Roboboat 2021: Technical Design Report

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Abstract*— Aterkia 6.0 is a fully autonomous surface vehicle (ASV) designed by Team Aterkia Diponegoro University with a custom modular catamaran hull made for entering the 2021 International RoboBoat Competition. Aterkia 6 Diponegoro only focuses on completing the first 3 courses, namely the Mandatory Navigation Channel, Speed Challenge, and Obstacle Channel. Aterkia 6 Diponegoro will have two main approaches that dominated the whole proposed strategy: (1) Rearranging the team management system. (2) Redesign and recompose the method to each course from the previous competitions and Upgrading the boat's hardware, software, and grand design.

***Keywords*—catamaran, courses, strategy, system, design (*key words*)**

I. Introduction

Aterkia 6.0 is Team Aterkia Diponegoro University's boat designed specifically for competing in the 2021 International RoboBoat Competition. This year, The Electrical and Programming Team is responsible for the entire process of designing and manufacturing the electrical system, navigation, and vision on the ship. Aterkia Diponegoro still uses Arduino-IDE as software to develop main programs for autonomous vessels. Aterkia 6 team will use PX4 Autopilot as the main software in developing a ship control system.

This Technical Design Report focuses on the competition strategy of the team, the design creativity, and the experimental results of Team Aterkia Diponegoro University's endless struggle. This shipbuilding method is different from the previous ship on our previous ship, the Diponegoro 6 Aterkia ship was designed using carbon material.

II. Competition Strategy

After considering insufficient resources with minimal time and space due to the Covid-19 pandemic, Aterkia 6 Diponegoro will only focus on completing the first two courses, namely the Mandatory Navigation, Speed Challenge, and Obstacle Channel. With several strategic approaches such as developing more integrated L1 control techniques, developing software and hardware that are more integrated, and achieving more exellent team management, the appereance of Aterkia 6 Diponegoro in the International Roboboat Competition will be better. Aterkia 6 Diponegoro will have two main approaches that dominate the proposed strategy: (1) Rearrange the team management system. (2) Redesign and recompose the method to each course from the previous competitions and Upgrading the boat's hardware, software, and grand design.

A. Team Management

In this competition, the Aterkia Diponegoro team comprises four central departments: Top management, Non-technical team, Mechanical Team, and Electrical and Programming team. Drawing on the findings of Hambrick and Mason (1984) [1], researchers have suggested that top managers play a crucial role in strategic change, in as much as "strategic-level managers formulate the organizations' interpretation" [2] and design strategic responses. Hence, the top management will be responsible for the strategy designing in this team.

The top management team consists of a chairperson, vice-chairperson, treasurer, and secretary. The chairperson focuses on the team's leaderboat, designing organizational sustainability strategies such as team regeneration, cooperative relationboats with outsiders, relationboats with advisors, relationboats with competition parties, and the welfare of each team member. The vice-chairperson focuses on designing and supervising the competition strategy, starting from research planning, boat testing, division of labour, and time planning design. The treasurer is responsible for financial management and the inventory for the team as a whole. The secretary is responsible for document management.

Unlike the Aterkia 5 Diponegoro team, where there is no specific division of responsibility, each division will be divided into several subdivisions according to their work. The non-technical team is responsible for all competition matters outside the technical development of the boat. This team consists of three subdivisions, namely, (1) Sponsorboat and Media partner manager, (2) External Relations manager, and (3) Marketing and Social Media Manager. The mechanical team is responsible for the entire boatbuilding process, starting from the design, production, and finishing stages of the boat's body and propulsion system. This time, the mechanical team is divided into three subdivisions: the Boat Designer, Propulsion Specialist, and manufacturer subdivisions.

The Electrical and Programming Team is responsible for the entire process of designing and manufacturing the electrical system, navigation, and vision on the boat. Unlike last year, where the division of labour was not specific, this team will be divided into three main subdivisions. The first subdivision is the electrical specialist team which is responsible for designing electronic systems and electrical troubleshooting. The second is the navigation team responsible for designing the boat navigation algorithm, compiling the boat control program; the third is the computer vision team responsible for developing the object detection program and machine learning on boat vision.

