Design and Manufacturing of Remotely Operated Vehicle

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Abstract – The objective of the paper is to design and fabricate such a robot, which will survey and inspect shallow lakes. The Remote Operated Vehicle (ROV) described in the following paper consists of acquisition of data such as videos, images, temperatures, pressures, etc. Remotely operated underwater vehicles which are also known as ROVs are a type of underwater robot vehicle which is widely used in the offshore industry or other applications. The main purpose of this type of tethered underwater mobile robots are to supersede human to work at hard-to-access or jeopardizing underwater region to do certain specific tasks like to survey a site, search for an item or person that has tremendous value. These robots are tethered by a series of wires that send signals between the operator and the ROV. The ROV is equipped with a video camera, propulsion system, and lights. Other equipments can be added depending on the application requirement. The design of ROV which we have conceptualize, is handy and can be powered by 12V DC power which can be easily available at remote location.

Key Words: ROV, AUV, UUV, fabrication, acquisition

1. INTRODUCTION

What is Remotely Operated Underwater Vehicle (ROV)

"ROV" stands for remotely operated vehicle; ROVs are unoccupied, highly maneuverable underwater robots that can be used to explore ocean depths while being operated by someone at the water surface.

Remotely operated vehicles, or ROVs, allow us to explore the ocean without actually being in the ocean. The unoccupied vehicle is similar to a robot, which is fitted out with sensors and sampling tools to collect various types of data. A network of cables is utilized to establish a connection between the operator and the remotely operated vehicle, which would enable the proper movement of the ROV. An underwater ROV is well-equipped with modern technology and consists of a lighting system and a video camera, to record a better sub aquatic panorama and contribute to geology education and sea life learning. These underwater robots are controlled by a person typically on a surface vessel, using a joystick in a similar way that you would play a video game. A group of cables, or tether, connects the ROV to the ship, sending electrical signals back and forth between the operator and the vehicle.

Most ROVs are equipped with at least a still camera, video camera, and lights, meaning that they can transmit images and video back to the ship. Additional equipment, such as a manipulator or cutting arm, water samplers, and instruments that measure parameters like water clarity and temperature, may also be added to vehicles to allow for sample collection.

2. PROBLEM IDENTIFICATION

In many active areas marine engineering there is a need to use unmanned underwater robotic vehicles (UUV's) with improved ability and increasingly autonomous or independent behavior in order to lower cost and increase safety and reliability of works. UUV's can be classified into two main categories which are Remotely Operated Underwater Vehicles (ROV's) and Autonomous Underwater Vehicles (AUV's). In early days there were no means to do marine exploration, oceanic cartography and it was difficult to do these tasks manually, since humans are not as versatile as machines, there is a possibility that there may be inaccuracies. Therefore, it is highly desirable to design and fabricate a ROV for underwater exploration.

3. OBJECTIVES OFPROJECT

The basic objective of this project is to reduce the human effort and to do most of the exploration automated which will reduce inaccuracy. Besides this, there are following objectives of project work:

1. The main use of this ROV is for the survey of swimming pool, water tank, rivers, lakes etc.
2. To reduce manpower required for underwater investigation.
3. Capturing high resolution images of underwater.
4. Diving into unknown water body to explore human accessibility.

4. METHODOLOGY

4.1Design process of a remotely operated vehicle

The design process of a remotely operated vehicle (ROV) may be divided into three phases, shown in Fig. 1, as a design process of any other underwater vehicle system

The pre-design phase, in which user of underwater system describes what task should be performed underwater. The design phase, in which designer realizes expectations of the user of the system taking into account technological constrains.

The post-design phase, when manufacturing, tests, and operation are realized. In this stage changes in the project with regard to tests results are introduced as well, giving an input to the future designs.

1. Pre-design phase

In the pre-design phase of the design process user or owner of a vehicle describes the underwater mission to be performed. Mission may be described additionally by a tasks which have to be performed, i.e. inspection, survey, sampling, monitoring, maintenance, search, rescue, etc. Specific underwater mission requirements for the vehicle have to be also given such as land-base or ship-base locations, task-site locations, work depth, description of work objects.

2. Design phases

The design process is composed of four design phases: conception, preliminary design, technical design and manufacturing design.

