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Progress Status of ITB Hybrid AUV Development

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Abstract— The hybrid AUV has been developed for the last year by center for Unmanned system Studies (CentrUMS)-ITB. The main concept of this hybrid AUV is to combine the Sea Glider concept and also the common AUV. By the sea glider concept, the buoyancy engine principal has been adopted to support the capability to manipulate the overall dynamic buoyancy from main body vehicle. By this engine, the vehicle has capability to change the state from fully afloat, neutral buoyant and fully submerged. From the common AUV concept, the ultimate survey capability has been adopted. Several sensors for underwater survey will be attached on this vehicle. This research needs multi-year to its completion. Step-by-step method has been carried out to finish the design until testing. In this paper, some progress will be shown according to multi-year project research.

Keywords— Hybrid AUV, Sea Glider, buoyancy Engine, Bouyancy

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I. Introduction

The general sea glider has capability to cycle vertically by changing the buoyancy and center of gravity on the sea water column. With additional wing lift, some of its vertical movement is converted to forward motion. Commonly the sea glider just have single oceanographic sensor like CTD (conductivity, Temperature and Depth). By the limited sensor, this vehicle can only execute simple missions. This kinds of underwater vehicle have a main advantages and superiority on long endurance and wide coverage area [1]. But the mission and emergency control system of this vehicle is very limited. Track record shows that the main failure of this kind of vehicle is by limited obstacle avoidance and navigation function even though some modern sea glider is supported by Inertial measurement unit (IMU) to enhanced the navigation system.

The Main AUV have more advantages and capability to manipulate the attitude by independent propulsion system and control surface. With the strength and complexity of navigation sensor that they have, this kinds of vehicle have flexible mission and maneuver to explore almost all depth of sea.

The comparison between sea glider and general survey AUV is shown below (Table 1).

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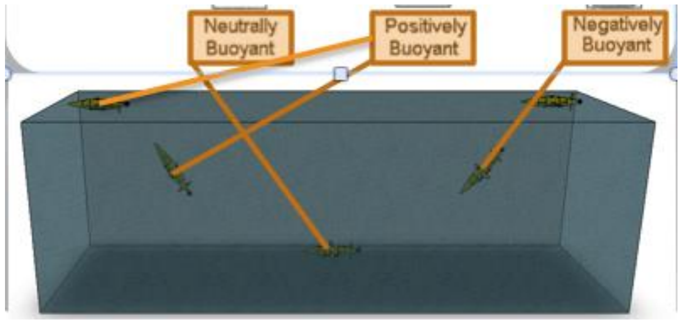

Figure 1 The Operation concept of Hybrid AUV

Table 1
Comparison concept between Sea glider and general AUV

Underwater Sea Glider	General AUV
Wide range	Dedicated range
Long endurance, limited maneuverability	Limited range, high maneuverability
No Wave to Environment	Obstacle Avoidance
Specific Mission	Flexible mission can be carried out

