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Manufacturing Process of Diver Propulsion Vehicle

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Abstract—A diver propulsion vehicle (DPV) Ganendra RI-1 mk. II, 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 and speed of exploration. The Diver Propulsion Vehicle is a good concept for spying and underwater documentation device. The design of the Diver Propulsion Vehicle is compact and sturdy to make it easy to be carried by two persons. The material used was fiber reinforced composite. The manufacturing process employed for this product is Vacuum Assisted Resin Infusion (VARI) process. The ultimate tensile test of the prototype's shell (GFRP) is 330.45 MPa. The prototype accomplished 150 mins dive at an average speed of 3.5 knots without any leaks.

Keywords— DPV, composite, glass-fiber, polyester, VARI

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I. Introduction

DPV is a device that is specifically developed to assist diver to maneuver in a fast and precise manner. The concept of Diver Propulsion Vehicle has allowed the design and engineering team to deliver a rugged, and compact underwater vehicle that requires only two persons to carry and maintain. The use of Diver Propulsion Vehicle enables a safer deployment near the shore and eliminates the need of deploying diver right into the service area.

Due to its tough service environment, Diver Propulsion Vehicle needs to be tough yet portable enough to be carried and endure its whole operation. In order to achieve such properties, we need to combine a few orientation arrangements of the fiber in the Fiber Reinforced Plastic, therefore delivering an ideal strength to weight ratio. The manufacturing process has a critical role since the composite properties will vary depending on its manufacturing process. The Vacuum Assisted Resin Infusion process was used in this project to deliver the required properties in a labor effective and timely manner.

Figure 1 Diver Propulsion Vehicle

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II. Design

Starting from the design of Diver Propulsion Vehicle delivered by our designer team, accompanied with the specification shown at **Table 1**, it becomes clear that the design requires light and strong material properties. The Diver Propulsion Vehicle design is shown at **Figure 1**.

Table 1 Diver Propulsion Vehicle specifications

Specifications	
Weight (kg)	140
Motor output (kW)	1.5
Maximum speed (knots)	3.5
Maximum depth (m)	10
Maximum operation time (min)	180

This Diver Propulsion Vehicle has a hydrodinamically optimized design that is compact and sturdy. The internal parts of the Diver Propulsion Vehicle are shown at **Figure 2**.

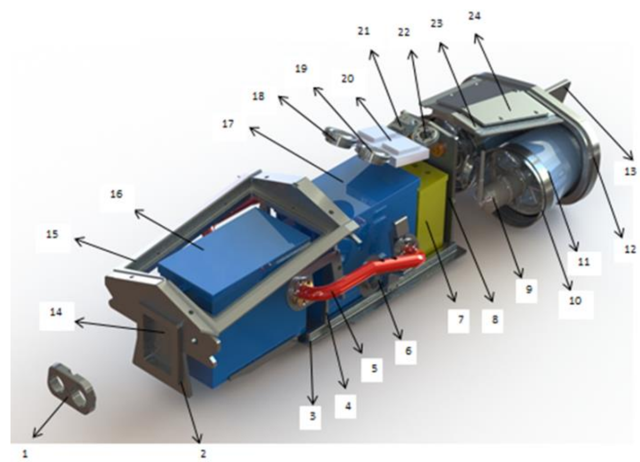

Figure 2 Parts of Diver Propulsion Vehicle

III. Material Selection

Since the Diver Propulsion Vehicle requires light material with good strength, Aluminum ribs laminated by Fiber reinforced plastic composite is one of a few materials that is able to fulfill the requirement. The specification of the aluminum ribs and the fiber is shown in **Table 2**.

Table 2 Material specifications

	Density (g/cm^3)	**Specific Strength**
Aluminum	2.68	7201
Glass-FRP	2.1	571

All control surfaces use glass fiber with 45 degrees of orientation to prevent the parts to twist. Aluminum 5052 with density 2.68 g/cm^3 is used in all critical part of the body assembly to keep the whole body rigid and keeping its shape. The Aluminum ribs also enable the body to absorb impact energy very well. The glass fiber reinforced plastic used in the belly part provides great durability, since the belly part is prone to friction and impact.

IV. MANUFACTURING AND TEST

The manufacturing process we used in this product was vacuum assisted resin infusion (VARI) method. The vacuum infusion process uses Busch vacuum pump model RA-063L with specification 63 m^3/h. The parameter we used in the process shown at **Table 3**.

