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Testing of ITB Hybrid AUV Bouyancy Engine

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Abstract— As part of ITB Hybrid Autonomous Underwater Vehicle (AUV) research program, we reached the stage of testing of bouyancy engine as a critical component of this vehicle. This paper describes the overview of ITB Hybrid AUV and the role of buoyancy engine in supporting vehicle operation. Step by step testing is described in detail to illustrate the working principle of this important component.

Keywords— hybrid AUV, sea glider, buoyancy engine, buoyancy

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I. INTRODUCTION

HYBRID Autonomous Underwater Vehicle is the collaboration concepts between Sea Glider and Autonomous Underwater Vehicle. The specific characteristic of Sea Glider is long endurance, wide range, and limited payload or sensor to support the mission. On the other hand, AUV is characterized by its complex equipment and instrumentation, and its limited endurance and range. Dual concepts of these characteristics will be combined. The main mission for this vehicle is adopted on AUV but for submerged and surfacing mode has been adopted from Sea Glider concepts with their buoyancy engine [1].

The concept of Sea Glider is to move vertically along the sea water column by changing their volume and buoyancy. With additional control surface, this vertical movement is converted into forward and turning movement, depending on the control surface configuration. Wing-lift drives forward motion both as the vehicles ascend and descend, so they follow sawtooth paths. The shallowest points on the sawtooth are at the surface where satellite navigation and communication are carried out [2]. How this mechanism work in this vehicle is illustrated in Figure 1.

Buoyancy propulsion is well suited with the performance objectives of this class of vehicle. It provides the vertical sampling needed in the stratified ocean where variability along horizontal path often results mainly from vertical migration of patterns.

Different with conventional Sea Glider, the hybrid AUVs have capability to maintain their depth level with neutral buoyancy condition. On this level and state, the hybrid AUV can execute the common AUV task. That is why this hybrid AUV have more complex sensor if compared with the conventional Sea Glider. How this vehicle work is illustrated in Figure 2.

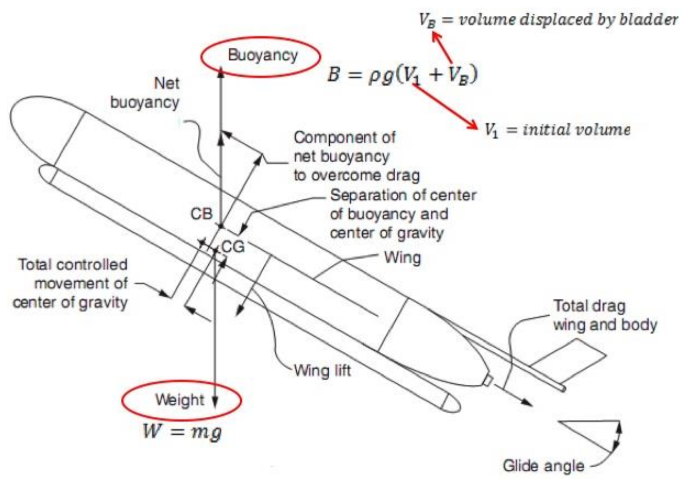

Figure 1 Bouyancy propulsion mechanism on underwater Slocum Sea glider [2]

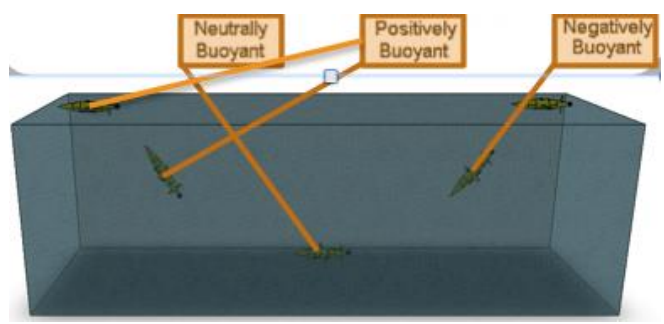

Figure 2 The state of hybrid AUV work [1]

The hybrid AUV research has started since 2009. Some design aspects are already studied to support this research program, which cover hydrodynamics, mechanical structure, instrumentation, stability, including the buoyancy engine design. The main arrangement of ITB hybrid AUV is shown in Figure 3.

