

AUTONOMOUS VEHICLE DEVELOPMENT FOR VERTICAL SUBMARINE OBSERVATION

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Abstract – This work proposes the development of an ocean observation vehicle. This vehicle, a hybrid between Autonomous Underwater Vehicles (AUV) and Autonomous Surface Vehicles (ASV) moves on the surface of the sea and makes vertical immersions to obtain the profiles of a water column according to a pre-established plan. Its design provides lower production cost and higher efficiency. GPS navigation allows the platform to move along the surface of the water while a radio-mo-dem provides direct communication links and telemetry.

Keyword – Autonomous Underwater Vehicle, Vertical Profiler, Computer Embedded

I. MECHANICAL DESIGN OF THE VEHICLE.

The vehicle has a double hull. The outside hull, made of fiberglass, is not watertight but it provides a good hydrodynamic characteristic. On this structure the steering and propulsion mechanisms are attached.. A propulsion engine, of the company Seaeye, has been located on the stern of the vehicle and individual Seabotix(™) engines are located on the sides of the hull. When these engines are used, the course of the vehicle can be altered [1] [2]. A watertight cylindrical module is located inside the outside hull. It houses the immersion actuator and the electronics control, as well as the power supply provided by the batteries. Figure 1 shows the design of the vehicle.

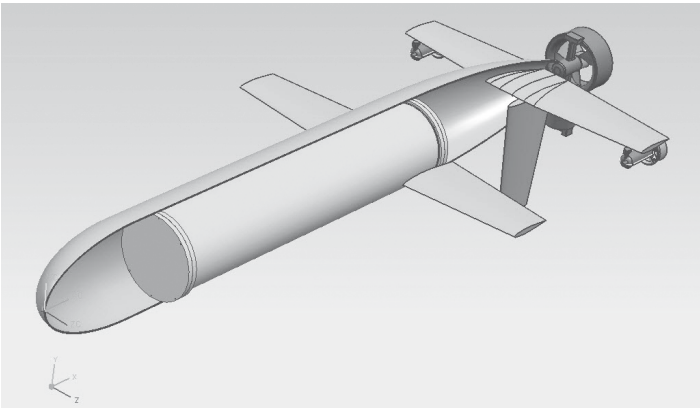


Fig.1. Design of the vehicle.

Outside Hull Design of the Vehicle.

The outside hull design is based on the Myring equations [3] that describe a body contour with a minimal drag coefficient for a given finesse ratio (body length/maximum diameter). Myring’s pParameters classifies body types by code of the form a/b/n/θ/0.5d. This vehicle has the code 15/55/2/0.4365/5. Figure 2 defines the parameters used to obtain the code and the Table I shows the dimensional parameters used. Finally, three stabilizers according to a NACA 63-012a profile, have been designed on the proportions of the outside hull.

Inside Hull Design of the Vehicle.

The watertight module is a cylinder made in 6063 aluminium with hard anodized treatment and designed to withstand 30AT, although the nominal pressure is 3AT.The cylinder dimensions are 250mm diameter and 1100mm long, and is covered in aluminium. An o-ring guarantee watertightness. The connection of the antennas and engines with the interior of the module is done through SubConn connectors. The watertight module houses the immersion actuator and the electronics control, as well as the power supply provided by the batteries. The design of the emersion and immersion equipment is composed of a commercial pneumatic stainless steel cylinder with a displacement of 1500cm3 and a linear electrical actuator which can cover a maximum distance of 200mm and a thrust force of 3KN.

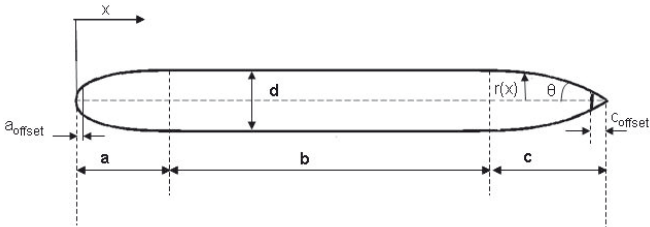


Fig. 2. Myring Profile: vehicle hull radius as a function of axial position

| Parámetro | Valor | unidad |
|-----------|-------|----------|
| a | 325 | mm |
| aoffset | 0 | mm |
| b | 1116 | mm |
| c | 924 | mm |
| coffset | 70 | |
| 55 | mm | |
| n | | n/a |
| θ | 2 | radianes |
| d | 326 | mm |
| lf | 1441 | mm |
| l | 2365 | mm |

