IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 16, Issue 2 Ser. III (Mar. - Apr. 2019), PP 54-61
www.iosrjournals.org

Fabrication and Study of an Unmanned Under Water Vehicle

Mohammad Harun-Or-Rashid, Diprajit Biswas
Department of Mechanical and Production Engineering, Ahsanullah University of Science and Technology, Dhaka, Bangladesh
Corresponding Author: Mohammad Harun-Or-Rashid

Abstract: *Construction as well as performance of an unmanned underwater vehicle is discussed in this paper. The unmanned underwater vehicle is developed to exploit the underwater environment. The body is 0.56 m long and 0.254 m diameter torpedo shaped. Different components of the vehicle are made by aluminum to reduce the weight. Four submersible pumps are used in two ballast tanks for water intake and exert through two solenoid valves. One propeller is used and a rudder is set behind the propeller. The thrust force generated by the propeller gives forward motion to the vehicle. In the present research, an UUV was developed and experiment was conducted. During experiment, major problems were water leakage and system stability. Very little amount of water enters into the pressure hull through different joints. To avoid this situation, glue is used in different joints and tape is wrapped at the outer surface of the body. In this study it is found that this small flat form can be used in various purposes like underwater research, military and civil works.*

Keywords: *Ballast Tank, Drag, Submarine, Unmanned Underwater Vehicle, Wireless Communication*

Date of Submission: 27-03-2019 Date of acceptance: 11-04-2019

I. Introduction

Unmanned underwater vehicles (UUV) are remotely operated vehicle (ROV) that requires minimum intervention of human operator from a remote distance. ROVs are usually mobile, small in size and highly efficient in performing tasks with unreachable depths of the sea. These are used extensively in offshore industries due to their higher advantages over human carrying submarines. Submerged sea-mines and submarines can be identified with the UUV and secure the harbor.

The first conceptual design of submarine was made in 1578 [1]. The first UUV was constructed in the form of a self-propelled torpedo in 1868. The first autonomous underwater vehicle (AUV) was developed at the university of Washington in 1957 [2]. The U.S navy constructed UUV in 1958. Later on, around 1980 it became popular to the oil and gas industries [3]. UUVs become essential for underwater photography, 3D image reconstruction, deep-sea mapping and imaging for geo-studies and marine researches [4]. Since 1817 most of the UUVs were given the torpedo shape to reduce the drag [5]. Feijun Song et al. (2000) proposed a sliding mode fuzzy controller for controlling AUVs [6]. Nuno Abreu et al. (2010) describe the tracking of the AUV mission in real time [7].

Main objective of this was to develop an underwater vehicle and study the dynamic behavior of it. Due to advancement of technology ROV becomes smaller and lighter for better stability. Therefore, a small size torpedo shape UUV is made. In this research, the unmanned under water vehicle is designed; manufactured and proportional integral and derivative based control system is developed to control it.

II. Manufacture of the UUV

The UUV is designed by CAD software (SolidWorks). Final model of the UUV is presented in Fig. 1. The structure of the UUV is composed of five main parts: two ballast tanks, blunt shaped front part for weight balance, housing for the electric control system, wireless communication part and rear part supporting propeller, rudder. The UUV is 0.56 m in length and 0.254 m in nominal diameter. The length of two ballast tanks is 0.3 m.

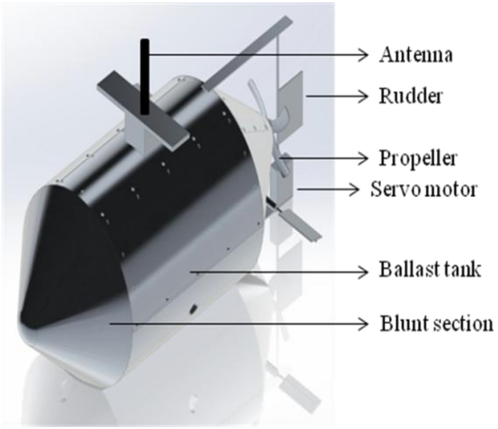

Fig. 1 3D model of the UUV

According to the SolidWorks design a wooden pattern is made. The wooden mould is shown in Fig. 2. Then the aluminum sheet is cut and put upon the mould and bent to get the shape. Finally, four individual sheets are welded together to get the front and rear blunt structure.