Buoyancy engine is a part of hybrid AUV that have responsibility to manage the dynamic buoyancy force of this underwater vehicle, especially when this vehicle is on gliding mode (descending or ascending). The configuration of buoyancy engine is shown in Figure 5.

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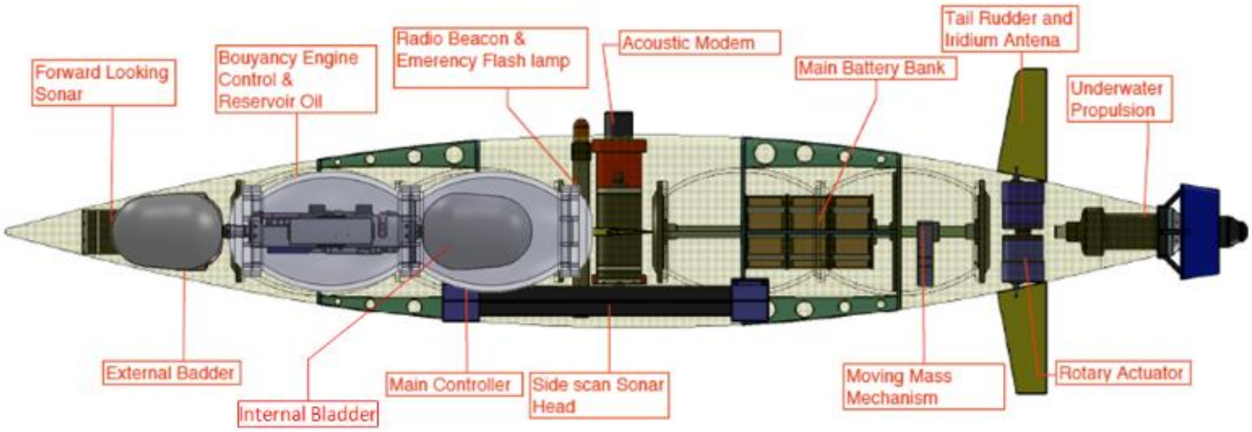