B. *Course Strategy Approach*

Using the Aterkia 6 Diponegoro boat, the team will focus on developing more robust algorithms and control systems for each mission. However, the time allocation for each course is also an important point to remark.

a) Mandatory Navigation Channel and Speed Gate

On these two courses, the Aterkia 6 Team will rely on (1) the stability of the boat design; the design of the boat itself uses a catamaran hull design known for its high stability. (2) The Boat Navigation System: The navigation system proposed in this competition is the Waypoint tracking control. Waypoint tracking control is the planned desired route for the moving boat, given as a set of waypoints connected with straight lines [3]. Although the previous team Aterkia 5 Diponegoro had been executed the waypoint tracking control in the last competition, this team could not perform well due to some diffuties in collecting the waypoint data using an external gps and compass. Hence, the data sets of the waypoint were not accurate which affected the whole control system. Some difficulties that might occur when collecting the waypoint data was strongly because it was done without any of filter implemented on the Controller. This will make The resolution of the GPS and its sensitivity to position changes frequently upset the Waypoint data . Furthermore, The control technique system for the navigation system carried by the previous team were still used classic PID control with gain parameters obtained from manual tuning through trial and error. This method is less practical because, in reality, the conditions on the field will change so that the parameters must adjust to the conditions without having to be reset manually. Nevertheless, Arduino Due in which was the main controller used by the previous team would make the development of the PID Navigation more complex. In this competition, the Aterkia 6 team used a Pixhawk 2 controller integrated with a compass and GPS as the central Controller for the boat, Mission Planner as a ground station control, and Mavlink as the Communication Protocol. By carrying out some of the developments mentioned above, data retrieval can be done automatically. In addition, the data from GPS and Compass wich have been processed by PX4 will reduce the risk of problems that cause sensor data to be inaccurate. To develop a more robust controller, Team Aterkia 6 will combine the classical PID and L1 control, which has been embedded on the Pixhawk PX4. L1 Controller has presented a superior guiding (UAV) performance on curved trajectories [4]. The L1 Controller is the highest level steering controller. It accepts position targets (i.e., latitude, longitude points) and the vehicle's current speed and outputs a desired lateral acceleration fed into lower-level controllers (including the Steering Rate controller. The Aterkia 6 Team's development will undoubtedly increase the boat's performance in completing the two primary missions: the mandatory navigation channel and speed challenge.

b) Course obstacle channel

Course obstacle channel is a mission that the Aterkia 5 Diponegoro team has never been tried before. Hence, implementing the strategy in this mission is a new challenge for Aterkia 6 Diponegoro. After some considerations, this mission requires the boat to have a reliable vision and the camera to detect objects. However, Team Aterkia 6 has a lack of resources for research that part. Hence, the Aterkia 6 team are planning to use the PING-Parallax ultrasonic sensor as a replacement for the vision. This sensor will not be used to detect objects on the boat's left or right. Instead, the boat will move autonomously using waypoint tracking through the obstacle and avoid obstacles in front of it by detecting objects using the PING-Parallax sensor.

III. Design Creativity

A. *Sensors*

This team proposes PX4 Autopilot with the rover configuration to control our boat. Aterkia 6 Diponegoro will maximize the navigation development with three sensors incorporating the sensing ability of the boat : (1) (GPS) Global Positioning System. GPS used in this boat is GPS Here 2. This sensor will allow the boat to acquire its latitude and longitude point in real-time. (2) Magnetometer, also known as the compass. This sensor is built and integrated into the main controller Pixhawk PX4. By Sensing the Earth’s Magnetic Field, this sensor will update information on the heading of the boat. (3) accelerometer. The accelerometer will sense and measure the acceleration forces acting on the boat to determine the boat’s position in space and monitor the boat’s movement. By combining These sensors, a good navigation solution will be achieved to track the desired waypoint for the boat.