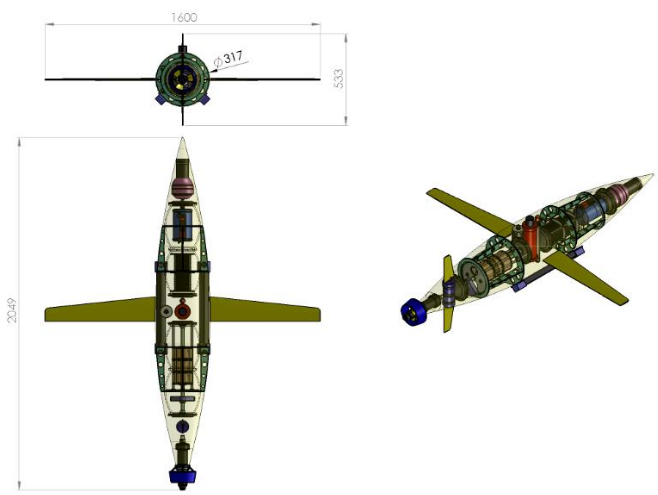

Figure 2 Technical Drawing of Hybrid AUV

To overcome this limitation, the concept of hybrid AUV has been proposed. Some additional sensor and propulsion system makes this vehicle can have more additional capability if compared to the conventional sea glider. This hybrid AUV has capability to stay on the certain sea level. And maneuver on this operating depth by single propulsion system and control surface. With this capability, the hybrid AUV can execute the task to survey on the certain sea level with neutral buoyancy (Figure 1). This is the main reason and the main advantage of the Hybrid AUV concepts.

The Overall design of previous Hybrid AUV will be shown in Table 2. The technical drawing of this Hybrid AUV prototype is showed in Figure 2.

Table 2
Technical specification of CentrUMS-ITB Hybrid AUV prototype

Dimension (L x W x H)	2700 mm × 1200 mm × 203 mm
Speed	Max. 4 knot
Weight on Air	50 Kgf
Power	1.5 HP
Endurance	10 hours
Max. Operating Depth	2500 m
Propulsion & Control	1 HP Electric Thruster & Bouyancy Engine
Payload	Obstacle Avoidance sonar, Acoustic modem, CTD, Iridium Satellite Communication (on surface)

II. Approach and Methods

There is some design aspect to develop the Hybrid AUV:

- Hydrodynamic aspect: low drag, laminar body and high maneuverability
- Mechanical and construction: strength-to-weight ratio, manufacturability, efficient and effective component placement (modular concept)
- Buoyancy engine: displacement volume, maximum displacement rate.
- Power and propulsion: battery type, power capacity, propulsion thrust.
- Control system and sensors: high precision control system, obstacle avoidance, side scan sonar.
- Propulsion and control surface: high efficiency propulsion and control surface mechanism.
- Communication: satellite link, radio data communication, acoustic modem.

The body hull is very important to dominate the efficiency of vehicle. The laminar flow body and the length-to-diameter ratio are very important in the design of body hull. The example of common body hull is shown in Figure 3. The correlation between diameter and length is shown in Figure 4.

The Hybrid AUV Hull design have diameter 317 mm and length 2049 mm, so the length-to-diameter ratio is 6.5. Refering the Figure 4, we can see that 6.5 is a good number that has lowest total drag. This method looks good enough as an empirical approach, but the detailed analysis requires more to be conducted such as Computational fluid Dynamic (CFD) method.

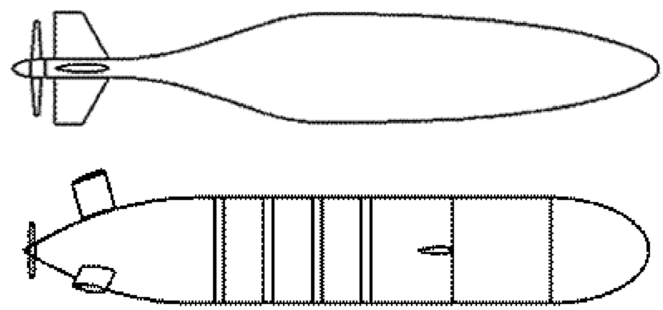

Figure 3 The comparison of laminar body hull (top) and torpedo shape (bottom).

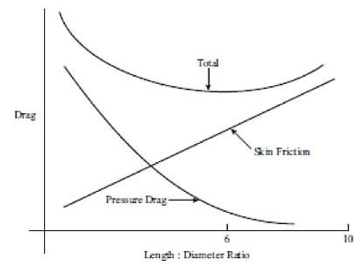

Figure 4 The correlation between Drag and ratio length to Diameter of underwater vehicle body hull [2]

