Barelang MRT: MRT PURVI EVO

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***Abstract* - Team Barelang Marine Robotics is a team that takes part in the International Roboboat Competition which focuses on building robot ship prototypes. The MRT EVO ship has an Autonomous system and Navigation system that uses GPS neo 6, IMU BNO055, and Computer Vision uses the YOLO V5 method to complete predetermined tasks. The EVO MRT ship was designed using 3D design and fabricated using balsa wood putty and resin. MRT EVO has 3 Thrusters as ship propulsion motors and is equipped with water shooters and ball shooters, and has an electrical system as a control system to regulate the navigation system, propulsion system, and sensor system so that it can be regulated and moved efficiently. The results of making this Robot Ship will be contested at the ROBOBOAT 2023 event.**

Keywords - Autonomous system, automated sensor, navigation system MRT PURVI EVO.

I. Competition Goals

A. Navigate the Panama Canal

Navigate the Panama Canal is a mission that must be carried out in order to be able to proceed to the Magellan's Route stage. To pass this mission, the ship uses a webcam sensor which functions to identify the location of obstacles on the track then the data will be received by the Mini PC and processed as input for ship motion [1].

B. Magellan's Route

Magellan's Route is a mission that must be carried out in order to proceed to the Beaching stage. In the Magellan's Route mission, the Onboard Camera functions to identify the location of the Red Ball Obstacle and Green Ball Obstacle and Black Ball Obstacle and Yellow Ball Obstacle [1].

1) If the webcam detects are green ball obstacle, the ship will turn left
2) If the webcam detects are red ball obstacle, the ship will turn right
3) If the webcam detects a green ball obstacle and a red ball obstacle, the ship will go straight
4) If the webcam detects a green ball obstacle and a yellow ball obstacle, the ship will turn left
5) If the webcam detects a red ball obstacle and a yellow ball obstacle, the ship will turn right
6) If the webcam detects a green ball obstacle and a black ball obstacle, the ship will turn left

7) If the webcam detects a red ball obstacle and a black ball obstacle, the ship will turn right

C. Beaching

Beaching is a mission that must be carried out to be able to proceed to the Northern Passage Challenge stage. In this mission, the T200 thruster is given the command to Forward Right for 10 seconds. After advancing 10 seconds, the camera will detect the Obstacle Beaching [1].

D. Northern Passage Challenge

Northern Passage Challenge is a mission that must be done. In order to proceed to the Ocean Cleanup stage, in this mission the camera will detect red obstacles, green obstacles and blue obstacles [1].

1) If the webcam detects are green obstacle, the ship will turn left
2) If the webcam detects are red obstacle, the ship will turn right
3) If the webcam detects a green and red ball, the ship will go straight
4) If the webcam detects a blue obstacle, the ship will maneuver for 7 seconds.

E. Autonomous System

The autonomous system that we use the Yolov5 method with visual aids using the Logitech Brio webcam which is communicated with a mini PC, the Yolov5 method functions to detect labeled objects. Besides that we also use the Inertial Measurement Unit BNO055 sensor as a direction towards the ship, so that the Inertial Measurement Unit BN0055 can provide instructions in which direction the ship should be facing, and we also use GPS which serves as a reference for the ship's location [2].

II. Design Strategy

A. Hull Design and Propulsion System

For the design of the MRT PURVI EVO ship, it uses a ship of the same type as the ROBOBOAT 2022, namely the catamaran type with a Length Over All (LOA) of 114cm /3.7 ft, Beam (B) 61 cm /2 ft and a Height (H) of 50 cm /1.6 ft. For the design process, the Barelang MRT team use AutoCAD software for 3D modeling and Maxsurf for hull design [3]. Barelang MRT's goal of choosing a catamaran-type hull is to get a smaller resistance result and a larger cargo space area, bearing in mind the tasks performed by ships require large space. The difference between the MRT PURVI and MRT PURVI EVO is that the MRT PURVI EVO use a frame system to unite the two hulls and make it easier to assemble the ship's system. For the material we use for the frame system is aluminum profile 2020 the team's goal in choosing this material is so that it can be adjusted according to the needs of the team itself [3]. For the propulsion system we use 3 thruster motors, 2 thruster motors using the azimuth system and 1 thruster motor as a bow thruster which is used to to get the motion of the ship to make it easier for ships to complete tasks in the Roboboat 2023.

