DESIGN AND CONTROL OF AUTONOMOUS UNDERWATERVEHICLE USING VARIABLE BUOYANCY SYSTEM

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ABSTRACT;

The autonomous underwater vehicles are operated by power thrust to reach the desired depth. This system consumes more power or thrust and it is overcome by variable buoyancy system. In this project a feedback system is used by employing a control pressure sensor. With the help of this pressure sensor, the depth sensor is to be designed. The signal from the pressure sensor will be used to find the depth of the immersion of autonomous underwater vehicle from the top of the water surface. The signal from the pressure sensor is used to maintain the autonomous underwater vehicle at desired depth level. The sea level pressure is measured with help of pressure sensor. The output of the pressure sensor is an analog signal and is given to the ADC (analog to digital converter) port of microcontroller which takes decision on pumping sequence depending upon the input voltage (the digital value given to it)the microcontroller will control the driver unit to pump either in or out based on control signal. When the required depth level is reached the driver circuits takes some delay and automatically drives the pump out circuit to pump out the water till the preset value is reached. This sequence of pumping in and pumping out of the water will be controlled by the microcontroller for various digital input values.

Keywords - Buoyancy, Pressure sensor calibration, depth control.

I. INTRODUCTION;

Under water research and exploration gains more attentions for the various oceanresources. The importance are given to theresearch of underwater robot, which is regarded as the most useful tool in exploring the ocean. The underwater robot classified as AUV (Autonomous Underwater Vehicle), ROV (Remote Operation Vehicle) and so on according to the different functions, and at the same time, it is also classified by the different shapes, such as streamline shell, combined framework and spherical structure. Besidesthe requirements of motion dimension, speed range and special function, the basic functions are same for all kinds of the underwater robot. Navigation and motion control is an important aspect of underwater robots.

Various methods of navigations are possible such as propellers system,synthetic foams, and two tanks buoyantengine. Initially Propeller optimizationwas popular among aircraft researchers for long time ago. The propeller design is easy with availability of previous data anddesign. Once the experiment data is available, the performance for each propeller design can be predicted. However this data is not applicable forunderwater propeller design.

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This paper describes the design of the VBS and the control software operating in two modes as depth control mode and trim control mode. Simplicity of the design and the robustness are evidenced by the performance in both fresh and salt water. It provides practical insight into the operation of a VBS with an AUV and discuses actual operational

experience. The simulator is based on the concept of the vehicle as a collection of generic elements (masses, thrusters, hydroplanes, bodies, struts and so on) which may be assembled to form avehicle. To begin with the structure whichis built up on screen and a number of design options may be tested using thesimulator to gauge characteristics such as maneuverability and stability. Navigation sensors and autopilots are simulated, togauge how easily the vehicle may be controlled, and to what accuracy. The sensor models include error and finite update rates, so they tested the robustness of the control system in the presence of instrumental errors.

The proposed project differs in design and fabrication of an autonomous under water vehicle with closed loop control system. The vehicle is to be maintained at a desired depth without using fins and thrust. This model consists of a hydraulic pump, DC motor, Control valves, and a pressure intensifier. The system uses the hydraulic system to alternate the movement of water to the tank and pumps the water out of the tank. The variable buoyancy system is used to achieve desired depth which iscontinuously monitored with the help of pressure sensor whose output is given as feedback to the controller. The controller sends the control signals to the pumps and valves to maintain the required depth thereby making it as a closed loop system.

II. FUNCTIONAL DIAGRAM OF VBS;

The variable buoyancy system consist of various units such as ballast tank,hydraulic unit such as valves and pumps , controller, depth measuring unit and powersupply unit. The power unit gives various voltage levels to control units such as

valve control, pump control and feedback controller. The hydraulic circuit consists ofvarious solenoid operated valves and check valves are sequentially controlled bythe separate unit. The system operation depends on this hydraulic unit. The functional block diagram of VBS is shownbelow.