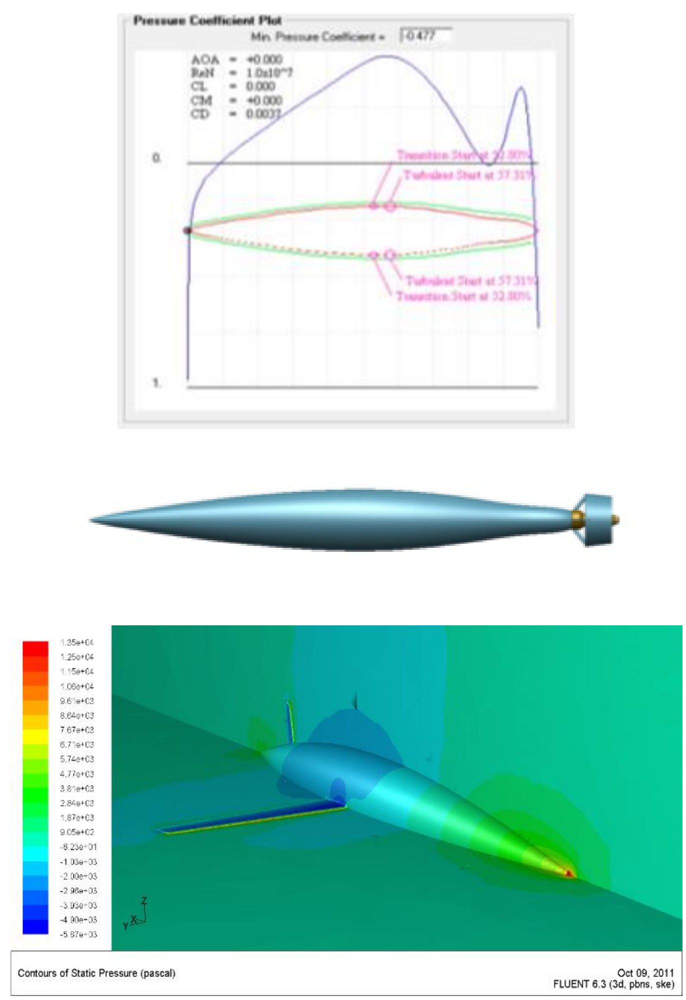

Figure 5 The CFD analysis result of Hybrid AUV Body Hull design

Table 3
The Numerical Analysis results of Hybrid AUV from CFD

Force vector: (1 0 0)

zone name	pressure force n	viscous force n	total force n
hybrid_auv	200.96867	96.65992	297.62859
net	200.96867	96.65992	297.62859

The construction of this vehicle uses a modular composite drybox. With this concept, we can arrange the compartment and also the internal system more flexibly. The internal arrangement of this hybrid AUV is shown in Figure 6.

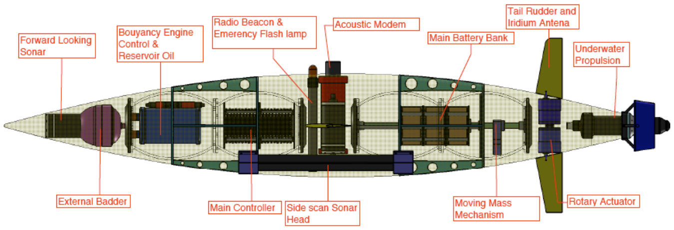

Figure 6 The Previous design of internal arrangement of hybrid AUV

III. Results

The main progress results on this development is shown below:

A. The Progress of Buoyancy Engine

The buoyancy engine was designed, manufactured and tested on the laboratory testing chamber. The overall design of this system is showed in Figure 7.