In the conception phase there is considered how to accomplish in the best way what the potential user wants to do underwater. The following problems have to be described in this stage:

1. System capabilities basing on mission requirements;
2. Determination of the principal characteristics;
3. Estimation of building and operating costs of the ROV system;
4. Identification of missions, which optimally meet design assumptions.

In the preliminary design phase major characteristics and cost estimations of the ROV system have to be defined taking into consideration optimization criteria. In the technical design phase contract plans and material specification are produced. There are also described tests and trials which must be performed. The manufacturing design phase consists of many detailed steps in which the systems of ROV are constructed and manufacturing procedure of all parts is described. This stage of the design requires the great amount of work.

3. Post-design phase

The post-design phase contains the following activities: manufacturing process, tests and alterations and operation. All these activities significantly influence the future design of the new built ROVs.

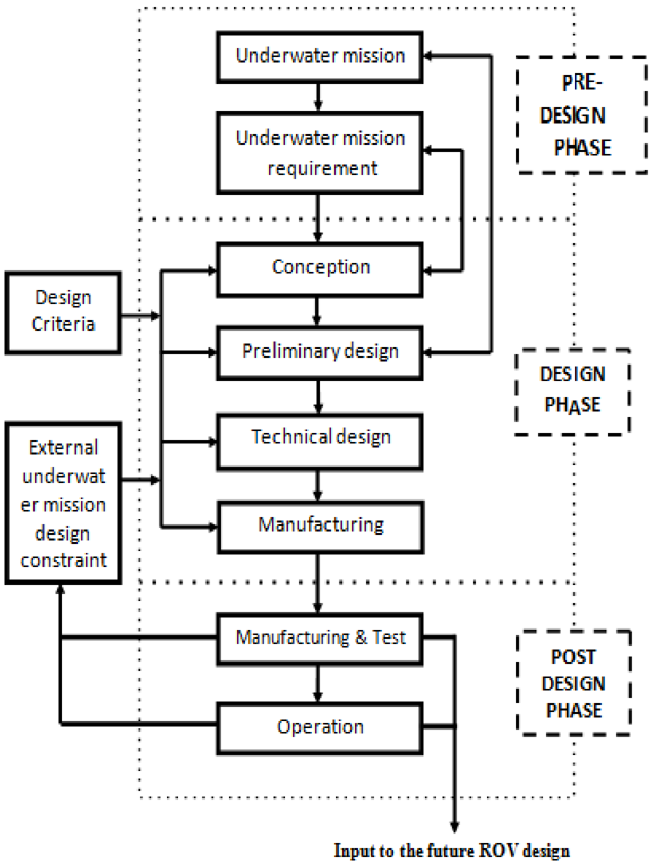

Fig -1: Methodology

4. CONSTRUCTIONAL DETAILS

4.1 Construction

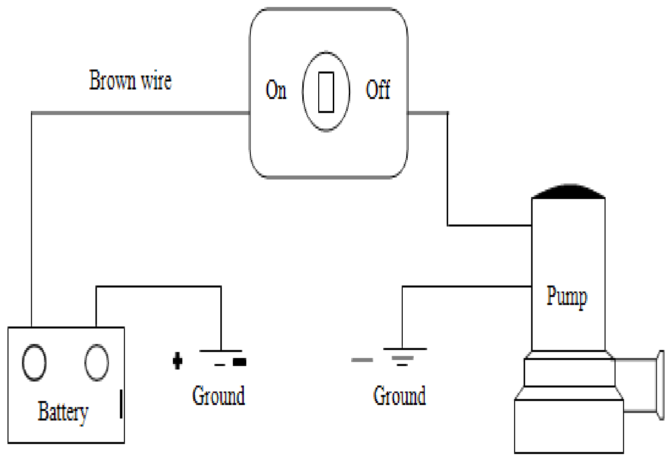

Fig -2: Layout of ROV

The body of this ROV is made up of Polyvinyl Chloride (PVC) pipe which are used for water piping at homes. On the either side of frame there are two bilge pumps attached such as one is on left and one is on right side (as shown in Fig 2). One bilge pump is located at the centre. These bilge pumps are controlled by simple ON-OFF switches. A Waterproof camera is attached on the front of the structure. The purpose of this camera is to record and display the video on the laptop. Also led lights are attached with the camera so that the camera can work clearly under dark water.

This three bilge pumps, camera, led lights are connected by using wire with the remote and battery. The output of camera is given to the laptop by using a specific software which was bought with the camera. The camera used is Endoscope camera which is used for pipe inspection.

