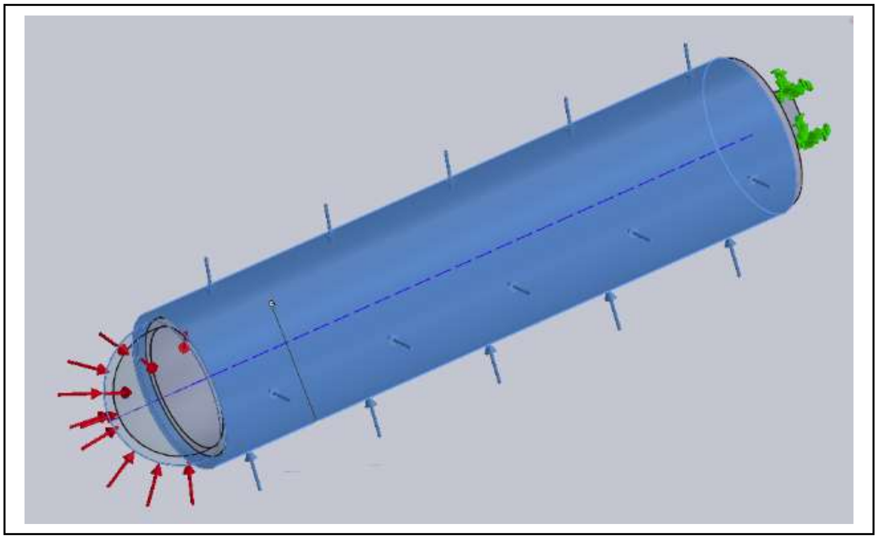

Figure 7. Location of the hydrostatic forces

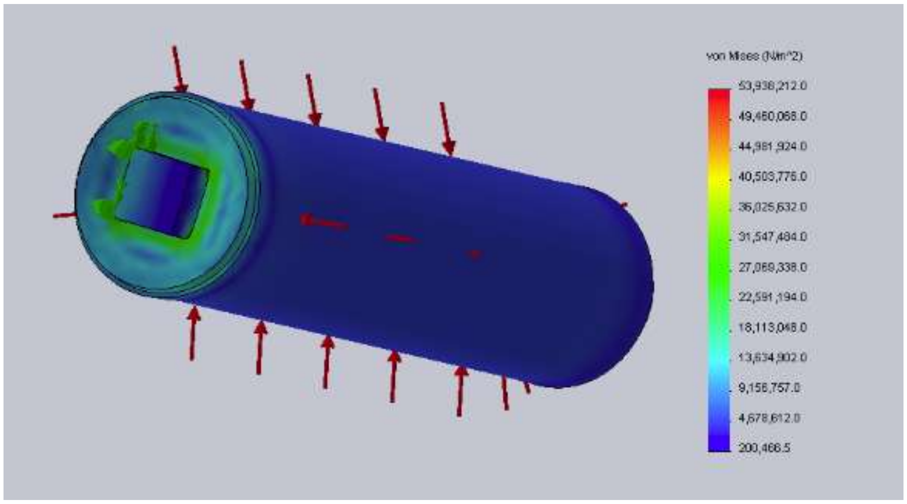

Figure 8. Von-mises stress results

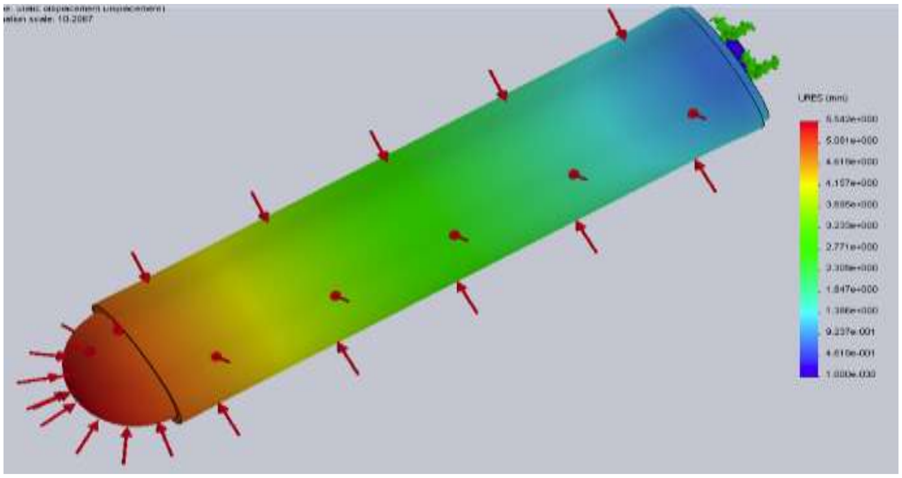

Figure 9. Max displacement (inward)

As seen in the images above, the inner cylinder that houses all the components is able to withstand over 50,000 N/m^2 with a inner displacement of 5mm.

Major Components

Propulsion

ROV uses motors and propellers to move itself through water. Such combination of motor and propellers are called thrusters. Thrusters with cowling on them and specially shaped blades to conform to the inside of the cowling are called Nozzles. [2]

Propellers have certain characteristics to them, which indicate what should be the right combination for the task and size of the ROV. These characteristics are as follows:

- Hub: the center section of the propeller.
- Blade Fillet: the radii defined by the transition of the blade faces into the hub.
- Pressure Face: the forward face of the propeller blade.
- Leading Edge: the blade edge adjacent to the forward end of the propeller hub.
- Trailing Edge: the blade edge adjacent to the back end of the propeller hub.