Table 1. Myring Parameters for the vehicle

II. ELECTRONIC DESIGN OF THE AUTONOMOUS NAVIGATION CONTROL SYSTEM.

The autonomous navigation control system is made up of an embedded computer and the necessary elements for communication, navigation and propulsion and safety. Data acquisition system, composed of a CTD for the temperature acquisition, depth and conductivity of the water column, are also included [4]. Communication between the vehicle and the station located on shore is bidirectional and a Farell Instruments(™) industrial modem T-MODC48 has been used. Its features include a data rate of 4800 bps and a configurable carrier power of 100mW/5W that allows a maximum range of 10km. A PC/104 embedded computer (PM-6100 AEWIN) makes up the central control of the vehicle. This is of limited size, weight and power consumption (max 12W). It is managed by a Windows XP operating system stored in a compact flash memory which provides good protection from vibration. The propulsion control system is a SSC32 Lynxmotion driver that transforms the RS232 signal from the PC/104 in a modulated PWM signal that acts on the engine power drivers. The navigation system is a digital compass and a three-axis inclinometer, PNI TCM-2.6. It is a 3-axis tilt-compensated compass-heading module with electronic gimbaling to provide accurate heading, pitch, and roll measurements over a ±80° tilt range. The navigation system also has a global positioning system GPS, Magellan DG14TM, which provides the precise location of the vehicle during a mission. The safety system includes a pressure transducer HPS DS2806, which provides the measure of absolute pressure, from which is possible to know the depth of the AUV. The low cost sSensor is resistant to corrosion, which allows a pressure variation from 0 to 10 bars. It also has a 4000 HIH sensor capable of detecting variations of 1% of relative humidity, which can detect a small flaw in the watertightness of the inside module. Finally, it has the LM3916 component to measure the voltage level of the vehicle battery.

III. CONCLUSIONS

An observation platform has been developed which is able to navigate on the surface of the sea making vertical immersions to obtain water column profiles. The vehicle has a double hull, a fiberglass exterior with a profile that provides a good hydrodynamic characteristic, and a watertight inner module built in aluminum. Also, an autonomous control system for the vehicle has been designed and implemented. Its proper operation has been tested in the laboratory. Now, all elements of the structure of the vehicles are being assembled and then a test of navigation at sea will be performed.

ACKNOWLEDGMENT

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REFERENCES

- [1] Blidberg, D. R. "The development of Autonomous Underwater Vehicles (AUV); A brief summary" Autonomous Undersea Systems Institute publications (AUSI), ICRA, Seoul, Korea, May 2001.
- [2] Byron, J. and Tyce, R. "Designing a Vertical / Horizontal AUV for Deep Ocean Sampling" Proceedings of MTS/IEEE Conference and Exhibition Oceans 2007. Sept. 29-Oct. 4. Vancouver, Canada pp. 1-10. 2007
- [3] D. F. Myring. "A theoretical study of body drag in subcritical axisymmetric flow". Aeronautical Quarterly, 27(3):186-94, August 1976. 14, 15, 43
- [4] S. Gomáriz, J. Prat, A. G. Ruiz, J. Sole, P. Gayá and J. Del Río. "Development of a low-cost autonomous oceanographic observation vehicle" Proceedings of MTS/IEEE Conference and Exhibition Oceans 2009. May 11-14. Bremen. Germany. 2009

FAULT TOLERANT ACTUATION FOR DORADO CLASS AUVs

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Abstract - This paper describes a new control surface actuating design for the Monterey Bay Aquarium Research Institute (MBARI) Dorado class AUVs. The intent was to increase reliability as part of obtaining the goal to greatly increase access to the Arctic Ocean. The new actuating mechanism is part of creating a robust and economical solution towards increased reliability and fault tolerance. Specifically, as part of developing the ALTEX Autonomous Underwater Vehicle (AUV) for Arctic research with basin scale endurance, the concept for under ice missions was redundancy in critical areas. As the development of the DORADO systems progressed from the original ALTEX concepts, added drivers came from the operations group looking for more useable volume in the aft section.

