

# Recent Advances in Diver Propulsion Vehicle (DPV) Ganendra RI-1: Design, Analysis, Manufacture and Performance

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**Abstract**—A diver propulsion vehicle (DPV) Ganendra RI-1, also known as an underwater propulsion vehicle or underwater scooter is an item of equipment used by scuba divers and rebreather divers underwater to increase the range. DPV has done the final stages of design, analysis, manufacturing, and performance test. The design has been completed to determine mechanical, electrical, and propulsion systems. Continued analysis of both structural analysis, and flow analysis that allows whether DPV is feasible to proceed in the next stage. Manufacturing has been done for RIB work that is by using 3-axis CNC machine. Performance of DPV has been done experiment, with thrust maximum up to 50 kgf, using 48 Volt and 80 Ah lithium-Fe battery, has been obtained maximum speed of DPV is 3.5 knots, endurance operational to 3 hours with operational depth up to 7 meters.

**Keywords**—Scuba divers, propulsion system, CNC machine

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## I. INTRODUCTION

A Diver Propulsion Vehicle (DPV) Ganendra RI-1, also known as an underwater propulsion vehicle or underwater scooter is an item of equipment used by scuba diving and rebreather divers underwater to increase the range. The range is limited by the amount of breathing gas that can be done, the rate at which the breathing gas consumed under power, and the time limits imposed by the dive tables to avoid decompression sickness [1].

DPV is a high-tech device built to the latest standards and safe to use. Using a CNC machine [2,3] for the rib structure with a coated composite material [4,5].

In the DPV operation, there is information for diver safety and safety of the DPV itself. Safety from the diver that must be required is to use complete dive equipment [6,7]. Continue to safety from DPV that must pay attention to propeller, piezoelectric button, safety system and battery [8], [9]. It aims to make DPV can be operated safely and can be used for diving.

## II. DESIGN OF DPV

In order to maintain the security and sovereignty of the territorial waters of Indonesia, required a vehicle that has the following characteristics, concise, agile, tough, versatile. DPV Ganendra RI-1 was developed with the pursuit of the four points above [10].

A design methodology is a time proven sequence of stages and procedures followed to plan, define, design, build, test, and implement a specific type of system. The initial stages clarify exactly what it is you are trying to accomplish with your design. The design of a DPV is classified in following steps [11]:

- Propose Design
- Analytical Analysis of Design Concept
- Choose Concept Design

However the design is progressed in the following main areas:

- A. *Design of Mechanical System*
- B. *Design of Electrical System*
- C. *Design of Propulsion System*

The design of a DPV is an iterative process. We need to optimize the size, weight, equipment and propulsion device on the basis of mission requirement.

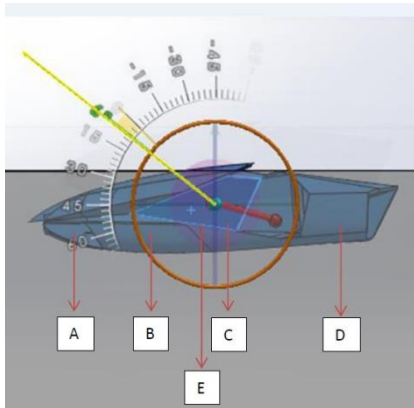
- A. *Design of Mechanical System*

In making DPV Section mechanical System that determines the buoyancy, weight, and size of vehicle, and leakage system of the vehicle.

- 1) *The determining stage of weight and buoyancy*

Buoyancy is a top priority in the design process of mechanical system [12], because in determining the right buoyancy will ease the process of using DPV. Continued weight determination also have relationship with buoyancy DPV design must have positive buoyancy, that is upward force is bigger than weight of DPV [13]. The weight of each on the images are, A = 7 kg, B = 21 kg, C = 23 kg, D = 12 kg, E = 87 kg, while the volume of DPV itself is  $\geq 149$  liters. So the DPV condition that is still have lift force up to volume of 1 liter

multiplied by mass of type from fresh water and also sea water [14].