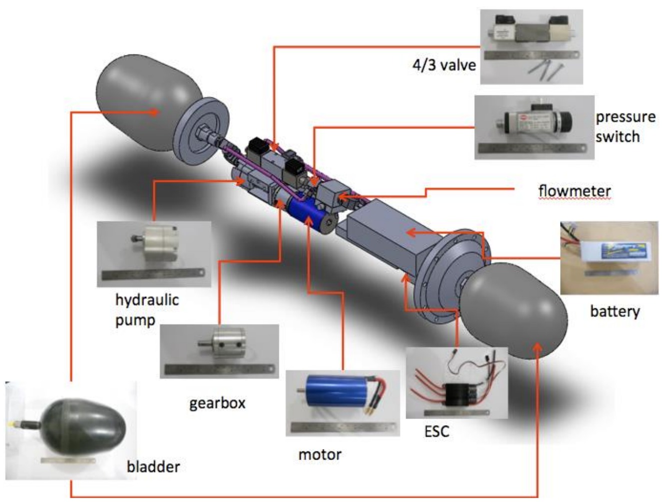

Figure 7 The buoyancy engine design and component arrangement.

The performance of this buoyancy engine is presented in Figure 8 while the arrangement on the modular drybox is shown in Figure 9.

This buoyancy engine was tested with the external pressure (Operating Depth Simulation). The purpose of this test is to make sure the buoyancy engine still works with external pressure load as the real operation on the full depth operating pressure. The schematic of this is described in Figure 10.

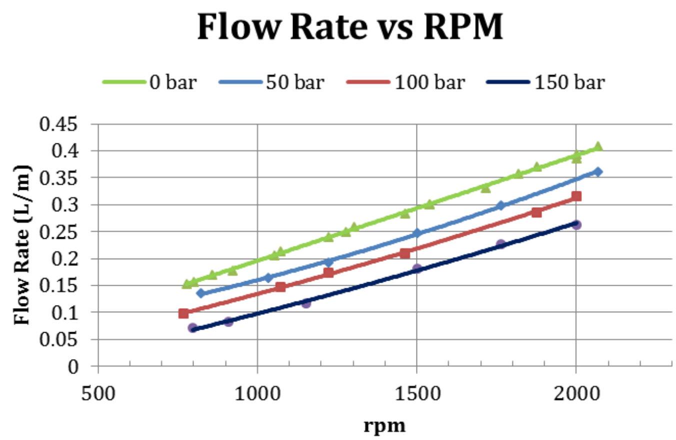

Figure 8 Performance of Bouyancy engine of Hybrid AUV

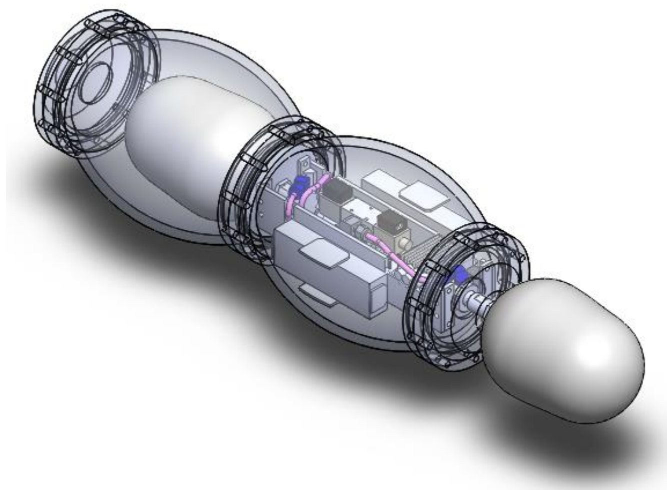

Figure 9 The buoyancy engine arrangement on the modular concept drybox

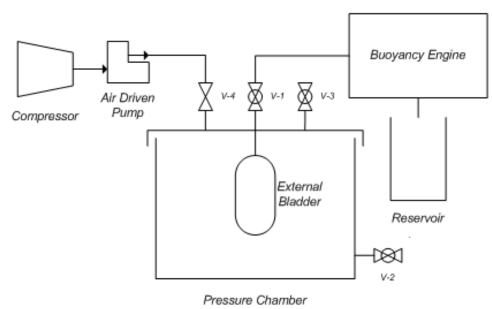

Figure 10 Testing schematic of buoyancy engine with Pressure Chamber.