Figure 3 ITB Hybrid AUV general Arrangement

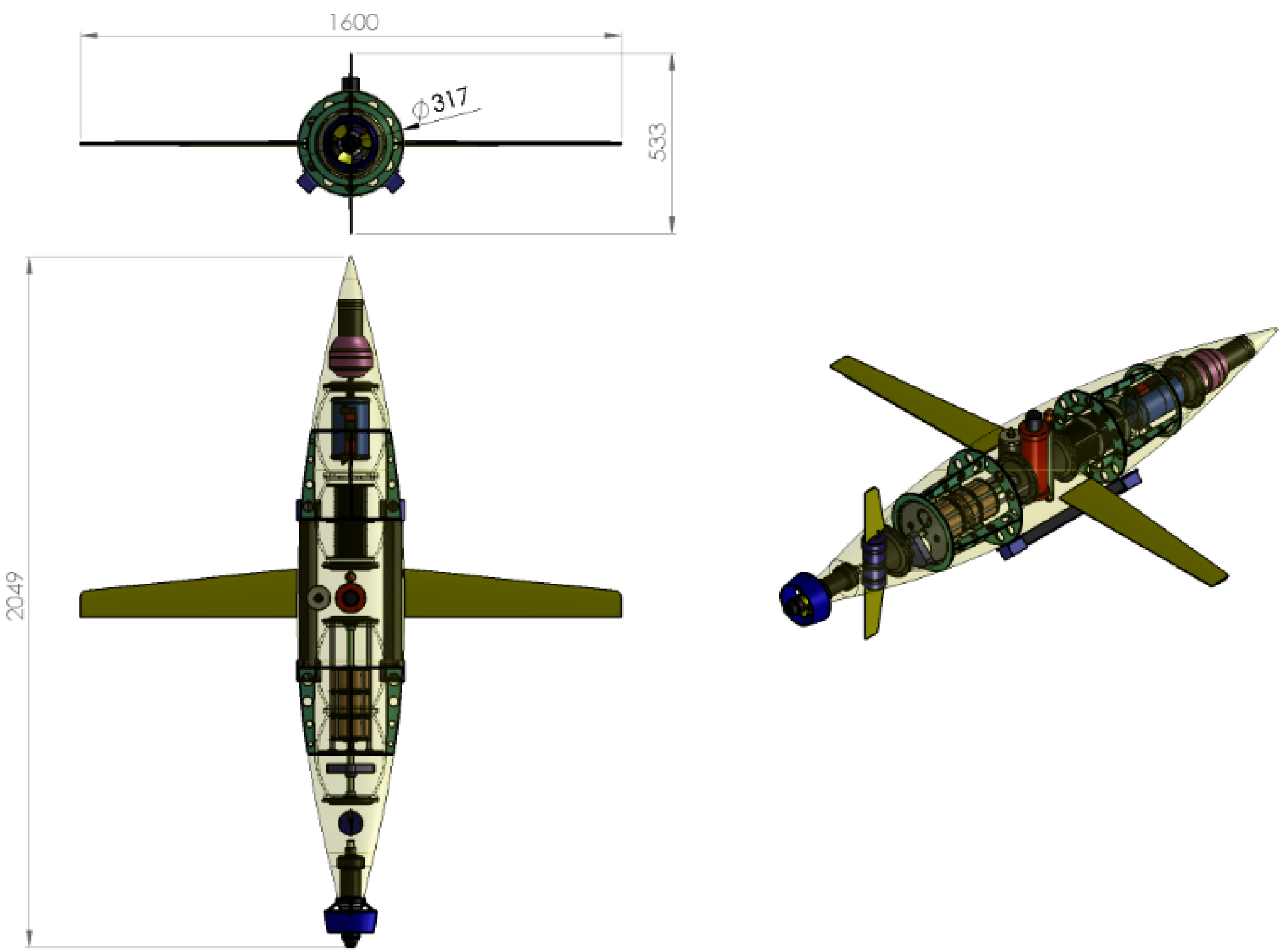

Figure 4 ITB Hybrid AUV general dimension

With this configuration, the buoyancy engine control system will be inserted on particular drybox that is shown on Figure 3. The overall system must have endurance for 2500 m operating depth. The series of tests that must be conducted on this buoyancy engine is described as follow:

1. Laboratory test: center of gravity setup, external pressure endurance.
2. Pool test: water sealing system, attitude (ascending/descending).
3. Sea test: hazardous environment testing and endurance.

In the laboratory, the series of tests have a purpose to check whether all parts can work properly according to the design. The pool test and the sea test have almost the same procedures and purpose; but on this paper, the test on the sea is not included.