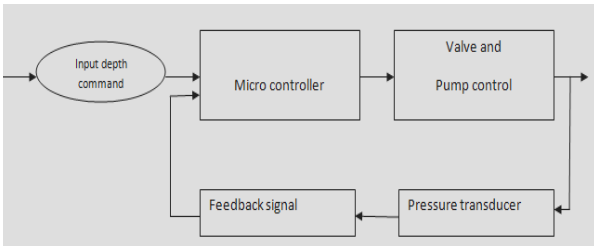

Fig 3.1 closed loop control

The pump flow rate is controlled by varying the dc motor speed. The ballast tank and sea water port is connected to thishydraulic unit. By controlling the hydraulic units and pump the sea waterenters into the ballast tank. Similarly wateris pumped out to the sea from the ballast tank. Due to this operation the system travels bottom and top of the water columnvice versa. The control module consists of batteries for power, display unit and input unit(depth

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command). The depth command signal from the external module is transmitted towards the vehicle using wire communication. This signal received by the microcontroller which transmits the control signals the valves and pump. Then pump starts to pumping water from the sea water to ballast tank. Then corresponding depth is sensed by the depth sensor and signal is transmitted towards the controller. Controller gives the corresponding feedback control to the valves and pump. This depth signal decides whether pump in or pump out. This process happen until maintain the commanded depth is reached.

III. VARIABLE BUOYANCY SYSTEM

The system operates two modes such as deep mode and surface mode. In the surface mode the systems center of buoyancy is equal to the center of gravity due to this balanced force the system floats in the water surface. In the deep mode operation the center of gravity is above the center of buoyancy. In this condition the system will moves towards the ground. The fig 3.1 shows the VBS arrangement

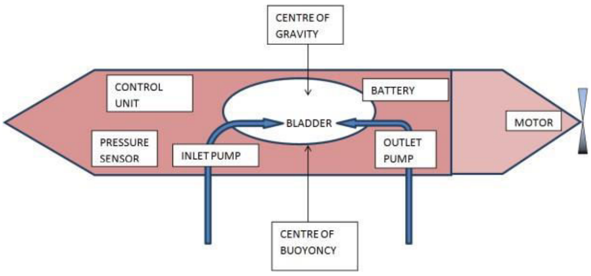

Fig 3.1 Model block diagram of AUV

The designed system is natural buoyant system to smoothly control the entire system, if we design more positive buoyant means that affect the entire control system, because the system reach very quickly to the bottom of the sea or surface. The center of gravity is depends on weight of system and center of buoyancy depends on ballast tank. The proposed design and control mainly focusing these two criteria to get perfect trim mode operation. When the ballast tank of vehicle loaded by a fluid, the weight of system increase and corresponding buoyant force reduce the vehicle starts to submerge in the water, if further adding or extracting the water fromthe ballast tank corresponding altitude will be reach the system.

Fig 3.2 VBS based AUV

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The fig 3.2 shows the VBS controller and its closed loop control. It performs the following operation

When the system reaches the commanded depth, the depth sensor gives continuous depth signal to the comparator and the comparators gives proportional error signal according to the depth. This error desires pump in and pump outprocess. The pumping processes depend on the vehicle corresponding depth of water column it desires pump in and pump out.

IV. HYDRAULIC UNIT FORBUOYANCY CONTROL

The hydraulic circuits are designed for the purpose of loading and unloading the ballast tanks. In this system the valves are solenoid operated that can be controlled from remote places. The important feature of this design is that a single pump does the operation of pump in and pump out by controlling the valves. In this circuit two 2/2 valves normally opened and two normally closed valves are used. The positive displacement , constant pump rate are used to calculate and control the flow rate, two check valves are used to allowthe fluid in only one direction.

A. Schematic diagram of Hydraulic circuit

The schematic diagram of the hydraulic circuit shown in fig 4.1, the circuit is designed for optimum number of components with D.C solenoid operated

valves and D.C diaphragm pump to pump the water at the rate of 1.8 LPM . In this application the pumps are combined with motor using highly insulated design for water proofing. The dc pump has a positive displacement with constant pumping rate

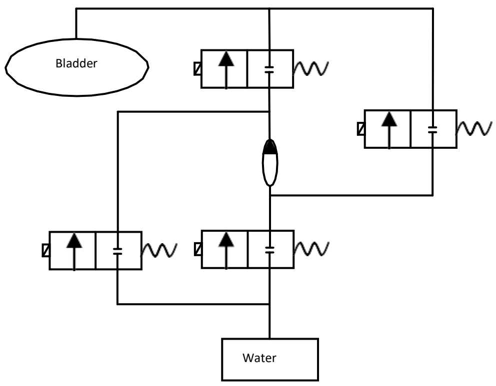

Fig 4.1 Hydraulic circuit

B. Pump in and pump out operation

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Fig 4.2 pump in operation

The fig 4.2 shows the single pump performs pump in and pump out operation by control the valves.

V. MODES OF OPERATION

The system operates in two modes named as depth control mode andnavigation mode.