B. *Software Architecture*

For the last two consecutive years, Aterkia Diponegoro still uses Arduino-IDE to develop main programs for autonomous vessels. However, this year Aterkia 6 Dipongeoro team will use PX4 Autopilot as the leading software in developing a boat control system. The PX4 are the leading open source autopilot systems designed to control any unmanned vehicle, including rovers, boats, and even submarines. [5]. Using Mavlink as the communication protocol to develop the programming command, the communication between user and boat will be utilized. In the software design, two program modules work parallel in the tracking waypoint process, namely the boat controller and the obstacle avoidance module.

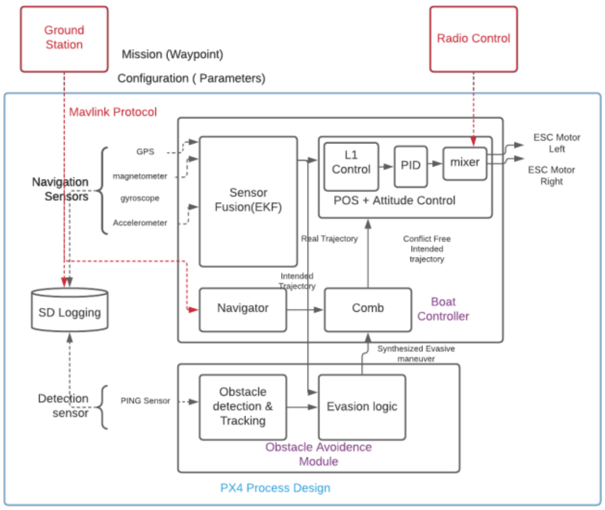

Fig. 1. PX4 Software Design

C. *Boat Controller*

Boat Controller is the core of this software design, where the Extended Kalman Filter (EKF) algorithm will combine sensor input and produce a navigation solution on the boat. (EKF) is very well known in performing sensor computation, this filter has three sensor processing blocks [6]:

- An AHRS (attitude and heading reference system) estimate the vehicle attitude and creates a direction vector used as a reference for vehicle displacement.
- An inertial navigation system (INS) to compute the trajectories and corrections when the vehicle moves between single points
- Enhancing the accuracy of sensor readings by reducing noise to produce navigation parameters on a vehicle.

Moreover, data from the EKF will be sent to L1 Control; L1 Control is the most powerful feature in updating lateral acceleration on this boat, the lateral acceleration will be essential for the PID controller in adjusting the steering motor so that the boat can continuously be on the desired path.

D. *Position and Attitude Control*

On the Position and Attitude Control Block. L1 Control and PID Controller will determine the steering output for the ESC Motor. AHRS and Waypoint that have been computed from the EKF then will be used to update the waypoint and produce the desired acceleration With L1 Control. The algorithm of the Controller shown as follows in Figure 2.

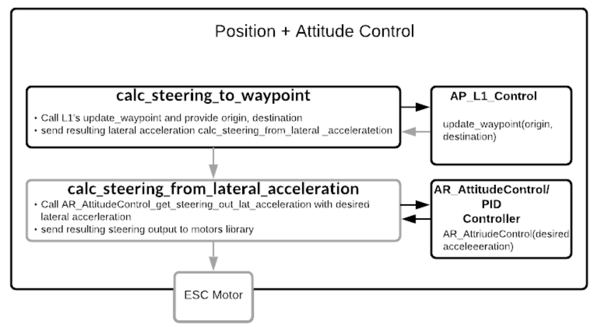

Fig. 2. Position + Attitude Control

1. The function calc steering to waypoint will call the update waypoint method from AP_L1_Control library's, providing it the location that the boat should drive towards.
2. The function update waypoint method on the AP_L1_Control returns a desired lateral acceleration which is passed into calc steering from lateral acceleration.
3. Calc steering from lateral acceleration sends the desired acceleration to AR Attitude Control which uses a PID controller to calculate a steering output.
4. The steering output is sent into the ESC Motors library using the set steering method and will make the boat stays in the desired trajectories.