Figure 1. Design of MRT PURVI EVO

Figure 1 is a design drawing of the MRT Purvi Evo ship which will be used in completing all the tasks given to the MRT Purvi Evo ship. After doing the design the team proceeded to the fabrication process of the Purvi Evo MRT boat. The fabrication process of the MRT PURVI EVO uses balsa wood for the ship model then coated with fiberglass to prevent leaks and to make it stronger. The MRT PURVI EVO propulsion system uses an azimuth propeller so that the MRT PURVI EVO achieved greater maneuverability at low speed in comparison with a conventional rudder system [3].

B. Electrical Design

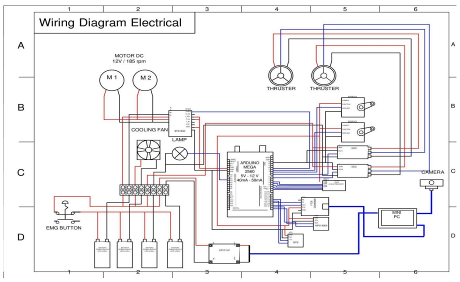

Figure 2. Wiring Diagram Electrical

Figure 2 is an electrical diagram design used on the MRT Purvi Evo ship. The electrical diagram system we use the Arduino Mega (5V) microcontroller as the brain that runs and controls all systems used on the ship, Logitech C290 (5V) Camera sensors, IMU BNO055 (5V), GPS Neo-6 to set the position and direction of the ship. as well as monitoring the ship while moving, 2 BTS 7960 (12-24V) drivers are used to drive the DC motors on Ball and Water Shooters, 3 ESC (electronic speed controller (16.8V)) are used as thruster controllers used on ships, FTDI (5V) used for communication between Mini PC and Arduino, Receiver (5V) is used to control the Remote which is used to control the ship manually and autonomously, Servo TD8120MG (5v) is used as an azimuth drive on the thruster, RGB indicator Lamp (12V) is used to determine the state of the ship in manual and autonomous positions, push buttons are used to activate and deactivate the power supply in the ship's electrical system, Mini PC Asus Ryzen 7 (19V) is used as a control system in autonomous devices and process ship data in real-time, as well as provide efficient control of the navigation system.

C. Sensor System

1) Camera Detection

The camera sensor functions to detect 0 objects while in the field. These objects are read in shape and color, then classified to determine the ship's movement by predetermined tasks [4]. The camera replaces the Pixhawk and becomes the main sensor that controls the movement of the ship while detecting an object. This function is processed by the mini-PC, according to the algorithm and the results are then sent to the Arduino system to drive the servo for ship movement.

2) IMU (Inertial Measurement Unit) Sensor

The BNO055 IMU (Inertial Measurement Unit) sensor is used to help determine the position and direction of the ship's face [5]. The IMU combines an accelerometer, gyroscope, and magnetometer to measure acceleration, angular velocity, and Earth's magnetic field. This information is then processed to determine the ship's position and orientation in real time. Ship orientation should be measured and updated periodically to ensure the ship can maintain the ship's position [5].

3) GPS (Global Positioning System) Sensor

GPS (Global Positioning System) sensors are used on ships to assist in navigation and determine the ship's position with high accuracy. GPS receives signals from orbiting satellites and uses this information to determine the ship's position, including latitude, and longitude. By using GPS, ships can monitor their position and determine the correct and predetermined course. GPS also helps in ensuring the ship is on the right track to avoid predetermined obstacles [6].

III. Testing Strategy

A. Hull Design and Propulsion System Test

The tests on hull and propulsion were performed by combining software simulation. The simulations were performed with Maxsurf Software [7].