The frame of PVC pipes is attached with the UPVC solvent cement which is used for fitting and plumbing purpose. The floaters are attached at the top of the frame andsome specific amount of weight are added at the bottom of the frame. The purpose of doing this is to balance the ROV perfectly underwater.

4.2 Working of ROV

The working principle of this ROV is to give thrust to an object underwater by using discharged water from pump. As water get discharged from pump it gives thrust to an object in its opposite direction. It is generally based on Newton's third law of motion. In this ROV the movement is done by using pumps. For taking left turn the motor which is on right side is started and for taking right turn left motor should be started. To take the ROV downward the motor at the center should started. And for upward motion the ROV automatically lifts up because of UPVC pipes, air entrapped in pipes and polyethylene sheets. The position of ROV can be seen by using display of camera.

4.3 List of Components

Table -1: Component Required for ROV

Sr. no.	Name of component	Description (size/dimension)	Qty
1	Bilge pump	110 GPH, 12V, 3A	3
2	Endoscope camera	720 pixel	1
3	LED light	-	1
4	PVC water pipes	Dia. 3/4inch, length 11 feet	-
5	PVC pipe Elbows	3/4 inch	8
6	PVC pipe Tee	3/4 inch	6
7	PVC Electric Conduit	Dia. ½ inch, 1m	-
8	PVC Conduit Elbow	½ inch	8
9	PVC Conduit Tee	½ inch	4
10	Electric wire	15 meter	1
11.	ON-OFF switches	-	4
12.	Floater	-	2

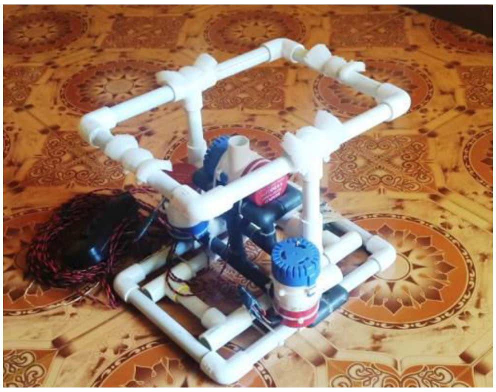

Fig -3: Image of Fabricated ROV

4.4 Technical Speciation's

4.4.1. Bilge Pump:

- Voltage required: 12V
- Current required: 3 Amp.
- Discharge of water through pump:110GPH
- Weight of the pump is 0.91Kg.

4.4.2. Camera:

- 720P/30fps
- USB Endoscope waterproof camera
- Inbuilt 6 LED
- 5m USB wire

4.4.3. 4.5.3. UPVC Pipes

Total 11 feet pipe is required to make ROV's frame

- Pipe is of 3/4 inch diameter.

4.4.4. Electronic Switches and Wire

- Total 4 only on-off type switches are required.
- For all connections total 15m wire is required.

4.4.5. 4.5.5. Battery:

- For electric supply two batteries of 12V and 5Amp are required.

5. MECHANICAL DESIGN CONSIDERATIONS

5.1. Design of a submersible

ROV The design of a submersible ROV necessitates a detailed consideration of design parameters and operational characteristics. The generic design process consists of the following stages:

- Definition of problem statement

- Identification of parameters
- Selection of material
- Determination of forces
- Design

The operational factors aimed for are: low cost, ease of control, portability and effective survey capabilities.

5.2 Definition of problem statement

The problem statement to be dealt with is the surveying of lakes for scientific as well as ecological purposes. It comprised the measurements of temperatures and pressures in various regions underwater and the visual inspection of lake beds along with detection and identification of foreign objects.

5.3. Identification of parameters

The operating conditions for the ROV are found to be: temperatures between 3 °C and 50 °C, working depth of 0 to 50 meters, translucent water with a pH greater than 6 and less than 8, under any type of lighting.

5.4. Selection of material

Keeping in mind the low-cost requirements and the operating environmental conditions, PVC pipe is use for the construction of the hull. The properties of PVC pipe are known to be its considerable weight reduction, good chemical and physical properties such as corrosion resistance, stiffness, shock absorption and neutral chemical behavior.