Fig. 2 Wooden mould

Then the main chamber (pressure hull) of the UUV is constructed. After that the top and side (left and right) covers are made. An antenna is attached with the top cover. Some holes on the frontal, rare and the sideways are cut for the control systems. The control systems are attached individually according to the weight balance ratio to their respective places in the submarine. By installing all the components like rudder, impeller, antenna final shape of the UUV formed. Fig. 3 shows the constructed underwater vehicle.

Fig. 3 Final setup of UUV (Manufactured)

The general purpose of constructing the unmanned underwater vehicle was to know the attitude of the vehicle. And another purpose was to explore the underwater environment. Finally, the unmanned underwater vehicle is constructed through different design phases. Technical specifications of the designed UUV are presented in Table 1.

Table 1: Technical Specifications of the UUV

Parameter	Value
Depth	0.5 m
Maximum speed	0.1383m/s
Maximum Drag	1.062881 N
Dimension	
Total Length	22 in
Length of main vessel	10 in
Length of front and rear part	5 in
Radius of Main vessel	5 in
Weight	
Designed body	10.94 kg
Actual body	13.520 kg
With water mass balance	20.250 kg (max.)
Volume	
Vehicle	17.69×10^{-3} m^3
Water inside ballast tank after mass balance	5.16×10^{-3} m^3
Air	12.53×10^{-3} m^3
Power System	
Voltage	12V
Current	6A
Power	210 Watt
Control System	Bluetooth control via Arduino mega
Propulsion System	Brushless DC motor

III. Different components of UUV

The microcontroller board is installed inside the pressure hull of the submarine. The electric circuit and the batteries operate the propeller, rudder, pumps and solenoid valves.

Four submersible pumps are used to suck and discharge water. A submersible pump is presented in Fig. 4. Head and flow rate of 12 volt DC submersible pumps are 0.3 m and 4 liters/min respectively. Two of them are used to suck water from outside to the two water chambers (ballast tank) when submarine is going to sink. On the other hand, another two are used to discharge water from water chambers to the outside during floating above water.

Fig. 4 Submersible pump

During experiment UUV was submerged in a pool. Solenoid valves are used to prevent the unwanted flow of water between UUV and the pool. A solenoid valve is shown in Fig. 5. When water is needed to take inside the vehicle then the valves are opened and submersible pumps work to pump water inside the ballast tanks. Also when the ballast tank water need to remove, solenoid valve is powered to open and the submersible pumps start to pump out the water from the ballast tanks which assist the vehicle to float above water. Two individual solenoid valves are used for two water vessels. Orifice size, valve type and pressure range of the solenoid valve are 8.5 mm, diaphragm and 0.2-0.8 MPa respectively.

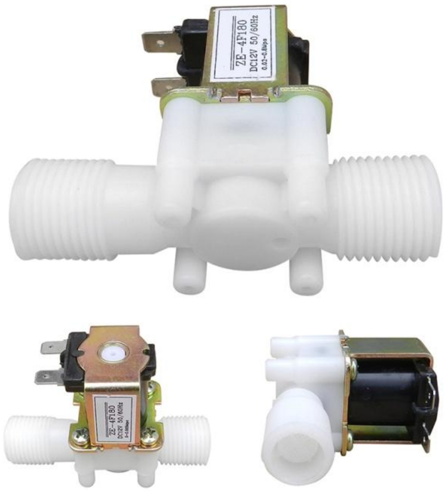

Fig. 5 Solenoid Valve

A high torque low RPM motor is used in this study because high torque motor is necessary for under water vehicle. A brushless motor and a propeller are presented in Fig. 6 and Fig. 7 respectively. This brushless DC motor is mounted on the rear side of the vehicle. The motor drives the propeller which results the forward motion of the vehicle. Shaft diameter, maximum current of motor are 3.17 mm and 20 A respectively.

Fig. 6 Brushless DC motor

Fig. 7 Propeller

In the present study, a servo motor is used to control the horizontal direction of the submarine. The Servo motor is attached with the rudder to give the vehicle a turning movement so that, it can change its direction. The stalling torque of the metal geared MG996R digital servo motor is 10 kg (Fig. 8). The rudder is placed after the propeller consequently the water directly hit the rudder blade. Therefore, the vehicle turns faster.