- Blade Tip: the blade edge on the outermost radius of the propeller.
- Emitter Holes: holes drilled into a channel near the leading edge. [2]

Two sets of numbers describe the size of the propeller to be used. These numbers specify the diameter and the pitch. The diameter will always be first and then the pitch.

- Diameter: distance from the center of the hub to the tip of the blade times two.
- Pitch: Pitch is defined as the theoretical forward movement of a propeller

during one revolution.

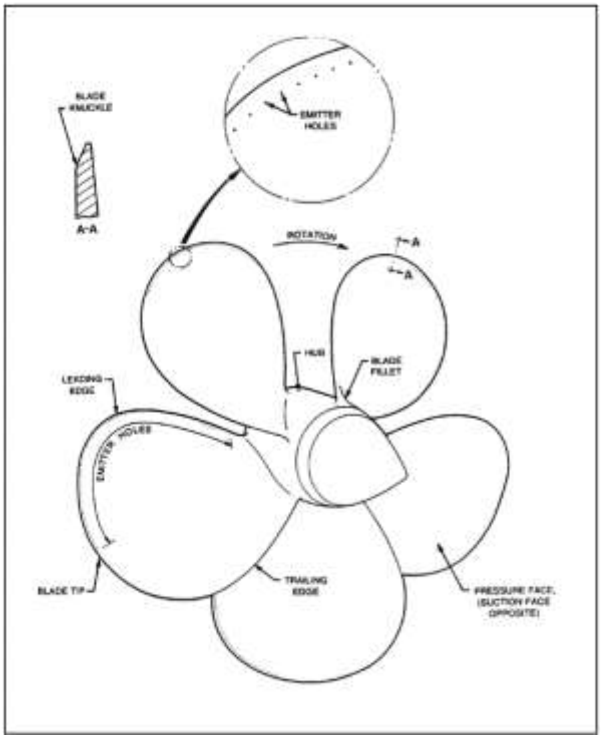

Figure 10. Propulsion Fan

- Cupping: Many of today's propellers incorporate a cup at the trailing edge of the propeller blade. Its purpose is to give it a better grip on the water.

- Rake: Rake is the degree that the blades slant forward or backwards in relation to the hub. Rake can affect the flow of water through the propeller. [2]

When choosing the motor, significant consideration was taken to ensure that the power is the output of the motor. Thus, when having a big motor it may draw sufficient current that could reduce performance but will be able to operate at low efficiency. In the other hand, when it is too small, the amount of thrust will be inadequate.