E. *Obstacle Avoidance*

The design of the obstacle avoidance function will be implemented as a parallel application running simultaneously with the boat controller. As shown in Fig. 1, the data processing working with actual data will be working in a module embedded in the PX4 flight stack. This obstacle avoidance module in real-time receives the range sensor data to apply the obstacle detection logic. When triggered, this logic computes an appropriate evasive maneuver to be inserted in the intended trajectory to guarantee the safety conditions and keep the low impact in the user-predefined intended mission. For the development, this design is still in ongoing research and will only be a complementary system for the software.

F. Elektrical Architecture

Making a new development on the software architecture will likely significantly impact the electronic design on the boat. Hence, This year Aterkia 6 Dipoengoro is trying a new solution to make a compact electronic design with a sufficient power supply. Electronic Design covers three main electronic systems: Computation, Actuator, and Powering. Pixhawk PX4 Hex Cube Black is the main board to perform a computation for the sensor and actuator. Since the board has a modular design, all the sensor input could be attached serially to the connectors provided by the board. Electrical Speed Control controls the actuator (Motors) (ESC). The ESC is waterproofed and could hold up to 150 Ampere load equipped with a safety switch to obstruct any unintended errors caused by the wiring configuration. This team has managed the powering system into two main parts for the power supply on this boat. The first part is for supplying the computation process, which includes the mainboard and sensors. This part is powered with a four-cell Lippo battery with a 4050 mah capacity. The second part is for supplying the propulsion process. This part is powered by a four-cell battery with a 10000 mah capacity. The idea of separating the propulsion part from the computation is to prevent any accidentally cut-off caused by the battery that will affect the computation process. Hence, With this method, any potential cut-off will not affect other processes on the boat.

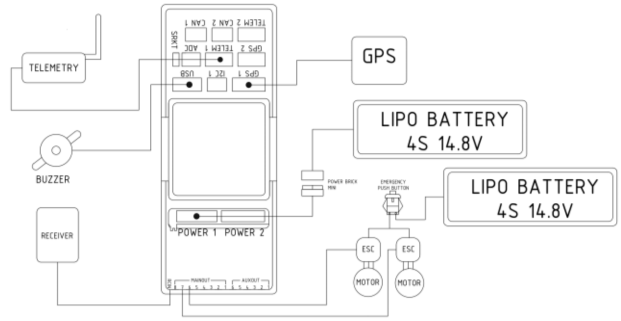

Fig. 3. Electronic Design

G. Boat Redesign

RoboBoat competition requires boats to use autonomous technology, so the boat must have good stability. The Aterkia 6 Diponegoro boat has a Lenght Overal of 102 cm, Height 14 cm, Draught 8 cm, and a Breadth 34 cm. The catamaran hull type was chosen from the comparison of the hull shape between monohull and catamaran because it has better stability than the monohull type. The catamaran hull shape has several advantages compared to a monohull boat. The deck area of the catamaran is relatively more expansive than the monohull boat. Furthermore, the immersed volume and the tiny wet surface of the catamaran will make the resistance smaller. Thus, the stability will be better [7].

On the other hand, there are some other improvements regarding the material of the boat. This year, the boat will be built using carbon material. This material has the advantages of being lighter than using balsa wood and fiberglass mainly used on the previous boat [8]. Hence, The advantages of carbon surely will cut the weight of this boat and reduce the level of resistance towards the hull.

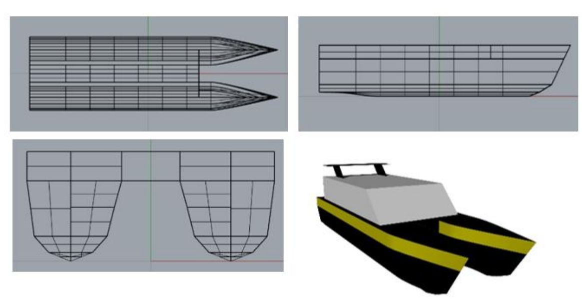

Fig. 4. Boat Redesign

IV. Experimental Result

In this section, the experimental results of the proposed strategy are showcasted. The experimental result covers the mandatory navigation channel, Speed Gate Challenge, Hull Stability, and the Material of the hull.