B. Composites Modular Dry Box Testing

The composite material technology is very promising as the next generation of underwater construction material. Composites have excellent strength-to-weight ratio. For this hybrid AUV, construction material is dominated by composite by almost 80 %. Before manufacturing and applying to this system, the design needs pre-analysis. A finite element analysis (FEA) was conducted on this modular composites dry box. The result of this analysis is shown in Figure 11.

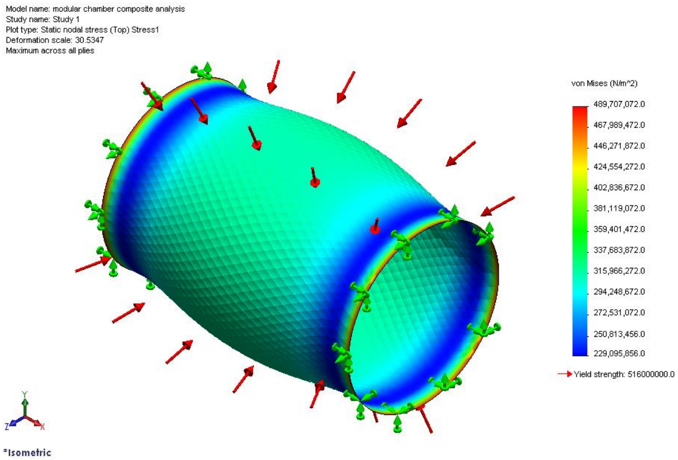

Figure 11 The FEA of modular dry box. [6]

Figure 12 The testing setup of composites modular dry box (top), Crush test until maximum pressure the specimen can hold it (Bottom).

And to validate the analysis of this design, series of tests were conducted. The tests use pressure chamber to simulate and represent the external pressure. The tests show good results. The tests configuration and setup is in Figure 12.

If compared with the same dimension of another material such as titanium, the composites have more advantages:

- Less weight
- Cheaper
- Available material
- Corrosion Resistance

But for the manufacturing process, composites material need a high level of technician and facility.

IV. Conclusions

From the current progress of this hybrid AUV development, we can conclude with the information as follow:

- The buoyancy engine as the main and critical system on this hybrid AUV has worked properly, with the maximum working volume 4.5 liter, or almost equal to 4.5 kg displacement.
- The flow rate of the buoyancy engine depends on the operating depth. The maximum flow rate at surface level is 0.4 L/min.
- The modular chamber can survive up to 300 bar external pressure, or equal to almost 3000 m depth.

By the new configuration of buoyancy engine, the overall configuration of Hybrid AUV is showed as follow (Figure 13).

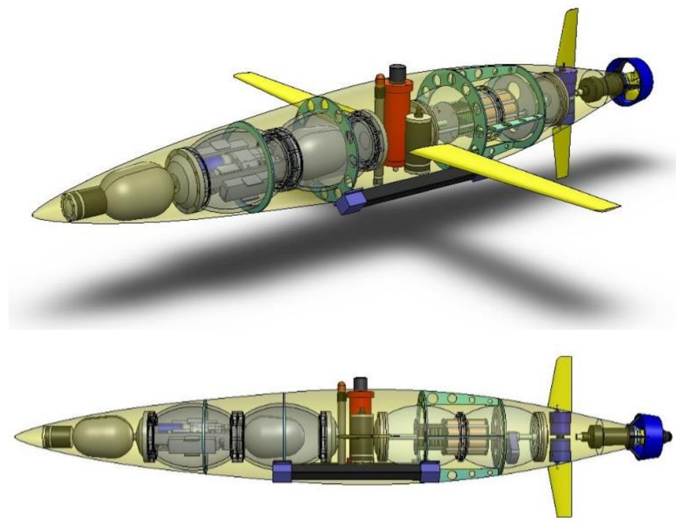

Figure 13 Final Configuration of ITB Hybrid AUV

Acknowledgments

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