Fig. 8 Servo motor with rudder

Two Lithium-Polymer batteries (6000mA and 1100 mA) are used for power supply to the whole UUV (Fig. 9). Here, 6000mA 12 volt lithium polymer battery is used to support all the equipment like pumps, solenoid valves and propeller. On the other hand, the 8 volt 1100mA DC battery is used to power supply to the micro controller board and the servo motor. It is used to reduce pressure on the main battery which will supply power constantly to the propeller to give the vehicle forward motion.

(a) (b)

Fig. 9. Battery: **(a)** 6000mA and **(b)** 1100 mA Li-Po

The Arduino Mega 2560 microcontroller board is used in this study (Fig. 10). It has 54 digital input-output pins of which 15 PWM outputs, 16 analog inputs, universal asynchronous receivers/transmitters (UARTs), a 16 MHz crystal oscillator, a power jack, an in-circuit serial programming (ICSP) header, and a reset button. The Mega 2560 board is compatible with most shields. In this research, 16 pins are used to control the UUV.

An eight channel relay interface board (Fig. 11) of 5V is used in this study. It is able to control various appliances with large current. It can be controlled directly.

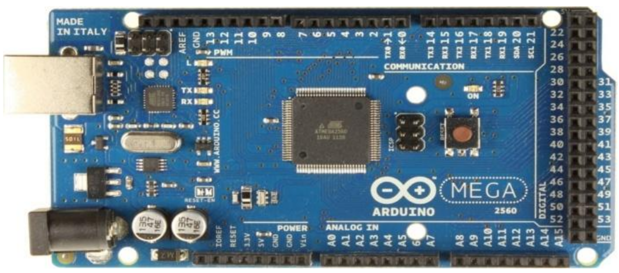

Fig. 10 Arduino Mega R3 2560

Fig. 11 Relay interface board

Fig. 12 Electric Speed Controller

An electronic speed controller (ESC) is used to control the speed of the brushless DC motor. An ESC is shown in Fig. 12. It helps to vary the revolution of the motor which facilitate to vary the speed of the vehicle. It also helps to speed up gradually to give the propeller a steady increase torque and consequently the forward thrust.

A Bluetooth device is shown in Fig. 13. HC05 serial port Bluetooth device works as a receiver of the signal. In the present study, submarine is controlled by a mobile phone. Bluetooth app is installed in the mobile phone. The signal is transmitted from a smart phone through Bluetooth technology. There are six pins of the Bluetooth device. Here, four wires are connected: two are for power to the device and another two are for receiving and transmitting data. After receiving the data from the Bluetooth device Arduino identify the command and does the task by sending the signal to the components that should be operated.

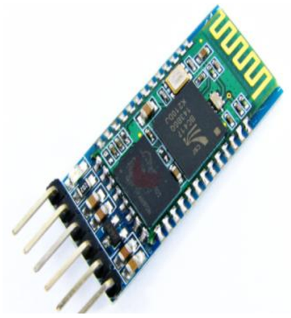

Fig. 13 HC05 serial port Bluetooth

A Veroboard is used for different wire connections. The submersible pumps and solenoid valves are connected through the relay interface board from where six channels are used for our purpose. The relay is controlled by the microcontroller board. The propeller motor is connected to the main battery through the ESC. All the signals come to the Arduino board through the Bluetooth device.

Connecting the battery with the Arduino Mega and relay we got the motion of the Submarine. Then Arduino Mega is connected with the smart phone via Bluetooth to operate the Submarine. Fig. 14 shows the electrical wiring of the control panel. A program is written and uploaded to the Arduino board. At first the submarine was drown underwater. To do so, first the solenoid valve was opened and the intake pumps were started to fill the blast tanks with water.