**Figure 1** Weight and buoyancy of DPV

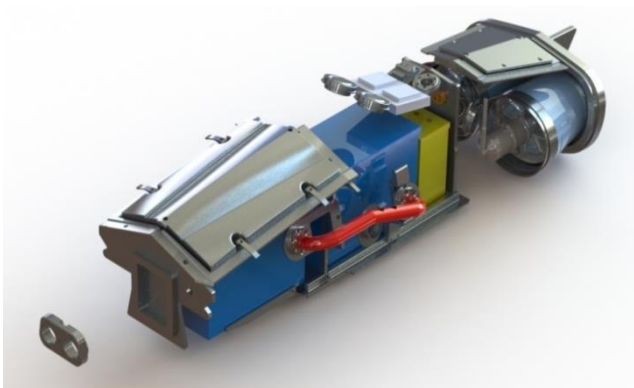
### 2) The shape of DPV

The measure itself is a consideration of the determination of buoyancy and the appropriate weight then the dimension will be adjusted and also associated with hydrodynamic analysis of the design. Design the size shape will affect the drag style of the vehicle itself, and should be made as detailed as possible and smooth, so that the drag style of DPV light so that the performance of good DPV. Changes in DPV design experience several stages from version 1 to 3, where in each version there is a dimension to the buoyancy effect of DPV.



**Figure 2** Version of DPV from model 1 to model 3

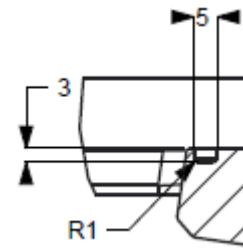
Form of interior design that is frame / rib to strengthen skin or surface. The frame design itself undergoes a change due to the structural and weight analysis that is appropriate to dpv. Here is a look for frame / rib design from DPV with aluminum material 5052 [15].



**Figure 3** Parts of DPV

### 3) For leakage of system

Make design with seal size 5 mm in diameter, with rubber silicon material [16]. The design of the leakage system is to create a trench with a semicircular dimension of  $\phi 5$  mm, it aims to avoid water entering the DPV system, where the inside of DPV consists of battery, electrical system and display. System seal for leaks alone has been tested with a depth of up to 30 meters [17].



**Figure 4** Sealing system design

### B. Design of Electrical System

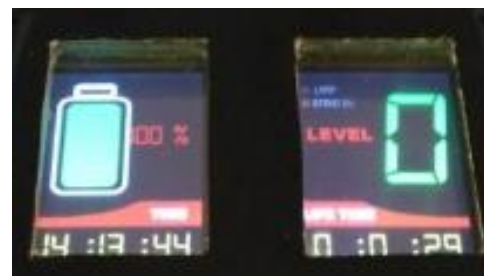
Things to consider in the preparation of electrical system design that is underwater lamp, instrument display box, safety system, power switch, electronics board [18], [19].

#### 1) Underwater lamp



**Figure 5** Underwater lamp

#### 2) Instrument display box



**Figure 6** Display box

#### 3) Safety System

Safety system is a component used as a safety in anticipating DPV separated from the user. This tool allows users and DPV survived in case of off-load control in the operation in the field. The system of this tool is using 2 magnets as on/off of the system. If one of the tools off then the system will immediately die and automatic DPV will not working.

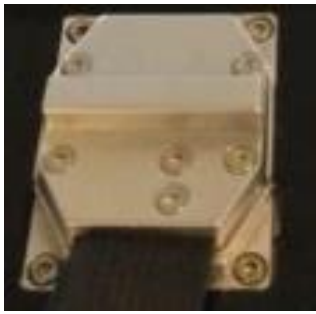


Figure 7 Safety system

4) Power Switch

Power switch is a section that serves to turn on and off the DPV system. This water-resistant power switch is designed using aluminum material that is resistant to corrosion of seawater with a coated sealing system of rubber material.



Figure 8 Power switch

5) Battery

Battery is the main current source in DPV operation. Specification of the battery itself is a type of Lithium-Fe 48 Volt 40 Ah.