A. *Mandatory Navigation Chanel*

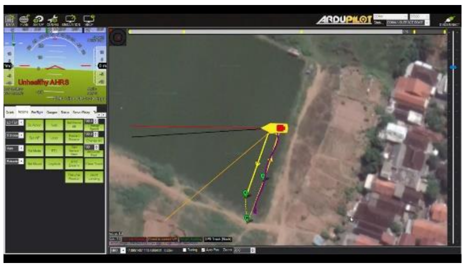

Fig. 5. Mandatory Navigation Channel

In the mandatory navigation channel,The boat must navigate autonomously between the gates without touching any of the buoys. By Looking at the footage, it is shown that the boat autonomously navigates 6ft from the gate. And by Placing several waypoints (latitude and longitude), the compass, GPS, and accelerometer automatically sense the navigation information (heading, longitude, latitude) and update the changes. This information will be helpful in the L1 control and PID controller to change speed and acceleration so the boat can stay on the desired path.

Furthermore. Based on GPS data on the graphic user interface. The EKF algorithm proposed in the strategy has successfully made the Navigation information accurate. It makes the boat track the actual waypoint smoothly.

B. *Speed Gate Challenge*

In the speed gate challenge, we have made two trials to test the sensor and controller of our boat. In the first trial, the sensor has sensed the navigation information accurately, but some oscillation occurs in several trajectories, it is mainly because of the changed parameters affected by the water wave. Thus, in the next trial, we have made some improvements by tuning the P I D controller of the boat.

In the second trial as in the figure 7, PID tuning has been executed. It shows that the Boat can navigate smoother then the first one. The use of EKF on both missions has successfully affected the navigation process of our Boat.

Although there is some room to improve, the Boat can moderately perform better in navigation in both missions, therefore, For further development, Aterkia 6 Diponegoro was looking forward to adding more sensors and using a different kind of protocols so more of the task could be done

Fig. 6. Speed Gate First Trial

Fig. 7. Speed Gare Second Trial

C. *Hull Stability*

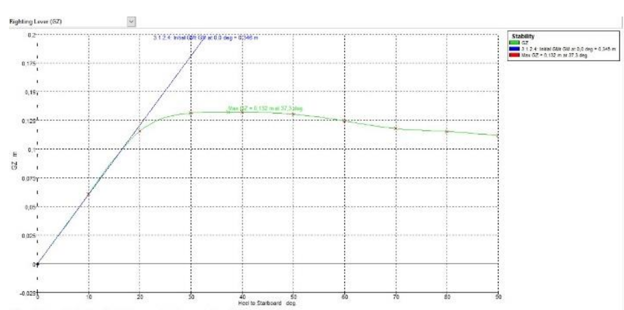

Fig. 9. Stability Graphic

	Heel to Starboard deg	0,0	10,0	20,0	30,0	40,0	50,0	60,0	70,0	80,0	90,0
1	GZ m	0,000	0,061	0,116	0,131	0,132	0,130	0,124	0,118	0,115	0,112
2	Area under GZ curve from zero heel	0,0000	0,3010	1,2037	2,4644	3,7855	5,1006	6,3767	7,5853	8,7486	9,8844
3	Displacement kg	8,000	8,000	8,000	7,999	8,000	8,000	8,000	8,000	8,000	8,000
4	Draft at FP m	0,059	0,058	0,053	0,033	0,004	-0,036	-0,095	-0,205	-0,519	n/a
5	Draft at AP m	0,057	0,056	0,052	0,032	0,003	-0,036	-0,093	-0,207	-0,563	n/a
6	WL Length m	0,966	0,978	0,989	0,991	0,991	0,990	0,990	0,991	0,998	1,013
7	Beam max extents on WL m	0,326	0,328	0,315	0,173	0,173	0,154	0,163	0,206	0,249	0,248
8	Wetted Area m^2	0,317	0,314	0,290	0,240	0,241	0,244	0,251	0,264	0,280	0,276
9	Waterpl. Area m^2	0,190	0,190	0,166	0,120	0,132	0,135	0,144	0,170	0,194	0,196
10	Prismatic coeff. (Cp)	0,867	0,860	0,865	0,870	0,870	0,873	0,872	0,858	0,794	0,723
11	Block coeff. (Cb)	0,422	0,320	0,287	0,517	0,545	0,659	0,644	0,558	0,526	0,521
12	LCB from amidsh. (+ve fwd) m	-0,050	-0,050	-0,050	-0,050	-0,050	-0,050	-0,050	-0,050	-0,049	-0,048
13	LCF from amidsh. (+ve fwd) m	-0,051	-0,050	-0,048	-0,044	-0,043	-0,036	-0,036	-0,047	-0,052	-0,044
14	Max deck inclination deg	0,1214	10,0004	20,0000	30,0000	40,0000	50,0000	60,0000	70,0000	80,0003	90,0000
15	Trim angle (+ve by stern) deg	-0,1214	-0,0940	-0,0186	-0,0366	-0,0448	-0,0137	0,0999	-0,1097	-2,5510	-90,000