No	Speed (m/s)	Froude No. LWL	Froude No. Vol	Resist. (N)	Power (W)
1	1.0000	0.329	0.606	137.03	228.39
2	1.2000	0.395	0.727	90.5	181
3	1.4000	0.461	0.848	118.96	277.57
4	1.6000	0.527	0.969	169.82	452.86
5	1.8000	0.593	1.09	196.72	590.15
6	2.0000	0.659	1.212	206.15	687.17

Table 1. Power Usage Analysis Table

Table 1 is a table of the results of the analysis calculations that the team carried out using maxsurf resistance software using the cylinder body method with an efficiency of 60% and a speed of 2 m/s.

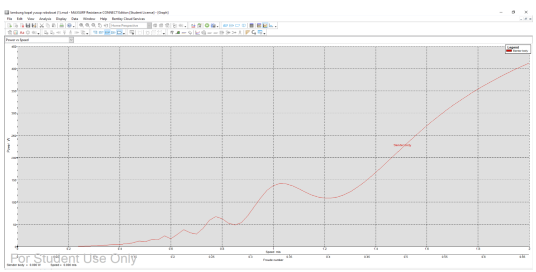

Figure 3. Power Analysis Chart

Figure 3 is a graph of the analysis of power gain to reach the specified speed, which is 2 m/s. It can be concluded that the MRT PURVI EVO requires a power of 412 W to reach a speed of 2m/s or 137 W to reach a speed of 1m/s. To meet the power requirements of the MRT PURVI EVO, the Barelang MRT team chose the T200 thruster from blue robotic, and the team chose the T200 thruster [7].

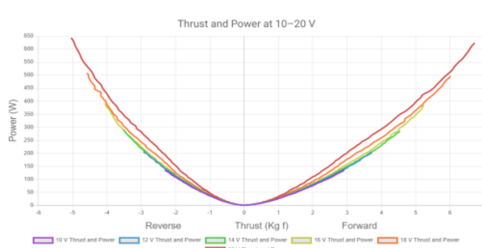

Figure 4. T200 Thruster Engine Power Chart

Figure 4 is a data compare with the power generated by the T200 thruster, it can be concluded that one thruster is capable of producing 281 W using a 14v battery, so the MRT PURVI EVO can be designed using two thrusters to meet the results of these obstacles and one thruster as a bow thruster. For the test results directly on the lake, for the motion test on the straight track of the MRT PURVI EVO ship at 50% and 100% speed, the following data is obtained.

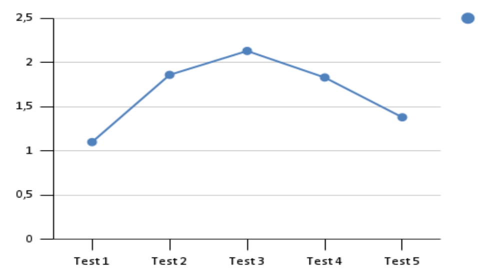

Figure 5. Graph of MRT PURVI EVO Boat Speed Data

Figure 5 is the result of testing the MRT PURVI EVO ship 5 times, the result is that on the 3rd test the MRT PURVI EVO ship can travel at a speed of 2 m/s and this data is by the test results using maxsurf resistance software.

B. Sensor System Test

1) Camera Detection

To do a test on camera detection, you do it by doing 8 tests on camera detection, then measuring the distance for each test, you get graphic data as below.

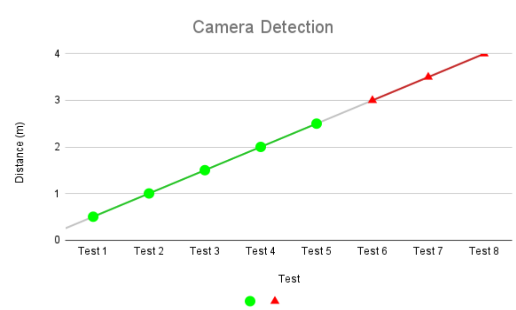

Figure 6. Result of Camera Detection

Figure 6 is a data graph obtained in the form of a camera on the MRT PURVI EVO ship that can detect objects as far as 2.5 m, and from these results, the Barelang MRT team concluded that the object detection camera on our ship can work well in the field.

