Design of a Body with Depth Control System for an Underwater Glider

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ABSTRACT

This paper describes a design development of an underwater glider which includes the body design, controller design and the sensor integration. The underwater glider is used for deep water to observe large areas with minimal use of energy and move through the water by changing the body weight. The glider contained a cylindrical body attached with two wings and a fix tail. The controller has been designed to use a comparator circuit integrate with a pressure sensor to control the depth level. The pressure sensor mounted on the glider used to sense the underwater pressure. For the beginning, this underwater glider is limited to a depth of 0-10 meters.

KEY WORDS: Underwater Gliders; Depth Control System; Cylindrical Body; Wings; Tail; Controller.

INTRODUCTION

The concept of the underwater glider was proposed by Stommel (1989). Since 1995, US Navy Office of Naval Research has sponsored Autonomous Ocean Sensing Network (AOSN) program (Davis et al. 2003) and have produced three oceangoing gliders including Slocum Glider (Webb et al. 2001) shown in Figure 1, the Spray Glider (Sherman et al. 2001) and the Sea Glider (Ericsen et al. 2001). These gliders are designed for long duration and ocean sensing missions (Osse et al. 2007).

Figure 1: The Slocum Glider

Underwater gliders are a new class of Autonomous Underwater Vehicles (AUVs) (Rudnick et al. 2004) with fixed wings and a tail to glide through the ocean. They have many useful application such as in oceanographic sensing and data collection and also sea mapping. In this application, the gliders are very suitable because it's capable for long duration missions, wide range areas, low cost and minimal used of power source. The gliders travel from place to place by produced of upwards and downwards glides (Webb et al. 2001). The Figure 2 shows the travel movement of the Slocum Glider. The glider glides in a sawtooth pattern by controlling their buoyancy using internal tanks and pumps. Propulsion of the gliders is created by changing the volume of the vehicle (Graver et al. 1998) either by moving oil from an internal tank to an external tank or by pumping seawater in or out of a tank. The glider has maintained a constant mass and changed its volume. Wings and body lift of the glider convert the vertical motion to a horizontal displacement like a sawtooth pattern.

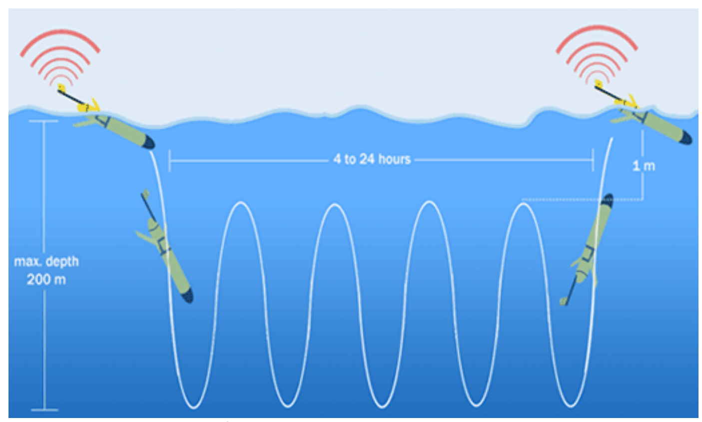

Figure 2: Illustration of Slocum Glider Movement

GLIDER DESCRIPTION

The glider is designed and developed to operate as a platform for range of research in underwater technologies mainly relating deep water and long range period. Based on the Slocum Glider criteria, the design criteria for this project were that the glider should be:

- low cost material for the glider body
- neutral buoyant
- considered for maximum depth of 10 meters
- mounted with pressure sensors as depth indicator

BODY DESIGN

Hull Description

The glider needs a pressure hull to store its components in a dry and watertight environment. The hull must allow the components to be easily accessible and maintainable in case of future changes or additions. The hull also needs to be corrosion resistant as it wills exposes to saltwater environment. Cylindrical hull provides the best structure and shape because spherical hulls offer the best structural integrity.

Design and Construction Process of Glider's Body

Figure 3 shows the classification of body design and construction process. The process has been classified into two stages. First stage concentrates on the design concept of the glider. Therefore, computer-aided software such as the AutoCAD and Maxsurf are applied to sketch and animate the glider that are recommended and expected. The second stage expressed the fabrication development of glider body. The fiberglass is used as the main material for glider body fabrication.