A. Depth control mode

In the depth control mode, the command signal (depth) transmitted from the controller that helps in the control of valve and pump. During the depth mode pumps are starts to pumping and the valves are being ideal until reaches the require depth. The idle valve 1&2 normally opened and 3&4 normally closed.

B. Navigation mode

The main objective of this work is to maintain the system at standstill position. During this mode the pump iscontinuously switched between on and off. The valves are used to change the direction of pumping. In this mode both normally closed (N.C) & normally opened (N.O) valves operates simultaneously to get the require depth.

VI. PARTS DESIGN

The overall vehicle geometry is based on the key requirements of hovering and turning that should be independent of forward velocity. Typically an AUV design is similar to that of a torpedo, using a tail mounted thrusters to provide forward propulsion. The forces required for turning and diving are developed using control actions of buoyancy system. Hydro dynamically efficient hull is designed. It has nose, mid and tail part of hull which is explained below.This pressure hull must be weight- efficient and it must also contribute the

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low drag. Packaging must also beconsidered. Internal items must be accessible, maintainable, and arranged so that the payload operation is not compromised. Additionally, the internal distribution of the various subsystemsmust leave the vehicle in proper trim.

TABLE I
MASS OF INDIVIDUAL PARTS OF ROBOT

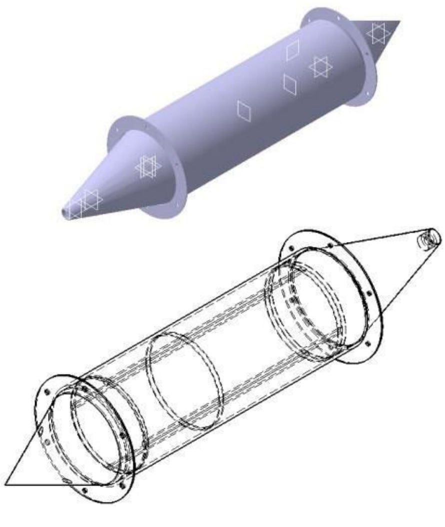
Part	Quantity	Mass(kg)
Motor	1	1.18
Pump	1	1.3
Solenoid valve	4	0.92
Connecting rods	6(0.3m)	3.6
Battery	3	4.8
Cone with propeller	1	2.2
Connecting tubes, fittings	-	1.2
Acrylic cylinder	1	1.5
Electronics board	-	0.45
Ballast tank	1	3.5
Dead Weight	2	3.35
Total		**24.00**

When an AUV is moving at constant speed, the thrust produced by the propeller is equal to the drag of the vehicle. So the propeller should be connected to tail part and nose part is designed as overcome the drag force.

A. Total Assembly

The hydrodynamic form of the AUV determines the propulsion energy required, as well as the stability and maneuverability at various operating speeds. A hull form may also impose limitations on vehicle access, launch and recovery, and maintenance for that the total assembly is designed as shown in Figure 6.1a&b.

Fig 6.1a&b Total Assembly



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The system has the following drawbacks: It has a significant design-time cost, it limits the amount of fin authority available for maneuvering, it incurs significant drag- induced energy penalties over a long mission, it limits slow speed operation, it limits the payload weight and placement which is significant in a AUV and it requires a trim/balance adjustment after every configuration change to ensure that the preset limits, it is important to notes that a variable buoyancy system (VBS). While this method has advantages, if it is have the high-fidelity hydrodynamic model and specific components with the specified ratings, if it use these two requirement will be able to specified ratings, if it use these two requirement willbe able to set the limited accurately on the weight of separation between center– gravity (CG) and center-of-buoyancy (CB) of the vehicle, it result a high flexibility and performance AUV able to obtain.

I. ELECTRONICS CONTROL UNIT

The control system comprises ofelectronic control and buoyancy control tocontrol the system The controller operates at 5v dc and it does perform a desire function by comparing stored data on the memory and it stores the current activity. The controller gets the command signal from depth sensor. Then the current depthsof the vehicle data transmitted to the external controller for the purpose of monitoring and simultaneously control.

TABLE II-SPECIFICATION OF VEHICLE

Dimension	1..08mx0.2mx0.5m
Mass	24 kg
Maximum Velocity Under Water	1 knot (0.514m/s)
Maximum Velocity on Water surface	0.753m/s
Maximum Depth	7m
Maximum Power Consumed	110 Watts

A. Control System Architecture

The Microcontroller chosen is an ATmega32 with AVR RISC architecture. The pressure transducer is interfaced with the microcontroller to find the depth and pressure variations in sea through PORT

A. A relay based motor driver’s withstanding reliably with large current. The motor driver is interfaced to PORT D of ATmega32. A 12v, 5A relays are used as the pump motor driver.

