EML 4551 Senior Design Project

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REQUIREMENT FOR THE DEGREE OF
BACHELOR OF SCIENCE
IN
MECHANICAL ENGINEERING

Remotely Operated Underwater Vehicle (ROV)

25% Report

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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 intends to recreate such 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 is currently researching design criteria and material selection. We are taking the various requirements of the competition 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 would like to be the first to take on the challenge and create a working prototype by fall 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 up bringing 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

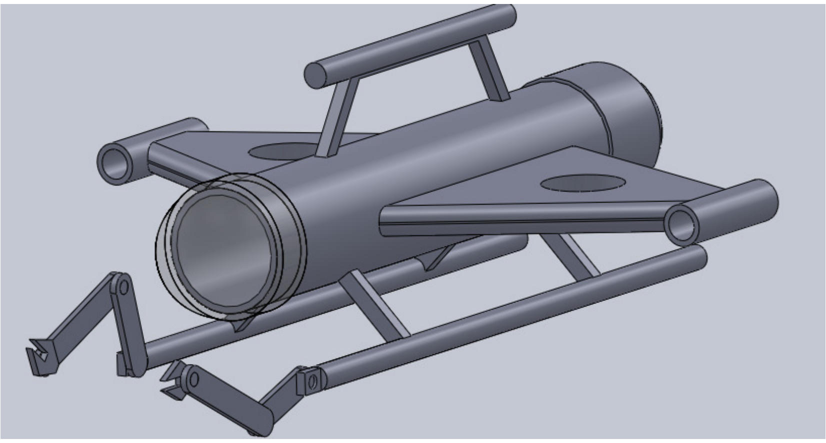

Figure 1. Design Alternative 1 Model

The first design being 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 has not been chosen yet, but there are a few materials that will be considered. The first one would be aluminum. Although aluminum is not relatively expensive, machining all the parts would be. The other material would be PVC. As of now this material is more 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

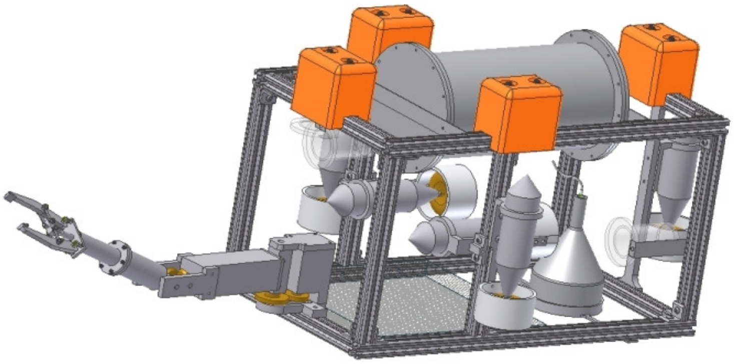

Figure 2. Design Alternative 2 Model

The second alternative of the design would be 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 being 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

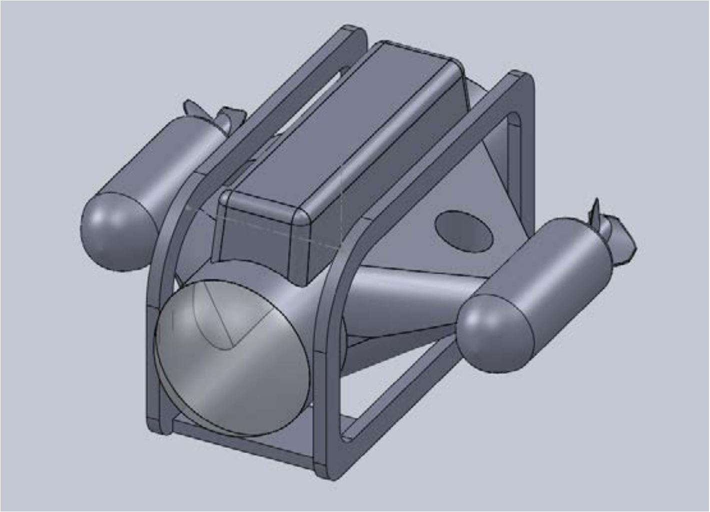

Figure 3. Proposed Design Model

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.

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.