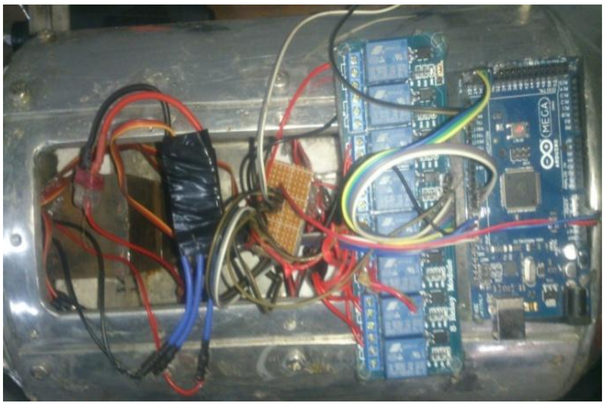

Fig. 14 Setup of control panel

After fill in the blast tank, the BLDC motor started to give the propulsion of the submarine. The motor transfers power to the propeller. Then the servo motors are used for operations if needed. The servo motors are attached to control the elevator and rudder. The elevator gives the submarine vertical movement and the rudder gives the submarine directional movement. If the submarine needs to come to the surface of water, then controller send signal to the submersible pumps to force the water out from the blast tanks. Thus the UUV starts to float in water.

IV. Governing Equations

Archimedes principle is quite useful to build the water vessels like ship and submarine. Here, Archimedes principle is followed and a UUV has been successfully designed and prototyped is built with low cost. Mass and volume of the UUV is 13.520 kg, and 1.769×10^{-2} m^3 respectively. Therefore, density of UUV is calculated by eq. (1).

$$D_{UUV} = M_{UUV} / V_{UUV} \qquad (1)$$

Then, the specific gravity of the UUV, is calculated by eq. (2).

$$SG_{UUV} = D_{UUV} / D_w \qquad (2)$$

The specific gravity of the UUV is 0.76427. Here, SG_{UUV} is less than 1. Hence, the UUV will float on water when the ballast tanks are empty. The drag force is calculated by eq. (3).

$$F_d = 0.5\times\rho\times v^2\times C_d\times A \qquad (3)$$

Here, C_d is the drag coefficient, ρ is the density of the fluid, v is the velocity of the submarine. The frontal area of the submarine (A) is 82×10^{-3} m^2. Here, for the blunt shape of the UUV, the coefficient of drag is 2.2.

V. Result and Discussion

The process of construction of an unmanned underwater vehicle is discussed in this study. Components of the UUV are selected based on availability and cost.

During the experiment, revolution of propeller at different speed of the UUV is measured. It is found that the efficiency is 73%. The run time to go a distance of 170 m for various propeller speeds is estimated. From that, velocity of the UUV is calculated. Fig. 15 shows the velocity the submarine at different speed of the propeller. From the graph is seen that, the velocity of the vehicle increase gradually with the increase of the propeller speed.

At different speed the vehicle faced different amount of drag force. For various speed of the vehicle, the drag is calculated. Fig. 16 shows the drag force versus velocity of the UUV. If velocity is increased then drag also increased.