After choosing a motor, the proper propeller must be chosen for the task. When doing so, we must select the diameter of the propeller to be bigger than the motor diameter. The pitch of the blade will depend on the diameter and the rotational speed of the motor in RPMs. The width of the blade determines the amount of water it pushes, thus lighter or thinner blades are used for higher speed applications. [2] Even though these characteristics will help us determine which combination will be the most adequate for our scenario, the final combination will be chosen during experimentation.

After doing some research on the appropriate combination of propeller and motor, two thrusters were chosen that will accommodate the necessities of the ROV. These thrusters will be listed below. Thruster 1 was chosen due to its low current necessity to work underwater since our speed controllers were rated at 30 amps max and still offering enough rpms.

Thruster 1: Brushless Motor with EDF Ducted Fan Unit

- Cost: ($13.71)
- Underwater Current: 9 amps
- 1000 kv

Figure 11. 1000kv Brushless Motor with EDF Ducted Fan Unit

Thruster 2: EDF65 fan with Motor Assembled

- Cost: ($17.99)
- Underwater Current: 17 amps
- 2730 kv

Figure 12. EDF65 Fan with 2730kv Motor Assembled

Camera

The main objective for the camera is to operate at low voltage, with a high resolution, and low Lux light sensitivity rating. The lower the Lux rating, the better the camera can function in low-light situations. Since the ROV will be descending to depths of about 80 feet, the light will definitely be a factor. The ROV has built in lights, but the lower Lux rating cameras will benefit from this the most. The three cameras that were researched are listed below. The GoPro Hero2 was chosen because it has the best resolution and a rechargeable battery that can allow us to eliminate power consumption from the onboard batteries that will be used to power the thrusters to maneuver the ROV.

GeoVision CAMCCR25 camera module

Advantages:

- Cost ($26.95)
- Vivid color video at 380 resolution

Disadvantages:

- 2.0 Lux sensitivity rating

Sony SN555 Color Camera

Advantages:

- Light-weight aluminum casing for camera protection
- .1 Lux sensitivity rating
- High resolution

Disadvantages:

- Must provide a clean 12V power source because it only has a 10% tolerance
- Cost ($99.95)

GoPro Hero 2 camera

Advantages:

- Can provide 1080P recording
- 1100 mAh rechargeable battery to make it a stand-alone system.
- 170 degrees lens view angle, for wide screen footage.

Disadvantages:

- Cost ($299.99)

Figure 13. Sony SN555

Figure 14. GeoVision CAMCCR25

Figure 15. GoPro Hero 2

Display Screen

The sole purpose for our display screen is to show a live feed from the inboard camera located at the front of the vessel. This feed is obtained through the CAT3 Tether and a composite to RCA Adaptor. The main concern with the screen would be portability and affordability. Three screens were chosen for comparison, among the three the Axion 7" LCD TV AXN-8701 was chosen because it offered the features needed to be compatible with the camera onboard the ROV. It was also the most affordable one out of the other options available.

Figure 16. Aputure VS-1 7" Broadcasting Monitor ($175)

Figure 17. Everfocus Electronics EN220 6" Monitor ($209)

Figure 18. Axion 7" Widescreen LCD TV ($120)

Robotic Gripper

The main objective behind creating the ROV is so it would complete the four tasks given by the MATE Competition Specs. In order to complete all the tasks the ROV needed a way to pick up and handle the various objects that need to be moved while competing. Generally, a one arm set-up is used by most of the other robots competing because it proves to be cheaper, but to keep stability of the object being handled Aquabot was equipped with two robotic grippers that are controlled separately to maximize the grip on the object.

Figure 19. Robotic Gripper

The cost of this design would be higher because it would require double the amount of components, but it would be of great advantage to have during the competition since there is a time limit to complete all tasks.