Table 3 Vacuum infusion parameters

Parameters	
Vacuum speed (m^3/h)	63
Pressure (bar)	1x10^{-2}
Viscosity (Poise)	4.5-5.0
Curing time (hours)	8
Gel time (minutes)	45
Temperature (K)	300
Resin input source	1

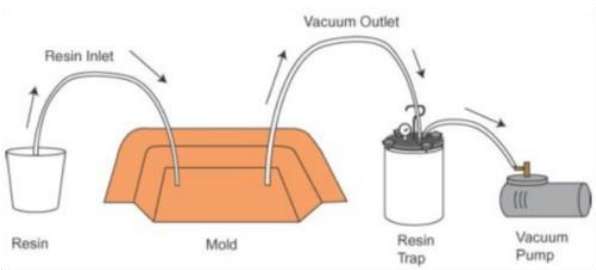

Figure 3 Vacuum infusion schematic [1]

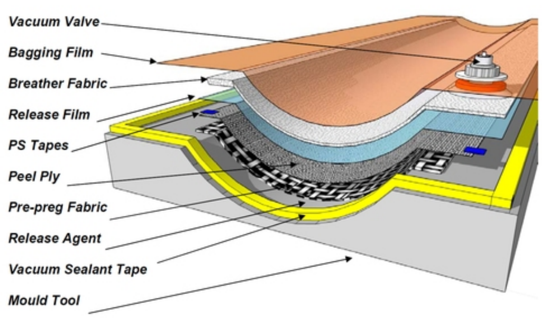

Figure 4 Infusion layers [2]

Figure 3 is the schematic figure of vacuum infusion process and the infusion layer is shown in **Figure 4**.

In this infusion process, the mold used is made of fiberglass. The result shows that there are small amounts of void left. The void occurred because of the mold shape is quite irregular, consisting of many crevices. To obtain a better result thus removing remaining void, the resin infusion rate was increased. The GFRP from infusion process is tested in Institut Teknologi Bandung (ITB) facility by using Tarno Grocki machine. The tensile test curve is shown in **Figure 5.** The result shows that the actual material properties is still far from the theoretical calculation [3,5].

The dive test is done in a specialized pool. The product is equipped with 50kg of thrust from the twin motor powered by 80 Ah Li-Fe batteries. The prototype tested to flew for 150 min with 4 km/h average speed. The product managed to pass the test and shows that the current material and design are still applicable.

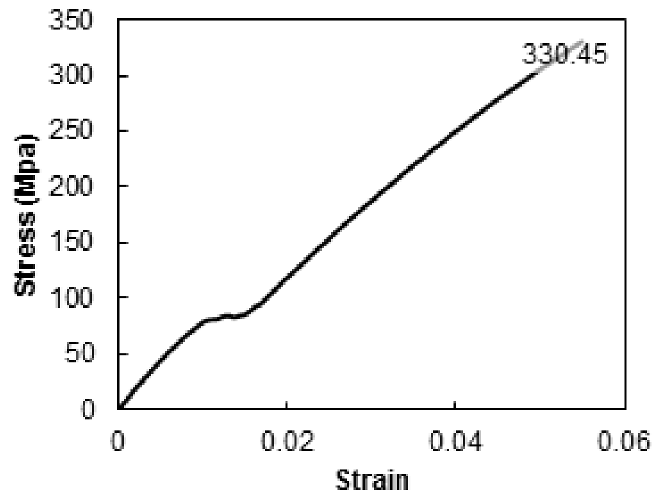

Figure 5 Measured tensile stress

V. FUTURE WORK

The low tensile test result may be caused by the viscosity of the epoxy that was still too high. The high viscosity may lead to bad impregnation. By modifying the viscosity of epoxy in the future we may get better tensile strength. To get lower viscosity of epoxy, the temperature needs to be increased to about 310K. The viscosity of epoxy will drop significantly by just moderate heat.

However, increasing the temperature may lead to a faster gel time. To achieve longer gel time, the amount of epoxy hardener need to be changed so that the epoxy still has enough time to impregnate the fiber in all the part during infusion process.

The current mold we used is made with fiberglass. It was hard to make the FRP to stick and allows a perfect flow of resin within the mold [4]. By changing the resin infusion rate, a better infusion and a complete elimination of void may be achieved. The absence of void will further improve the tensile strength and the Diver Propulsion Vehicle can withstand even more external forces it might encounter during its operation.

VI. CONCLUSION

The Diver Propulsion Vehicle is a good concept for spying and aerial documentation device. Since the Diver Propulsion Vehicle's compact and modular design allows an easy assembly enhancing the portability even further. The fiberglass reinforced plastic is a good choice for the whole housing since it provides both protection from water, has good strength while at the same time maintains lightweights for easy transportation.

The ultimate tensile test of the FRP structure of the product is 330.45 MPa. The product succeeded to dive for 150 min at an average speed of 6 km/h and proved to be water tight. The vacuum assisted resin infusion manufacturing process is capable to produce the Diver Propulsion Vehicle but the mold design and infusion rate need to be improved to prevent the forming of void [6]. The viscosity of epoxy also needs to be decreased to ensure a homogenous impregnation [7].

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