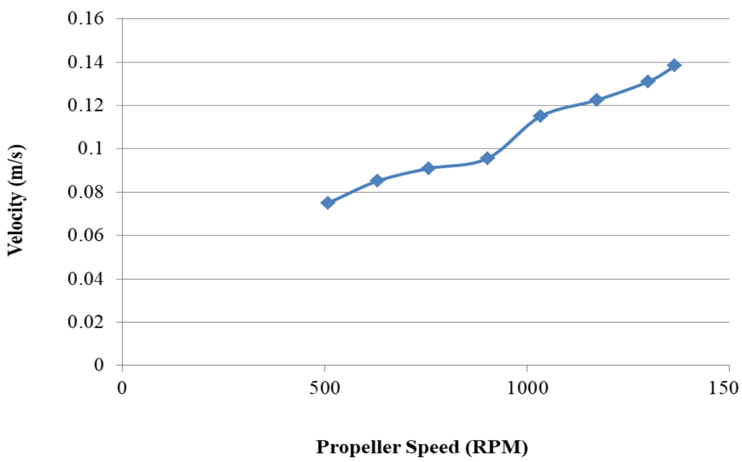

Fig. 15 Propeller speed versus velocity

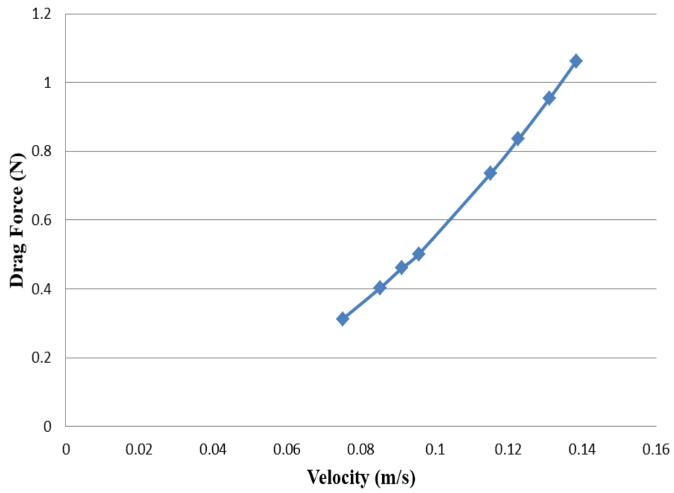

Fig. 16 Drag force versus velocity of UUV

VI. Conclusion

Objective of this research was to develop a prototype of an UUV with available facilities and to Fig. out its characteristics. For this UUV no fuel is required. The efficiency of the vehicle largely depends on the perfect transmission system, load, shape and the design of the propeller. There was leakage problem. Water leak was prevented by using gaskets, tape and gum. The biggest limitation of the setup: it is not perfectly water protected. The basic use of our unmanned underwater vehicle is to monitor the underwater environment. As it is operated from a distance without a living soul in the vehicle, therefore, the risk of the loss of human's life being decreased in the war and uneven situation. UUV can inspect the submerged pipelines those are used to transfer crude oil and communication cable. In future, camera, light, and different types of sensors can be fitted with the UUV for different applications.

Acknowledgements

Thanks to Ahsanullah University of Science and Technology, Dhaka, Bangladesh.

References

[1]. Augus Budiyono, Advances in Unmanned Underwater Vehicles Technologies: Modeling, Control and Guidance, Perspectives, *Indian Journal of Marine Sciences*, Vol. *38*, 2009, 282-295.

[2]. Sandeep Kumar, Sultan Mohammad, Suyog Bora, Mahender Singh, A Review Paper on: Autonomous Underwater Vehicle, *International Journal of Scientific & Engineering Research, 6(2)*, 2015.

[3]. W.H. Wang, X.Q. Chen, A. Marburg, J.G. Chase, C.E. Hann, Design of Low-Cost Unmanned Underwater Vehicle for Shallow Waters, *International Journal of Advanced Mechatronic Systems*, 2009.

[4]. Chris Roman, Oscar Pizarro, Ryan Eustice, Hanumant Singh, A New Autonomous Underwater Vehicle for Imaging Research, Deep Submergence Laboratory, Woods Hole Oceanographic Institution, 2000.

[5]. Robert W. Button, John Kamp, Thomas B. Curtin, James Dryden, A Survey of Missions for Unmanned Undersea Vehicle, RAND Corporation, *NATIONAL DEFENSE RESEARCH INSTITUTE*, 2009.

[6]. Feijun Song, Samuel M. Smith, Design of Sliding Mode Fuzzy Controllers for an Autonomous Underwater Vehicle without System Mode, *MTS/IEEE conference and exhibition*, Providence, RI, USA, 2000, 835-840.

[7]. Nuno Abreu et al., Automatic Interface for AUV Mission Planning and Supervision, *OCEANS MTS/IEEE conference*, Seattle, WA, USA, 2010.

[8]. Mohammad Harun-Or-Rashid et al., Design and Fabrication of an Unmanned Underwater Vehicle, *International Conference on Mechanical, Industrial and Energy Engineering*, Khulna, BANGLADESH, 2018.

[9]. Orhan K. Babaoglu, Designing an Automatic Control System for a Submarine, Naval Postgraduate School, Monterey, California, 1988.

[10]. Md. Al-Amin, Md. Hasanuzzaman, Nahin Bahar Chowdhury, S.M. Humayun Kobir, Fazle Rabbi, Design and Fabrication of a Submarine and Comparative Study with 6000m Driving Submersible Submarine, *International Journal of Novel Research in Engineering and Science, 1 (1),* 2014, 22-29.

Mohammad Harun-Or-Rashid "Fabrication and Study of An Unmanned Under Water Vehicle." IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) , vol. 16, no. 2, 2019, pp. 54-61.