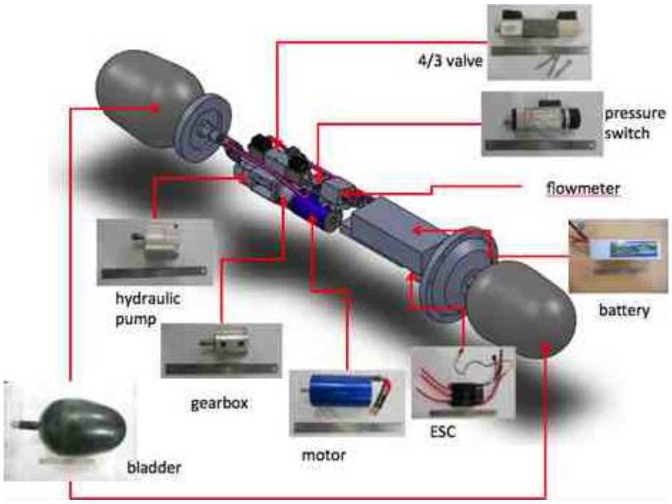

Figure 5 Bouyancy Engine General Arrangement

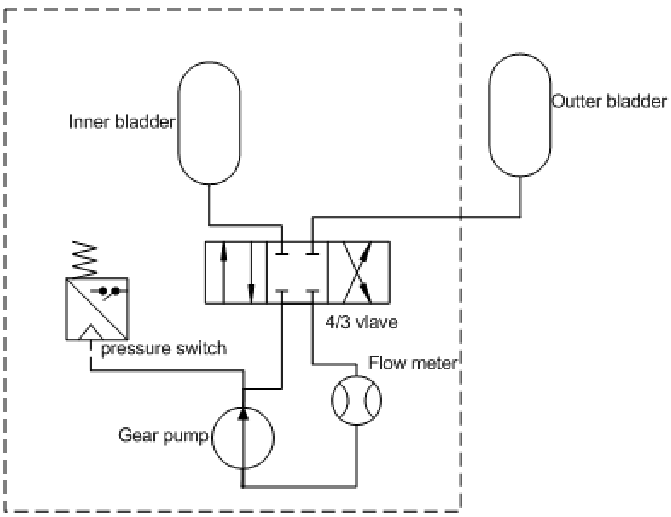

Figure 6 ITB Hybrid AUV Bouyancy engine hydraulic schematic

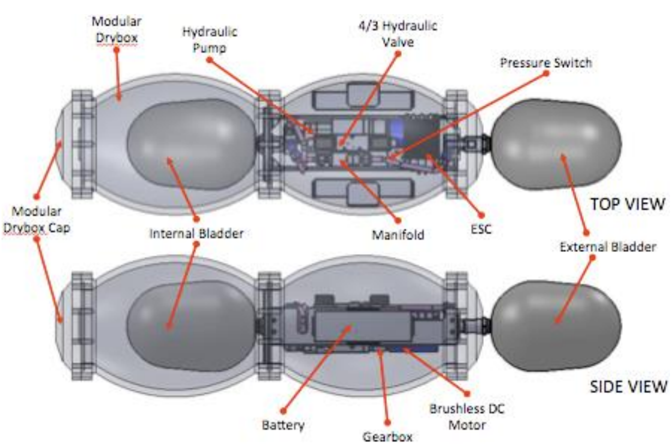

Figure 7 Bouyancy Engine overall configuration

II. System Design

There are some important aspects that must be taken into consideration to design this buoyancy engine. Based on the design requirement and objectives of this hybrid AUV, methods to fulfill the requirement has been established. The first step is to select and decide the correct buoyancy engine mechanism. There are so many buoyancy engine types that are already applied in the underwater vehicle applications [4]. All of them had been compared to and compromised with the availability component on the market. The buoyancy engine that is suitable for the hybrid AUV has already been compared carefully. Finally the buoyancy engine mechanism of this hybrid AUV is generally the adoption of hydraulic oil bidirectional pump [1][4]. The schematic of ITB Hybrid AUV buoyancy engine is described in Figure 6.

To make this buoyancy engine work properly, there are some required supporting parts such as hydraulic pump, bladder, electric motor, pressure switch, power system and also the controller. All of this buoyancy engine with special drybox must be sufficient to hold the pressure until 2500 m. The final configuration of this system is shown in Figure 7.

There are some critical parts that need to be designed and analyzed in order to accommodate the high operating pressure. One of them is manifold that is functioned as the main platform for hydraulic fluid distribution [3]. To ensure that this part would survive at the operating pressure, finite element analysis was conducted to support the design process of this part. The result of the finite element analysis of this part is shown in Figure 9. The final assembly of this buoyancy engine is shown in Figure 8.