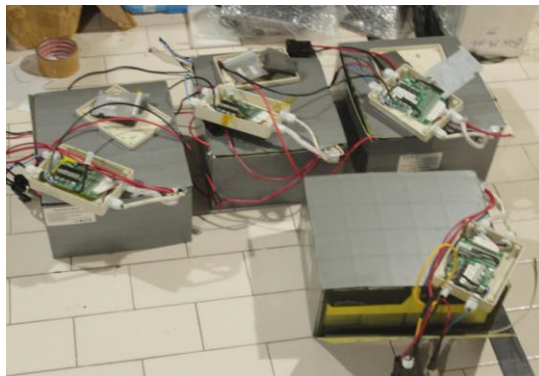


Figure 9 Battery

6) Electronics Board

Electronic box is designed to control all components including thruster, lamp, battery, safety system and display. Electronic board itself as the heart of DPV, because it is very important in the regulator of all electrical systems and systems that allow to turning on the thruster. Electronic board is designed to be waterproof and can also heat transfer from the system.

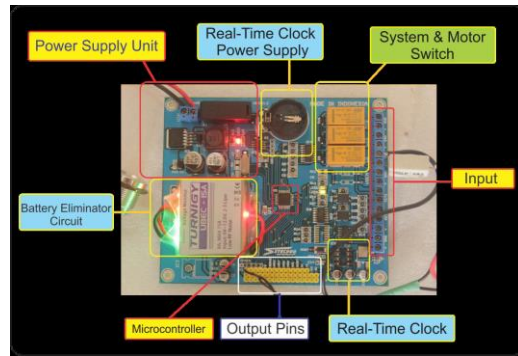
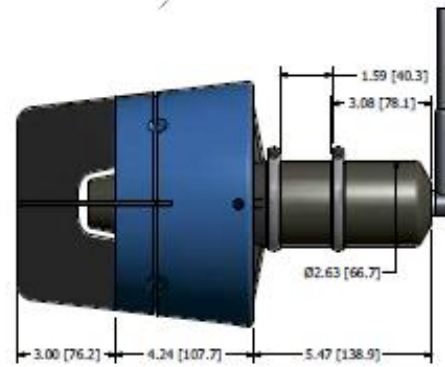


Figure 10 Electronics box

C. Design of Propulsion System

Propulsion system from DPV is using thruster with specification reach 50 kgf, it is related to simulation flow result from DPV where requirement drag force from simulation reach 30 kgf [20].



(a)



(b)

Figure 11 (a) Side view of thruster [23].  
(b) Rear view of thruster [23].

III. STRUCTURE AND FLOW SIMULATION ANALYSIS

Analysis of the structure itself is used in determining the strength of the material in the manufacture of DPV that must withstand the pressure of 4 atm, or depth reaches 30 meters. Then the flow analysis is used in determining the force of the thrust required to push the DPV to a certain speed. Both of these are very important in the process of manufacturing DPV.

### A. Structure Analysis

The finite element analysis (FEA) is a numerical technique for finding approximate solutions to boundary value problems for partial differential equations. In the implementation of the principle of minimum potential energy as the basis of approximate solutions by means of the finite element method of analysis, the region under consideration is divided into a finite number of sub regions, say  $N$ , called “elements” (Figure 12).

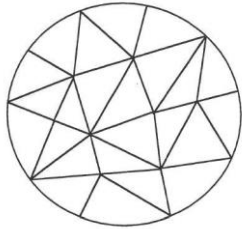


Figure 12 Division of a region into sub regions [26]