2) IMU Sensor.

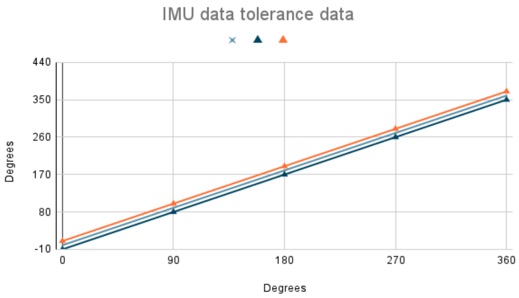

Figure 7. IMU Torerance Data Graph

Figure 7 is the result of data retrieval for IMU use. Based on BNO055 immune testing was carried out on the ship in 4 directions facing the ship at positions 0°, 90°, 180°, 270°, and 360°. In this experiment, the direction of the ship has an error tolerance at the point of facing 5 degrees down and 5 degrees up depending on the wave or wind direction can change the direction of the ship's course. So the team sees with this little tolerance data the team concludes that sensor science can be used in the Roboboat 2023 Competition [8].

3) GPS Sensor

For testing the GPS sensor on the MRT PURVI EVO ship, it is carried out by simulating the Roboboat arena into monitoring the ship's location will be read automatically and the data obtained will be in the form of x and y coordinates.

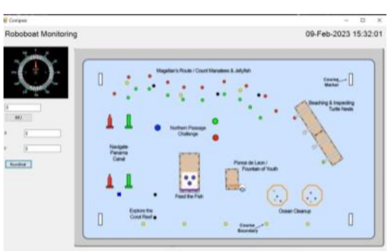

Figure 8. Monitoring the Position of MRT PURVI EVO

Figure 8 is monitoring from the MRT PURVI EVO ship from the monitoring obtained facing direction data from imu and GPS coordinate points, from these results the team concluded that GPS sensors can be used in the 2023 Roboboat race to complete the mission [8].

4) Localization System

System localization is useful for determining the point where the ship is located. Localization of this system uses data from imubno055 and also data on the distance traveled by the ship. To determine the location of this ship we have to get yaw data in the range 0-360 degrees. The equation for getting the imu data for the range 0 -360 is as follows.

$$yaw = (yaw + 360)\ \%\ 360 \qquad (1)$$

After getting science data, we also have to get data on the distance traveled by the ship. To get distance data, we can use the following equation;

$$s = v\ x\ t \qquad (2)$$

After getting yaw data from imu BNO055 and ship distance data, then we have to convert local data into global data. To search for global data we use the method used is the 2-dimensional rotation method.

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} \cos\theta & -sin\theta \\ \sin\theta & cos\theta \end{bmatrix} = \begin{bmatrix} x \\ y \end{bmatrix} \qquad (3)$$

So that the coordinates (x'y') of the coordinates (x,y) after rotation are

$$x' = x\ cos\theta - y \sin\theta \qquad (4)$$

$$y' = x\ sin\theta + y \cos\theta \qquad (5)$$

If value x =0, so ;

$$x' = (0)\ sin\theta - y \sin\theta = -y \sin\theta \qquad (6)$$

$$y' = (0) sin\theta + y \cos\theta = y \cos\theta \qquad (7)$$

so get :

$$x' = x' - y\sin\theta \quad (8)$$

$$y' = y' + y\cos\theta \quad (9)$$

IV. Conclusions

Technical Design Report was written to present information regarding the competition strategy, design creativity, and experiment results of the MRT PURVI EVO. This Technical Design Report also presents several developments such as the placement of the ship's propulsion system which already uses an Azimuth 2 propeller system, hull shape, the addition of sensors that already use IMU and GPS sensors, ball shooters that use ejection systems, and ships designed with a knockdown system. Our team hopes that this Technical Design Report will be useful for everyone who reads this report.