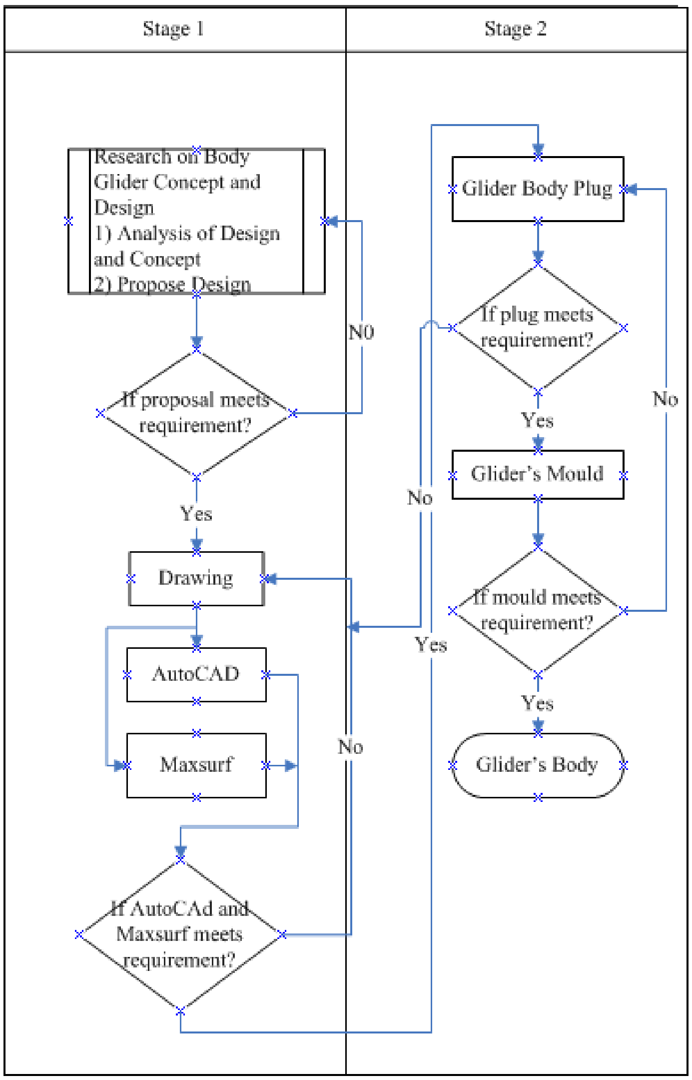

Figure 3: Design and Construction of Glider Body

ELECTRICAL/ELECTRONIC SYSTEM DESIGN

Sensor Suite

The glider controller will receive feedbacks from the sensor which installed in the glider's body for decision making. The glider controls its depth with feedback from a pressure sensor to activate the pump. The pressure sensor MPX4250 is used to measure the dept which produce small voltage when the depth increases. The MPX4250 needs supply voltage in between 4.85 to 5.35 Volts to operate. The MPX4250 is a low cost and capable to measure maximum pressure of 36.3psi or about 2.47atm. At sea level, pressure due to open air is 14.7psi or 1atm and for every 10meters of depth, the pressure increases about 1atm. The absolute pressure at 10meters underwater is 2atm or 29.4psi.

Power System

The glider used battery pack that contains of 12 Volts for powering all electrical and electronic equipment. These batteries supply 5 Volts power lines to the sensor and 12 Volts power lines to the water pump. The onboard power supply is crucial to enable the glider to operate in autonomous mode. The battery pack is placed at the center gravity of glider's body on the dry compartment to ensure the vehicle stability.

GLIDER SUBMERGING OPERATION

The volume of the underwater glider is remains constant, hence, to submerge deeper, the glider need to increase the downward force to overcome the buoyant force. It can achieve via increasing its mass by using ballast tanks or by using external thrusters. In this project, a ballast tank is used to encounter the buoyant force. Ballasting is a good approach because it involves employing pumps and compressed air to take in and remove water. Trajectory of the glider is illustrated in Figure 4, where V, L, D, F and G represent moving direction, lift, drag, buoyancy and gravity respectively. The process is:

1) To submerge, the motor begin to pump water into the ballast tank.
2) The glider submerges due to negative buoyancy. Upward lift is generated by the fixed wings and body.
3) The glider reach at point Y, the motor begin to pump out the water from the ballast tank.
4) The glider ascends due to the positive buoyancy.
5) The glider reach at point X, the motor begin to pump in the water into the ballast tank. The glider prepares to submerge to point Y.

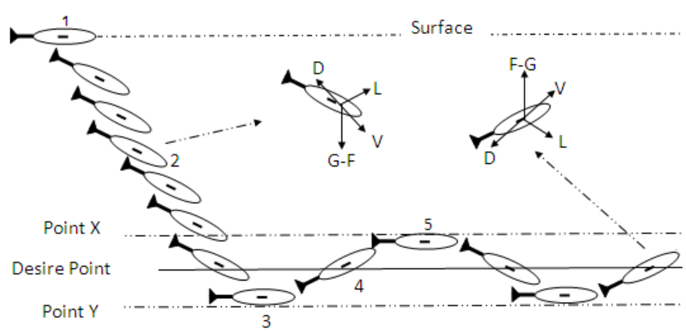

Figure 4: The Glider Trajectory and Force Analysis

RESULTS

At the first stage, the glider was sketch on a paper and it is based on the Henry Stommel glider concept shown in Figure 5. It consists of a cylindrical hull, two wings and a tail with four fins. These were designed with the objectives in being easily deployed and recovered by only a couple of people.