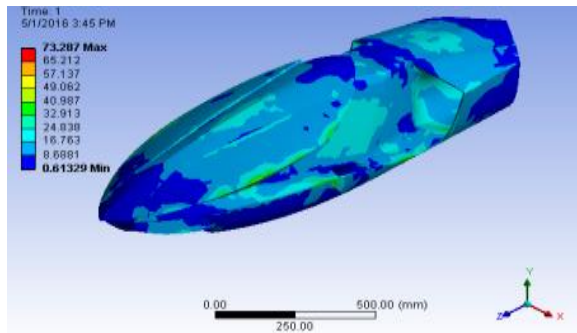


Figure 13 Maximum stress is 73.287 MPa

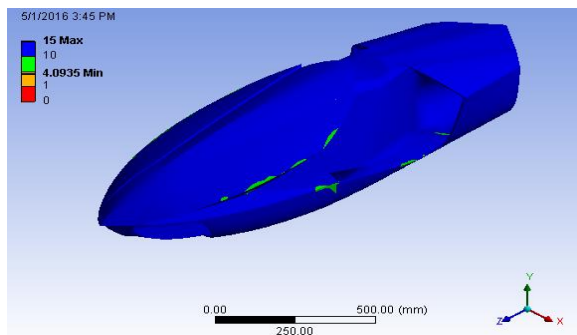


Figure 14 Safety factor of DPV

Also known as safety factor (SF), is a term describing the capacity of a system beyond the expected loads or actual loads. Essentially, the factor of safety is how much stronger the system is than it usually needs to be for an intended load. Buildings commonly use a factor of safety of 2.0, pressure vessels use 3.5 to 4.0, automobiles use 3.0, and aircraft and spacecraft use 1.2 to 3.0 [21]. Simulations are carried out by the above input parameters, with a load pressure 0.5 MPa in out of surface diver propulsion vehicle. For the purpose of analysis, figure of the results are stress and safety factor of the DPV Ganendra RI-1.

### B. Flow Simulation Analysis

Computational fluid dynamics (CFD) are having a strong impact on both ship design and model test evaluation. The impact on ship model basins is occurring in a number of ways. As applications for CFD increase, the purpose of ship model tests is shifting from evaluation to validation. Also, systematic series investigations are becoming computer based rather than experiment based. Model tests required by the designer are becoming more selective and, when performed, include more detailed measurements. Also, extensive flow measurement experiments are conducted today for verification of CFD results [22]. Based on the simulation for DPV flow obtained is the magnitude of drag force of 30.57 kgf for speed 5 knots. This is a consideration in determining the type of thruster in the process of use in DPV.

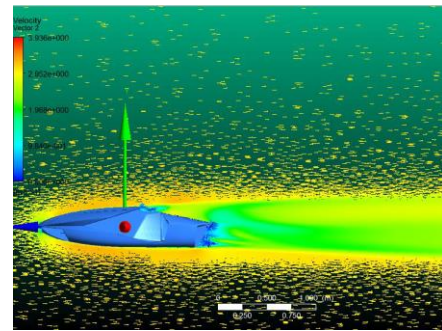


Figure 15 Drag force for flow simulation of DPV

## IV. MANUFACTURING PROCESS OF DPV

The manufacturing process in the DPV workmanship processes are CNC workmanship, Integration between RIB with composite with vacuum assisted resin infusion (VARI) method, assembly electrical part and functional check of DPV.

### A. CNC Process

CNC machining process is used to work on the framework of DPV made of Aluminum 5052 series. The process itself is done after the completion of the design stage in the form of RIB that has been done detail dimension checking of RIB. The works process using CNC machine type Hartford LG-1000, 3 Axis Vertical Machine Center.



Figure 16 LG-1000, 3 axes, Vertical Machine Center

**B. Integration**

Integration process is the process of unification between RIB aluminum with composite. The process is done with vacuum assisted resin infusion (VARI) method. The vacuum infusion process uses Busch vacuum pump model RA-063L with specification 63 m<sup>3</sup> / h. The integration process required by the operator in the checking process of integration, whether it is strong enough or not combined between aluminum with composite. This determines the quality of DPV made that is resistant to depths up to 7 meters.



**Figure 17 Composite manufacture results**

**C. Assembly Process**

Assembly process is the stage where the unification of all components of DPV is in the form of unification of all mechanical, electrical, and propulsion system. This stage is the final stage in making DPV. After all system assembled and checked for DPV, that is checking function after assembly process. Here is the look after the whole system in assembly.