Remote Controller

The ROV has multiple functions that allow it to move fluently and to manipulate both robotic grippers. In order for it to achieve all the functionalities successfully, a total of six operations must be able to be controlled by the user at any given time. The Futaba Skysport 6 channel controller was chosen since it would permit the regulations of all four motors separately and also controls the robotic grippers depending on when they were to be used.

Figure 20. Futaba Skysport 6 Channel Controller

It was important for all motors to not activate at the same time since the ROV had to turn about its axis, move forward or backwards without deviating sideways and surface or descend with minimum complications. The separate nobs of the Futaba Skysport would allow controlling the amount of grip each robotic arm would apply when trying to grasp objects.

Structural Design

Following the conclusion drawn by our Material Analysis above, PVC Schedule 40 was chosen to house the electrical components of the ROV. Another PVC pipe of a different diameter and schedule was selected in order to recreate the proposed design, which was modeled in Solid Works.

Figure 21. PVC Pipe Initial Layout

The smaller PVC pipes were used to place the motors in them, this would protect from external damage. With the initial layout in place, the team started the process of making the ROV rigid. At this stage, the implementation of fiberglass and polyester resin was used.

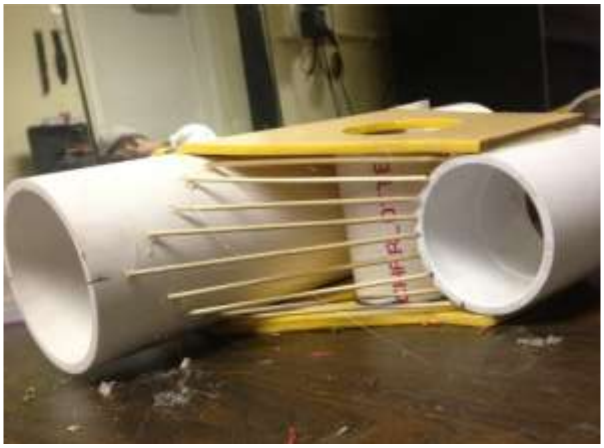

Figure 22. Placement of wooden dowels to give desired shape

Figure 23. Application of Fiberglass and Polyester Resin

The pressure analysis was only done for the single large PVC Schedule 40 Pipe in the middle because it would be the only part of the ROV subjected to pressure under water. All the other surfaces are open, so water may flow inside it. This would eliminate any hydrostatic pressure acting on the remaining parts.

Figure 24. Cured Fiberglass and Polyester Resin

Once the fiberglass and polyester resin hardened, it was sanded and the whole ROV was painted with marine gel-coat which is normally used in the fabrication of boats. Once the gel-coat dried, the acrylic dome and motors were mounted. The end product was perfectly symmetrical body with an airtight sealed pressure vessel in the center for the storage of components.

Figure 25. Final Structural Design

Testing

The competition requires stability and very precise maneuvering. The testing involved leaving the ROV underwater for approximately two hours to ensure that there was no water leakage. In addition, the controls were tested as well to make sure the vessel was able to maintain a position, as well as submerge and emerge without any problems. The ROV surpassed all expectations, and was able to turn on its axis without any issues.

Figure 26. ROV During Testing

These two pictures were taken while testing its ability to submerge and emerge on its own. As it's shown the vessel maintains stability. Proof of our testing will be available in video format as well. The time spent testing the maneuverability was roughly ten minutes underwater. Everything remained operational throughout testing deeming the operation successful.

Cost Analysis

Estimated Cost Analysis			
Product	**Quantity**	**Cost ($)**	**Total cost ($)**
6" Diameter Sch. 40 PVC pipe by ft.	10	4.24	42.4
Camera dome housing	1	75.6	75.6
2000 GPH bilge pump	2	154.34	308.68
1500 GPH bilge pump	2	100.56	201.12
Fiberglass resin (gallon)	1	19.99	19.99
Fiberglass sheets (square yard)	1	12.79	12.79
Sony SN555 color camera	1	99.95	99.95
Cat5 cable (50' tether)	1	59.96	59.96
			820.49