Fig. 10. Stability Data Characteristic

The boat has good stability characteristics because the value of static stability and dynamic stability has a positive value up to an angle of 37.3, and the value of the coupling arm (GMT) is positive which indicates that the ship is in a state of positive stability where point G is below point G. M. This means that the ship has a maximum tilt angle of 37.3 and has a reversing force to a neutral angle.

D. *Material of The Hull*

TABLE 1. MATERIAL OF THE HULL

Power

Material	Fiber Mat	Carbon Fiber	Woven Roving
Fiber Mat	Moderate	High	High
Carbon Fiber	High	Moderate	High
Woven Roving	High	High	Very high

Weight

Material	Fiber Mat	Carbon Fiber	Woven Roving
Fiber Mat	Moderate	Light	Weight
Carbon Fiber	Light	Very Light	Weight
Woven Roving	Weight	Weight	Weight

The material selected: 2 layers of carbon fiber with a mixture of epoxy resin and 1: 1 hardener. The fiber mat inside is mined as reinforcement. Because carbon fiber has strong properties with a binding structure and is lightweight. With the addition of a fiber mat on the inside to strengthen the hull. Using a fiber mat because it is hard and not too heavy.

V. CONCLUSION

Aterkia 6 is a fully autonomous surface vehicle (ASV) designed by Team Aterkia Diponegoro University with a custom modular catamaran hull made for entering the 2021 International RoboBoat Competition. Aterkia 6 Diponegoro will only focus on completing the first two courses, namely the Mandatory Navigation, Speed Challenge, and Obstacle Channel. In this competition, the Aterkia 6 team used a Pixhawk 2 controller integrated with a compass and GPS as the central Controller for the boat, Mission Planner as a ground station control, and Mavlink as the Communication Protocol. the Aterkia 6 team are planning to use the PING-Parallax ultrasonic sensor as a replacement for the vision. This team proposes PX4 Autopilot with the rover configuration to control our boat. Aterkia 6 Diponegoro will maximize the navigation development with three sensors incorporating the sensing ability of the boat : (GPS) Global Positioning System, Magnetometer, and accelerometer. This year Aterkia 6 Dipongeoro team will use PX4 Autopilot as the leading software in developing a boat control system. On the Position and Attitude Control Block. L1 Control and PID Controller will determine the steering output for the ESC Motor. The design of the obstacle avoidance function will be implemented as a parallel application running simultaneously with the boat controller. Electronic Design covers three main electronic systems: Computation, Actuator, and Powering. Pixhawk PX4 Hex Cube Black is the main board to perform a computation for the sensor and actuator. The Aterkia 6 Diponegoro boat has a Lenght Overal of 102 cm, Height 14 cm, Draught 8 cm, and a Breadth 34 cm. On the other hand, there are some other improvements regarding the material of the boat. This year, the boat will be built using carbon material. PX4 Software proposed in the design creativity has successfully managed the waypoint tracking control of the boat from the experimental results. With robust sensors supported by EKF, the navigation information has become smoother. Hence, the process of tracking by the L1 control can perform better in navigating the boat. Furthermore, the carbon material that has been researched proved theoretically can make the boat's hull more stable. Although, this team has successfully tested and developed the strategy proposed. Nevertheless, there is still some room for improvement. Especially for the variety of the boat’s sensor