V. Acknowledgements

Barelang MRT would like to thank all those who have supported and participated in this competition. Our biggest thanks for:

1. Manager projects of barelang MRT which are Hendra Saputra, S.T., M.Eng., Ryan Satria Wijaya, S.Trt., M.Trt., Naufal Abdurrahaman, S.T., M.T.
2. Politeknik Negeri Batam for supporting and facilitating our team in the 2023 International Roboboat Competition
3. All team members of Barelang Marine Robotics Team who have worked hard and tried to compete in the 2023 International Roboboat Competition

VI. Reference

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APPENDIX A: COMPONENT SPECIFICATION

Component	Vendor	Model/Type	Specs	Custom/ Purchased	Cost (USD)	Year of Purchase
ASV Hull Form/Platform	Self Developed	Catamaran	Length Over All (LOA) = 114cm /3.7 ft Beam (B) = 61 cm /2 ft Height (H) = 50 cm /1.6 ft	Custom	198.47	2023
Waterproof Connectors	No Brand	GX16 Waterproof Aviation Connector Plug Socket Sensor Encoder	Maximum Current = 5A Material = ABS Pins = 2/3/4/5/6 Color = Black	Purchased	2.66	2022
Propulsion	Blue Robotics	T200 Thruster	Length = 113 mm Diameter = 100 mm Voltage = 7-20 volts	Purchased	200.00	2022
Power System	Venom	Venom Drive Series 50C 4S 5000mAh 14.8V LiPo Battery	Voltage = 14.8 Volts, 12 Volts	Purchased	92.62	2022
Motor Controls	Servo TD8120MG	Motor Servo TD8120MG high torque 20kg 20 kg metal	TD8120MG high torque 20kg 20 kg metal	Purchased	9.23	2022
CPU	ASUS	ASUS MINI PC PN51-S1-BB5700U-MT	AMD Ryzen™ 7 5700U Processor 1.8GHz (12M Cache, up to 4.3GHz)	Purchased	508.54	2022
Teleoperation	N/A	N/A	N/A	N/A	N/A	N/A
Compass	N/A	N/A	N/A	N/A	N/A	N/A

Inertial Measurement Unit (IMU)	No Brand	Modul Sensor BNO055	Triaxial Accelerometer = 14 bit Atriaxial 16-bit gyroscope with a range of 2000 degrees per second	Purchased	23.15	2022
Doppler Velocity Logger (DVL)	N/A	N/A	N/A	N/A	N/A	N/A
Camera(s)	Logitech	Logitech C920 HD Webcam	Max Resolution = 1080p / 30fps - 720p / 30fps Focus type = Auto focus	Purchased	180.94	2022
Hydrophones	N/A	N/A	N/A	N/A	N/A	N/A
Algorithims	N/A	N/A	N/A	N/A	N/A	N/A
Vision	N/A	N/A	N/A	N/A	N/A	N/A
Localization and Mapping	Marvelmind	Starter Set Super-MP-3D	https://marvelmind.com/product/starter-set-super-mp-3d/	Purchased	599	2023
Autonomy	N/A	N/A	N/A	N/A	N/A	N/A
Open Source Software	N/A	N/A	N/A	N/A	N/A	N/A