Figure 8 Bouyancy engine full assembly

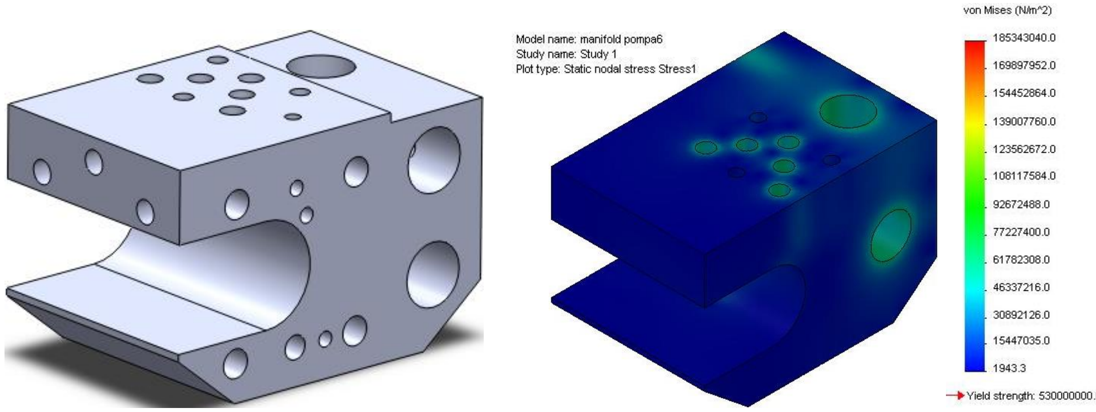

Figure 9 Finite element analysis of Manifold Bouyancy Engine

III. TEST METHOD

As described in the previous section, there are several series of tests that have been conducted for this buoyancy engine. The first test is in the laboratory. The main purpose of this test is to test the buoyancy engine under the simulated operating pressure. The simulated environment is provided by pressure chamber. The test setup is described in Figure 10.

This test setup is expected to produce the following results:

- Variation flow rate with different external operating pressure
- Mechanical efficiency of system
- Overall efficiency system
- Endurance or maximum cycle

The buoyancy engine is designed with specific displacement, buoyancy, and center of gravity. Before being deployed into the water, this system must pass the static loading test as illustrated in Figure 11.

And the results are:

- A: distance from scale to support (mm) = 456.5 mm
- B: distance from CoG to support (mm)
- C: distance from support to absolute origin = 187.5 mm
- W: buoyancy engine weight (kg)
- R: support reaction force (kg)
- P: scale reaction force (kg)

The static buoyancy test was also conducted to ensure the exact capacity of buoyancy engine. The procedure of this test is shown in Figure 12.