B. Micro Controller

The ATmega32 is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. The ATmega32 provides 32K bytes of In- System Programmable Flash Program memory with Read-While-Write

capabilities, 2K byte SRAM, 32 general purpose I/O lines, 1024 bytes EEPROM, a JTAG interface for Boundary scan, On- chip programming, three flexible Timer/Counters with compare modes, a serial programmable USART, a byte oriented Two-wire Serial Interface, Internal and External Interrupts, an 8- channel 10-bit ADC, a programmableWatchdog Timer

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with Internal Oscillator and an SPI serial port. The On chip ISP Flash allows the program memory to be reprogrammed in-system through an SPI serial interface, by a conventional non- volatile memory programmer. PWM signals are generated using the timers. ATmega 32 micro controller board is shown in the Fig 7.1

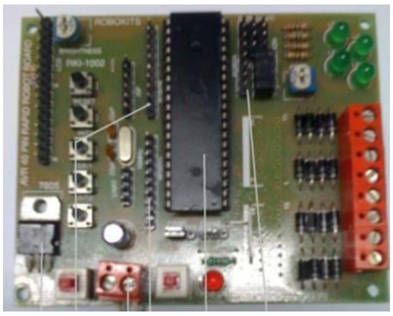

Fig 7.1 Micro controller Board

A General purpose AVR microcontroller board with suitable voltageregulators, extended ports and accessories is used.

IX. RESULTS AND CONCLUSION

The system is successfully designed and fabricated and its meets the high stability on the water. Balanced arrangement of components in frame and placement of ballast tank in center, proper fabrication works results highest insulation and safety of internal components. The function ofhydraulic unit works successfully on the desire logic and able to switching pump in process to pump out float, moves on the water surfaces and finally sinks into the water. The VBS based AUV system can able to meet its required specification, objective and mission. The problem is that the small changes in weights causes unbalancing and the depth changes drastically.

X. Future Scope of Work

The system can be improved in many ways. One way is that a flow meter can be introduced for the same system (but using two pressure sensors) such that the volume of flow inside the bladder could beknown. One more way to improve the system includes introducing a PID control loop. Here, the present depth is compared with the actual depth and the difference between the two is generated as an error signal. Depending upon that whether the buoyancy must be increased or decreased is decided such that the air/water would be pumped in/out and thus the closed loopcontrol gets maintained.

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REFERENCES;

[1].Bob Anderson and Jon Crowell, *"Workhorse AUV – A cost-sensible new Autonomous Underwater Vehicle for Surveys/ Soundings, Search & Rescue and Research*" Ocean server Technology, Inc, 2006.

[2].Chunzhao Guo and Naomi *Kato "Mini Underwater Glider (MUG) for Education"*, Department of Naval Architecture and ocean engineering, OsakaUniversity, 2009.

[3].Damus.R .and Navelkar.G, "*Design of an inspection class autonomous underwater vehicle*"AUV lab,Massachusetts Institute of Technology, Cambridge, pp.180-185.2002

[4].Henry Robinson and Brain Phillips, *"3D Autopilot and Mission controller for AUVs"* H scientific Ltd, U.K.2001.

[5].Jeffery Reidel .S, Anthony Healey.J, "*Design and Development of Low cost Variable Buoyancy System for the Soft Grounding of Underwater Vehicles"* Naval postgraduate school (Centre for AUV research),1998.

[6].Phil Bagley, Mark Worall and Anne Holford *"Variable buoyancy device"*University of Aberdeen, ocean lab, Newburgh, U.K.2006.

[7].Pramod Maurya, Desa. E, Pascoal.A, *"Control of the Maya AUV in the vertical and horizontal planes".* National Institute Of Oceanography Goa, India, 1998.

[8].Sekhar Tangirala and John Dzielski, "*A variable buoyancy control system for a large AUV"* IEEE journal of oceanic engineering, Vol.32, No.4, Oct 2007.

[9].Spiwak.JM and Jouvencel.B, "*A new design of AUV for shallow water applications"* Proceedings of the Sixteenth International Offshore and polar Engineering Conference, San Francisco, pp233-237, June 2006.

[10].Tadahiro Hyakudome, Taro Aoki, Tosho Maeda, Takashi Murashima Satoshi Tsukioka, Tadahiko Ida and Takuji Ichikawa. *"Buoyancy control for deep and long cruising range AUV",* Japan Marine Science and Technology Center Yokosuka, Japan.