APPENDIX B: ELECTRICAL DIAGRAM

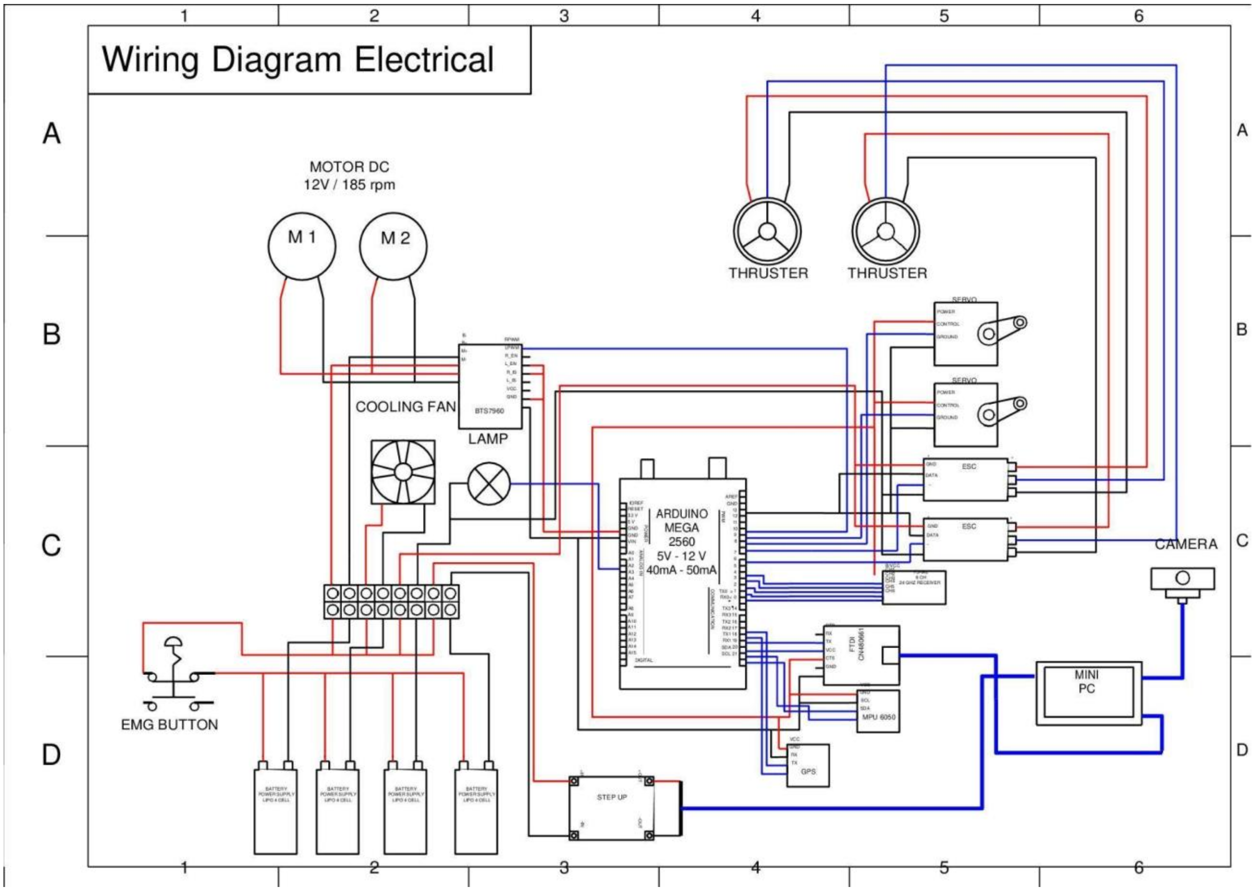

Figure B. 1 Electrical Diagram

APPENDIX C: POWER DATA