**Figure 18 Manufacturing result of DPV**

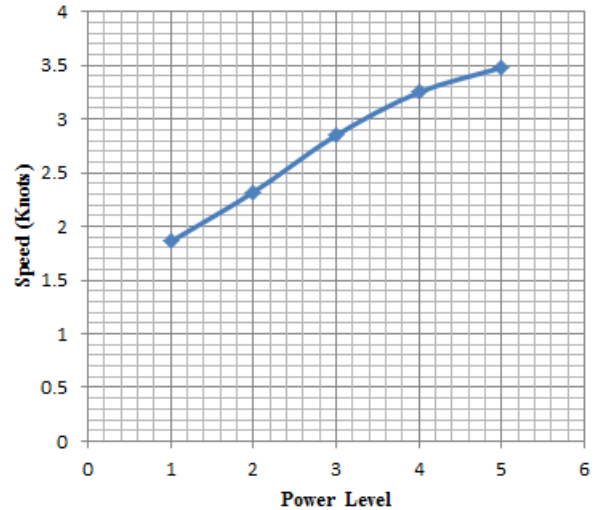
**V. PERFORMANCE OF DPV**

It is a goal created from DPV that is obtained maximum performance that will be used in the process of dive and its operation is used easily. Performance DPV tested in swimming pool and sea. The test is done to get the performance of DPV

that are in the form of speed, endurance, maneuver and depth test operation.

**A. Speed Testing**

Speed test is to test the maximum performance obtained from DPV by using a speed measuring instrument with a maximum speed of DPV is 3.5 knots. Here is a graph of the maximum speed measurement results of DPV.



**Figure 19 Speed test of DPV**



**(a)**



**(b)**

**Figure 20: (a) Leakage and maneuver testing; (b) depth sensor indicator for depth testing**

### B. Endurance testing

Namely the layout of how long for the operation of DPV in the operation, based on the test data test that has been done that reaches 3 hours more in operation.

### C. Maneuver test

Namely testing the operation of DPV with varying angle turns, starting from 45, 90, 180 and 360 degrees. This shows the maximum performance in terms of ergonomic design handle. Testing with the angle as above has been done with the design handle is feasible because it can operate with a predetermined angle.

### D. Testing leakage and depth of operation

Leakage testing and depth of operation is done at sea with a depth of 7 meters. It aims to test the capabilities of DPV based on data analysis and applied in experimental. Here is the result of leakage test and inside of DPV.

## VI. CONCLUSION

This work presents a diver propulsion vehicle (DPV) Ganendra RI-1, also known as an underwater propulsion vehicle or underwater scooter is an item of equipment used by scuba divers and rebreather divers underwater to increase the range. DPV has done the final stages of Design, Analysis, Manufacturing and Performance Testing. The design has been completed to determine mechanical, electrical, and propulsion systems. Mechanical systems consist of determination of shape, buoyancy, weight and leakage. Electrical system consists of determination of underwater lamp, instrument display box, safety system, power switch, electronics board. Propulsion system from DPV is using thruster with specification reach 50 kgf, it is related to simulation flow result from DPV where requirement drag force from simulation reach 30.57 kgf. Continued analysis of both structural analysis, and flow analysis that allows whether DPV is feasible proceed to the next stage. The structural analysis process obtained for safety factor 4 and for flow simulation drag force is obtained at 30.57 kgf. Manufacturing has been done for RIB work that is by using 3-axis CNC machine and also welding process for handle of DPV. After the CNC process continued with the integration process with fiber reinforced composite using vacuum-Assisted Resin Infusion (VARI) process. Performance of DPV has been done experiment, with thrust maximum up to 50 kgf and using 48 Volt and 80 Ah Lithium-Fe battery, have been obtained maximum speed of DPV is 3.5 knots, endurance operational to 3 hours with operational depth up to 7 meters. For further research is to improve the performance of DPV either in the form of speed, endurance, and depth in operation.

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