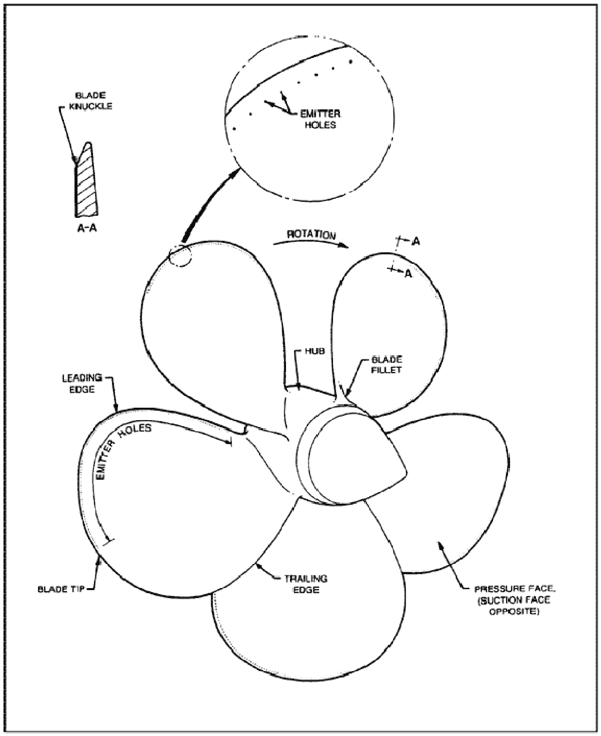

Figure 2. Propulsion Fan [2]

- 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 a motor, significant consideration must be 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.

Camera

The camera for the ROV has not been chosen, but there are several candidates listed below with their individual advantages and disadvantages. The main objective for the camera is to operate at 12 volts, 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 will have built in lights, but the lower Lux rating cameras will benefit from this the most.

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)

Figure 3. Sony SN555

Figure 4. Geovision CAMCCR25

Project Management

Timeline

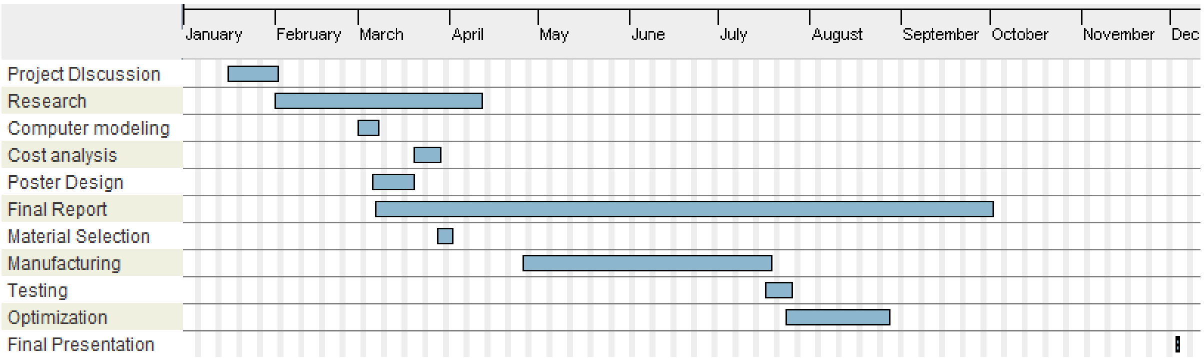

Table 1. Timeline for Entire Project

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 2. Breakdown of tasks and hours spent

Cost Analysis

<table>
<tr><th colspan="4">Cost Analysis</th></tr>
<tr><th>Product</th><th>Quantity</th><th>Cost ($)</th><th>Total cost ($)</th></tr>
<tr><td>6" Diameter Sch 40 PVC pipe by ft.</td><td>10</td><td>4.24</td><td>42.4</td></tr>
<tr><td>Camera dome housing</td><td>1</td><td>75.6</td><td>75.6</td></tr>
<tr><td>2000 GPH bilge pump</td><td>2</td><td>154.34</td><td>308.68</td></tr>
<tr><td>1500 GPH bilge pump</td><td>2</td><td>100.56</td><td>201.12</td></tr>
<tr><td>Fiberglass resin (gallon)</td><td>1</td><td>19.99</td><td>19.99</td></tr>
<tr><td>Fiberglass sheets (square yard)</td><td>1</td><td>12.79</td><td>12.79</td></tr>
<tr><td>Sony SN555 color camera</td><td>1</td><td>99.95</td><td>99.95</td></tr>
<tr><td>Cat5 cable (50' tether)</td><td>1</td><td>59.96</td><td>59.96</td></tr>
<tr><td></td><td></td><td></td><td>820.49</td></tr>
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Table 3. Cost Analysis

Conclusion

For the purpose of this project, a relationship between buoyancy, materials, propulsion, and size needs to be determined. There is currently 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 currently makes 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.

References

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2. Eastern Edge Robotics. "*ROV PROGRAM*". December 2010. http://www.marinetech.org/files/marine/files/MIROV2MANUAL.pdf

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