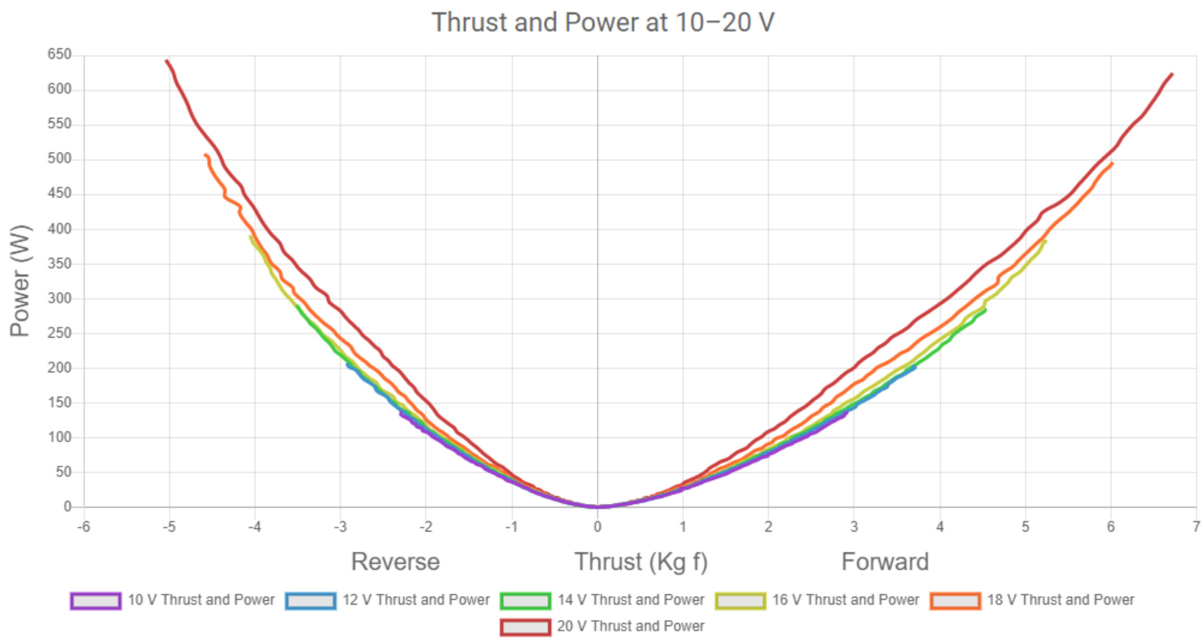

Figure C- 1 T200 Thruster Engine Power Chart

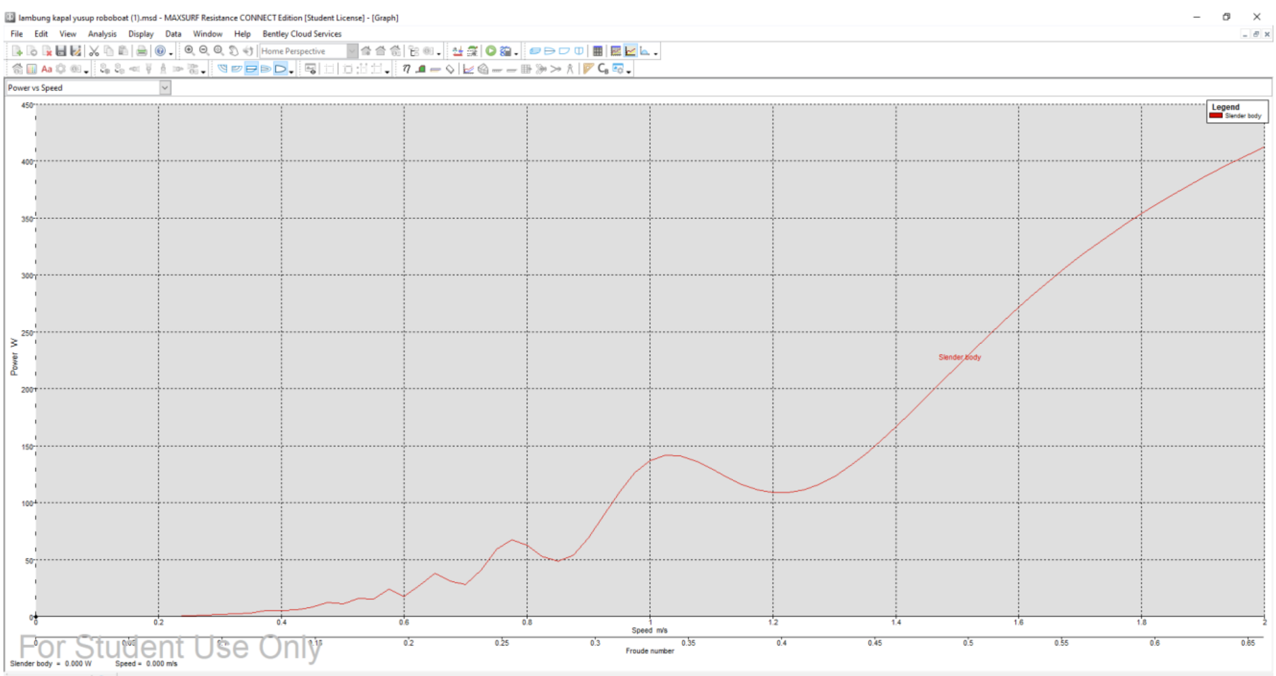

Figure C- 2 Power Analysis Chart