The glider designed can be enhanced by using Maxsurf software shown in Figure 6. The software enables the user can design variety of dimension and can make any changes if required. Early design, the glider was small scale of sizes, hence it changes the dimension because the material used needs a bigger size to be practically construct.

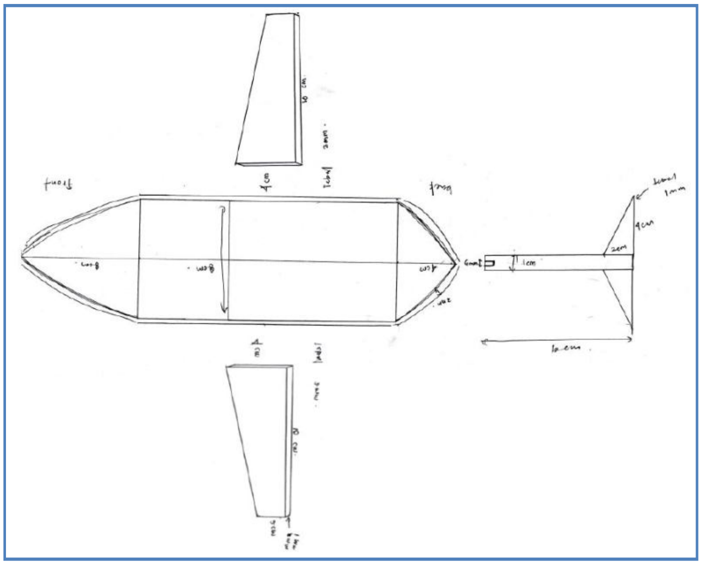

Figure 5: Preliminary Sketch

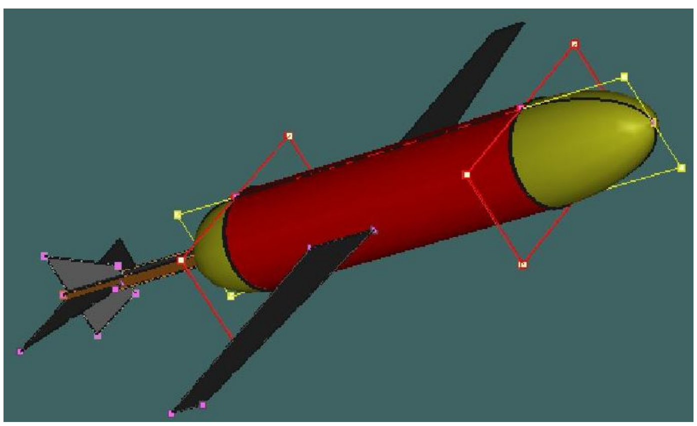

Figure 6: 3D Maxsurf

After several adjustments have been made to meets the requirement, the construction of the glider begins with using fiberglass as the main material. At the first stage of construction, the plug is build by using polyvinyl chloride (PVC) pipe according to the hull size. The process to build the plug requires two weeks as it needs several adjustments to suits the design specification. Figure 7 shows the finishing product as the actual model of the glider.

Table 1. Dimension of the glider

Dimension	Unit
Hull Length	0.82 m
Hull Diameter	0.34 m
Wing span	0.30 m
Weight	3.5 Kg
Tail Length	0.23 m
Tail Fin	0.12 m

Figure 7: The Actual model

FUTURE RECOMMENDATION

For the future developments, the hydrostatic and stability criteria of the glider need to be specified. The hydrostatic study will shows the characteristics of the glider under the water such as displacement, centre of gravity, centre of buoyancy, lift and coefficient, roll and pitch angle.

Table 2. Expected characteristics of the glider

Criteria	Estimation
Speed	0.03 m/sec
Depth Range	10 m
Communication	Satellite
Range	1 km
Navigation	GPS

CONCLUSIONS

This paper has been of tremendous success for my enhancement and advancement in knowledge and understanding of the robotic submarines. They are a part of the autonomous and unmanned vehicles used as low cost tools.

The design structure and construction process of the project has been well discussed, while the research results and problem finding also has been describe. The practical body that we produce from our project will be used to test the performance of depth control system and advanced control algorithm. With a limited budget, a practical body of underwater glider has been developed.

ACKNOWLEDGEMENTS

We would very much like to express with grateful thank you to Universiti Teknologi Malaysia especially to higher management. The authors also would like to thank Universiti Kuala Lumpur for the conferences grant.

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