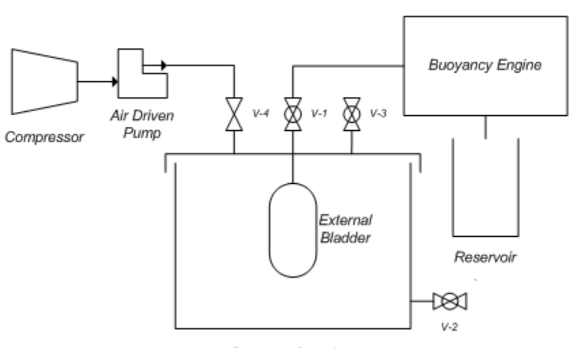

Figure 10 Pressure chamber testing setup

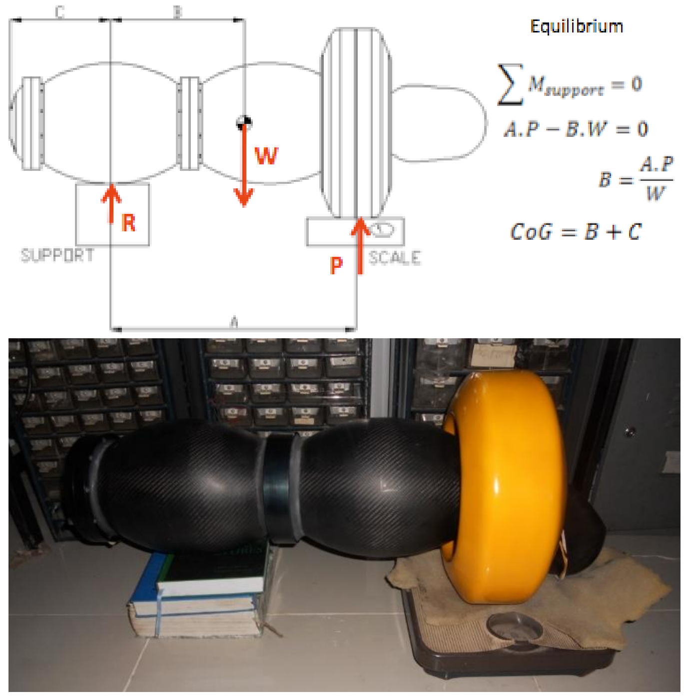

Figure 11 Center of Gravity Testing and measurement

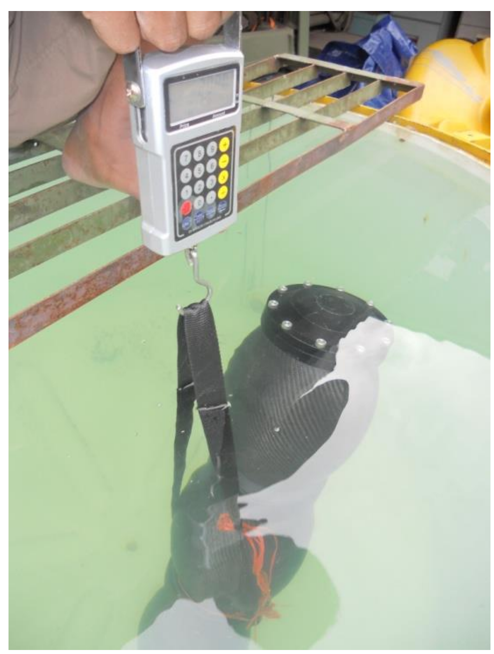

Figure 12 Static Bouyancy testing

IV. Test Results and Analysis

The series of all tests step by step is described as follow:

A. Pressure chamber test setup

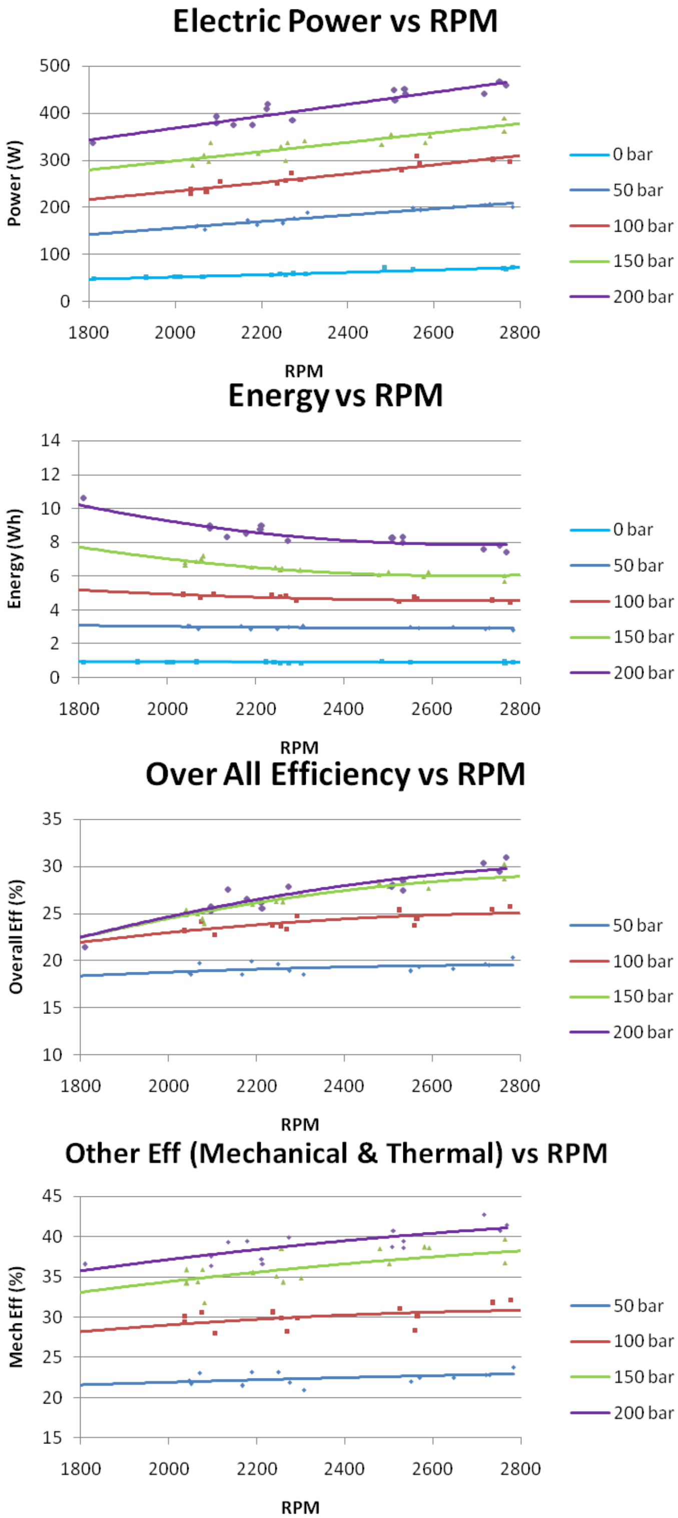

Figure 13 Buoyancy engine performance inside the pressure chamber testing results

B. Static buoyancy test

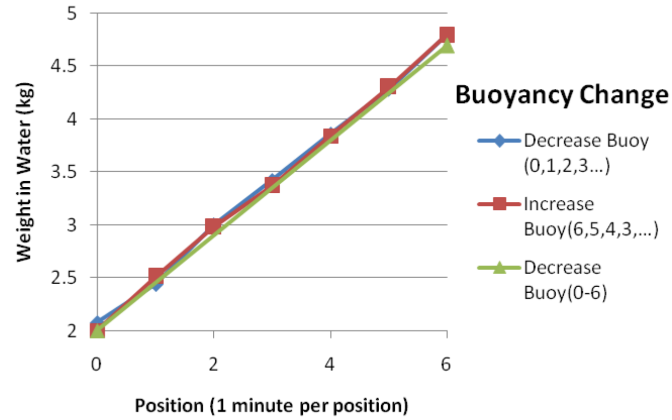

Figure 14 Static buoyancy test results

C. Pool test

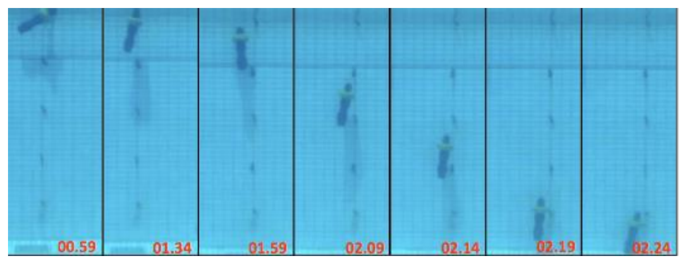

Figure 15 Pool test of buoyancy engine (descending)

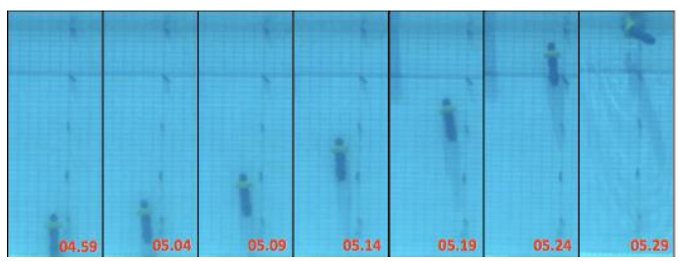

Figure 16 Pool test of buoyancy engine (ascending)

V. Conclusion

From the test result data above we can make some notes and conclusions as follow:

1. All tests series that were already conducted to the buoyancy engine ITB Hybrid AUV have shown good result.

Table 1 Buoyancy engine specification

Operating Depth	2500 m
Weight on Air	22.99 kg
Dimension (Length × Diameter)	886 mm × 225 mm
Operating Bouyancy Change	3.94 kg
Bouyancy Change Rate	0.46 kg/min.

2. The next test will be conducted in the open sea environment with real operating depth, to ensure all buoyancy engine will work properly before being integrated into the hybrid AUV control system.
3. For further study, the buoyancy engine will be tested by operating it with several types of batteries.

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