ACKNOWLEDGMENT

The participation of the UNDIP Aterkia Team in the 2021 International Roboboat Competition was made possible thanks to the support of various parties. First, the UNDIP Aterkia Team would like to thank UNDIP for providing moral and financial support to the UNDIP Aterkia team as well as facilities that support conducting research. Second, the UNDIP Aterkia Team would like to thank Dr. Iwan Setiawan, ST., MT as the supervisor in the preparation of the Technical Design Report. The Technical Design Report will not be well prepared without the guidance of Dr. Iwan Setiawan, ST., MT. Third, the UNDIP Aterkia Team also thanked DEKANAT UNDIP as the facilitator of the room used in conducting the research.

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Appendix.. 1 Material Research

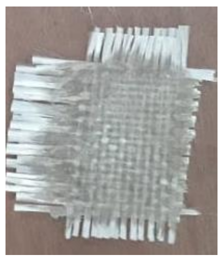

1 layered carbon fiber


2 layered carbon fiber


carbon fiber + fiber mat


1 layered fiber mat


carbon fiber + woven roving

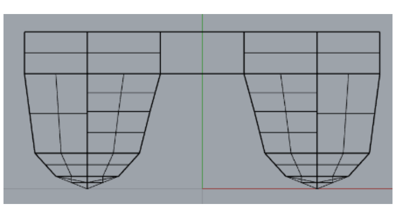

2 layered woven rovings

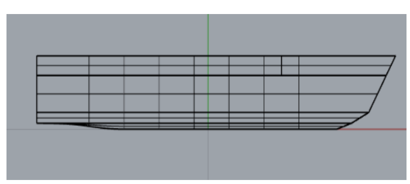

Fiber mat + woven roving

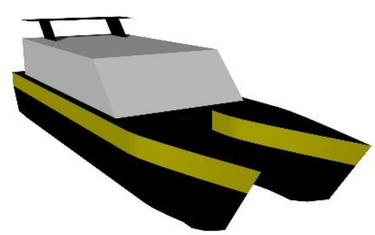

2 layered fiber mats

Carbon mix
157 1: 1 resin hardener: can not be stiff, a little sticky (can not dry)
157 2: 1 hardener resin: can be dry but not stiff
Epoxy resin 2: 1 hardener: dry, stiff
Epoxy resin 1: 1 hardener: dry, more rigid

Appendix 2. hull Design







Appendix 3. The Trial in real environment

Mandatory Navigation channel

Speed Gate

Component	Vendor	Model/Type	Specs	Cost (if new)	Status
ASV Hull form/platform	Carbon	Catamaran	Carbon 240 gsm	-	
Waterproof connectors					
Propulsion	Rudder				
Power system	ACCU	-	12 Ah		
Motor controls	Flycolor	Brushless ESC	150 A	USD 118.95	
CPU					
Teleoperation					
Compass	Hex	Here2	Compass, gyro, accelerometer : ICM20948 Barometer : MS561	USD 125	
Intertial Measurement Unit (IMU)					
Doppler Velocity Logger (DVL)					
Camera(s)	Logitech	C920	1080p	USD 94.46	
Hydrophones					
Aerial vehicle platform					
Motor and propeller	Blue Robotics	T200		USD 179	
Power system	Tattu	4S 25C Li-Po	1000 mAH		
Motor control		Brushless ESC			
CPU	Intel	NUC7i 5BNH	Intel i5	USD 528.27	
Camera(s)					
Autopilot					
Algorithms	EKF				
Vision					
Acoustics					
Localization and mapping					
Autonomy					
Team size (number of people)					
Expertise ratio (hardware vz software					
Testing time :simulation	Miison planne				
Terting time : in-water					
Inter-vehicle communication	MAvlink				
Programming language(s)	Python, Arduino/C				