5.5. Determination of forces

When the ROV is submerged, the magnitude of forces acting on it changes drastically. These changes occur due to change in pressure of water caused by variation in depth. The relation can be obtained using the equation

$$P=\gamma h \qquad \text{........ (1)}$$

Where:

p = Pressure change [Pa]

γ=specific weight of the liquid [N/m3]

h = Elevation change [m] Substituting the values in equation

The specific weight of the water is 9805 N/m3 (at 15°C) and a depth of 50m.

A pressure exerted by water column of 0.4905MPa is obtained.

5.6 Pressures on a tube submerged in a fluid

The net pressure Pr equals to the difference between atmospheric pressure inside the cylinder and the pressure exerted on the cylinder by the surrounding water, as per equation (2). Substituting the value of pressure exerted by water at a maximum depth (50 m) and the value of internal pressure of the ROV (atmospheric pressure 101,325 Pa) in equation (2), the net pressure of 0.49MPa was obtained to which the structure is subjected to.

$$Pr = Pwater(abs) - Patm \qquad \text{..........(2)}$$

Where

Pr = Net Pressure [Pa]

Pwater(abs) = Water pressure at 50m [Pa]

Patm = Atmospheric pressure [Pa]

5.7 Critical pressure

The critical pressure of a material refers to the pressure it can withstand before failure. The value is found by using equation (3).

$$Pcr = \frac{2E}{1-\mu^2}\left(\frac{e}{D-e}\right)^3 \qquad \text{.......(3)}$$

Where

Pcr = Critical pressure (failure condition) [Pa]

E = Modulus of elasticity of the material [GPa]

e = Pipe thickness [m]

D = External diameter of the pipe [m]

μ = Poisson's ratio

Substituting the values in equation (3), elasticity for PVC as 2.89 GPa, the Poisson's ratio as 0.410, the thickness of the pipe by 0.0012 and the outside diameter of the pipe as 0.01905m, a critical pressure of 2.109 MPa is obtained. This was greater than the net pressure acting on the ROV and indicated that the hull would be safe under the working conditions.

5.8 Design of Immersion System

When an object is immersed in a liquid, the liquid generates a force that tends to push the object towards the surface, known as the buoyant force B, given by the equation (4).

$$B=\rho g V \qquad \text{...........(4)}$$

Where,
B = Buoyant force [N]

ρ= Fluid density [kg/m3]

g = Gravitational acceleration [m/s2]

V = Volume of displaced fluid [m3]

The immersion system facilitates the vertical motion of the ROV in the water. Substituting in (4), density of water is 1000 kg/m3, gravitational acceleration of 9.81 m/s2 and the volume of displaced fluid as **0.001592 m3**, the force was determined to be **15.6172 N**.

Based on the above result, the force required for immersion and vertically downward motion of the ROV was obtained. To calculate the power required by the pump overcome this buoyant force, using a pump impeller of diameter **0.04 m** and radius of **0.02m**, rotating at **780 RPM**, The linear velocity of the propeller is found to be **1.63 m/s**, whereas the force being exerted by the motor was equal to **15.6172 N**. The required power of the motor is then calculated using equation (5).

$$P=Fv \qquad \text{........(5)}$$

Where

P = Power [W]

F = Force [N]

v = Linear velocity [m/s]

Using above equation, P was found to be **25.5 W.** A commercial motor of power **36 W** is chosen.

6. FUTURE DEVELOPMENT & SCOPE:

In future various improvements can be done in this ROV. Like we can attach camera of very high resolution on each side of ROV so that controlling of ROV can be done very easier. Also we can add the ultraviolet distance measuring sensor in this ROV so that we can check the position of ROV directly. Also we can add mechanical arms and various cleaning instruments to this ROV so that the manpower required for cleaning of water tank is reduced. Also by adding special type of mechanical arms we can use ROV for grabbing animals like snakes which come in swimming pool, water tanks etc.

By improving these techniques in future this ROV can be very useful. This ROV can be used for underwater investigation at every time. And there is no need for diving into unknown water body.

CONCLUSIONS

We designed, assembled and finally construct a ROV and tested its surveillance system under the water. Using this we were able to recognize object under water almost perfectly with the assistance of flashlight. Our ROV's main limitation is its dependence on wire length. To get rid of this constrain our ROV can be updated into AUV's (Automated Underwater Vehicle). Turning the ROV into AUV might increase the cost thus the challenge here will be to keep the cost minimum and develop further.

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