Table 3. Estimated Cost Analysis

Part	Quantity	Cost	Total Cost
Turnigy 5000mAh 3S Lipo Battery Pack	2	$26.31	$52.62
Lipo Battery Charger/ discharger	1	$27.00	$27.00
4 mm gold connectors (10 pairs)	4	$3.09	$12.36
EDF Ducted Fan Unit 5Blade 2.5inch 64mm	4	$7.44	$29.76
1000kv Brushless Motor	5	$9.69	$48.45
HobbyKing Brushless Car ESC 30A w/ Reverse	5	$15.55	$77.75
GoPro Hero2 camera	1	$299.99	$299.99
200' CAT3 tether cable	1	$19.99	$19.99
Portable LCD monitor	1	$49.99	$49.99
Video baluns (6 pairs)	1	$15.66	$15.66
BNC female to RCA female adaptor	2	$2.51	$5.02
GoPro composite video cable	1	$4.50	$4.50
Sea dog bus bar terminal	2	$11.56	$23.12
Clear acrylic 4.5" dome housing	1	$35.54	$35.54
Marine starboard sheet (24" by 24")	1	$19.99	$19.99
PVC sch40 4" threaded cap	1	$6.74	$6.74
PVC sch40 4" pipe (48" length)	1	$5.72	$5.72
robotic gripper assembly	2	$26.43	$52.86
6 channel transmitter/ receiver	1	$99.99	$99.99
			$887.05

Table 4. Actual Cost Analysis

Project Management

Timeline

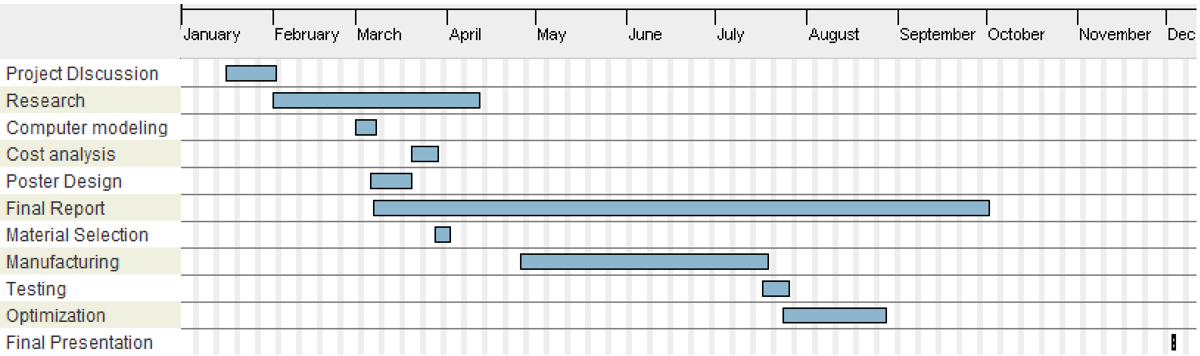

Table 5. Timeline for Entire Project

Division of Task

Breakdown of Tasks and Hours Spent		
Task	**Team member(s)**	**Hours spent**
Camera	Gabriel	8
Camera dome housing	Gabriel	6
Propulsion	Sahivy	16
Buoyancy	Gabriel	12
Claw(s)	Sahivy	29
Proposed Design	All	70
Wiring / controller	Ashley	25
Video display	Ashley	14
Simulation	Ashley	10
Testing and Analysis	All	30
Optimization	Gabriel	20
		240

Table 6. Breakdown of Tasks and Hours Spent

Conclusion

For the purpose of this project, a relationship between buoyancy, materials, propulsion, and size was determined. In early discussion, there was some consideration of a neutrally buoyant ROV compared to a variable ballast tank. The fact that a neutrally buoyant ROV can be directed in all axes with the proper placement of thrusters made this option more appealing and cost effective. A variable ballast tank would also hinder performance because it would be another variable to control while attempting to complete the competition tasks at hand. The ROV proved to be capable of completing all task within a timely manner, and team Aquabot feels confident about competing in the upcoming MATE competition.

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