The DORADO vehicle is guided using an articulated tail steering section. The tail is comprised of a ducted propeller acting as control surfaces and propulsion, in contrast with the more traditional fin control surfaces used by most vehicles. This approach was taken to be more robust to impacts as experience using Odyssey IB vehicles showed the control surfaces damaged during launch and recovery were the number one failure by far. As predicted by analysis the design also improved propulsion efficiency. Also worth noting is that this entire tail system stays inside the 21" diameter of the main vehicle body. The new system being developed is unique in that it keeps all of the key propulsion and actuators but eliminates the current gimbaled tail through the use of what we refer to as a false center. While several new components are being developed, the objective is to leverage the existing technology to the degree possible and allow for an inexpensive as well as direct swap into existing systems.

The new steering mechanism uses a Three Actuator False Center Control solution. The design was first modeled and tested for feasibility. After passing the preliminaries, the decision was made to build a full-scale sea going unit. We now have that system built and in bench testing, ready to swap in for at sea testing in the very near future. We've already demonstrated that the new design offers a superior use of space yielding more useable volume for other equipment. The model demonstrated the added redundancy that we will duplicate at sea. We believe the design is very robust and has a broad range of uses in long duration unattended operations where fault situations must be dealt with by the autonomous system. In this paper we will discuss our progress to date, our current test efforts, and the near term future uses of this new control section for DORADO science vehicles.

Keywords: Control surfaces, Tailcone, Dorado, AUV, autonomous platforms, fault tolerant actuation

I. INTRODUCTION

MBARI's Dorado Class Autonomous Underwater Vehicles (AUV's), Figure 1, are both propelled and steered by a single thruster mounted at the rear of the vehicle [1]. The usual fins for rudder or elevator control have been replaced by a tailcone using a ring wing with foil section support struts. Turning the vehicle is accomplished by moving the articulated tailcone, which consists of the propeller, shroud, and motor mounted in a gimbaled mechanism driven by two linear actuators. The gimbal consists of an outer ring that rotates about the vertical axis (providing rudder control or yaw), and an inner ring that rotates about the horizontal axis (providing elevator control or pitch) [2]. The main computer, navigation and controls of the core AUV are contained in the tail of the vehicle. The needs of the Dorado program were therefore primarily concerned with developing a robust, versatile AUV tail section.

Additionally, the DORADO vehicles are required to support a broad range of missions. The use of modular sections made this possible, but it also puts requirements on the core vehicle systems, in particular the tailcone. For example, roll stability is critical to multibeam mapping and is a high priority, so any tailcone advancements are required at a minimum to maintain the current capabilities. A second key requirement is the tailcone must be capable of accepting the frequent adjustments to the vehicle control gains. The control gains are altered as the reconfigured length varies due to adding or removing modules installed for various missions.

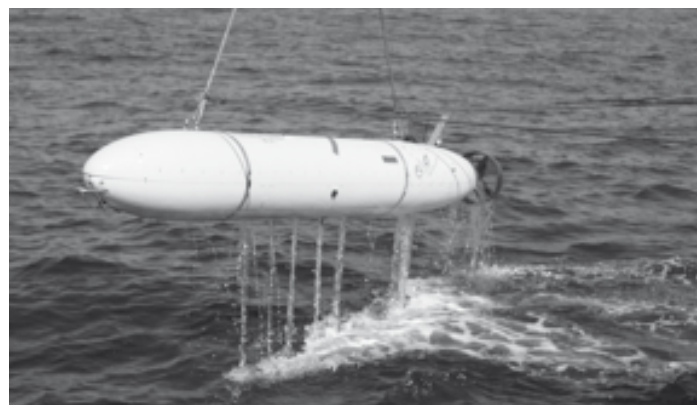


Fig. 1: An early version of DORADO during development