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Feasibility of Electric Fishing Boats based on Evaluation of Hydrostatic Forces and Resistance

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ABSTRACT

Conventional gasoline engine fishing boats have several disadvantages, such as high exhaust emissions, high fuel consumption, and low service life. The disadvantages of the gasoline engine can be resolved by using the electrical engine. Electrical fishing boats is an improvement on conventional boat to reduce the fuel consumption and emissions. In realizing an electric fishing boat, a feasibility analysis of the design, shape and weight that can be accommodated is required. The feasibility of an electric fishing boat has been successfully carried out by simulating the boat on Maxsurf Software. The aim of this research is to analyze feasibility of conventional boats by designing electric fishing boats. Improving feasibility is carried out by calculating hydrostatic forces and resistance. Electric fishing boats design using the simulation model in Maxsurf Modeller and simulation of resistance in Maxsurf Resistance at speeds of 1, 3 and 5 knots, with Wyman method. The modeling results show that the electric fishing boat design has a pointed front configuration with a V-shaped bottom. Main dimensions LoA 3.49 m, width 0.8 m; height 0.5 m; and a draft of 0.2 m, the boat produces a hydrostatic force which includes a displacement of 301.5 kg, a midship draft and submerged area of 0.2 m, a wet area of 3.08 m^2, and a waterline of 0.5 – 1.5 m. Testing 1, 3, and 5 knots, the boat experienced resistance of 26.11 N, 234.96 N, and 652.73 N respectively. The power required for the boat to operate was 13,43 W, 362.66 W, and 1678,97 W. The feasibility of designing an electric fishing boat is the main key to developing an electric fishing boat.

1. Introduction

Fishing boats generally still use gasoline-powered engines that are directly connected to the propulsion system [1]. Based on the results of direct observations in the waters of the Sulawesi Sea, the type of fishing boat used to determine the presence of fish is the Pakura boat. The small pakura boats are LOA = 3 - 4 m, BOA = 0.8 m, H = 0.5 m and draft (D) = 0.5 m using a gasoline engine.

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The use of gasoline as a fuel by fishing communities is based on several conditions, namely easy to find, relatively cheap price, easily compressed by sparks from spark plugs [2]. Research gasoline engine on previous studies by Tumigolung *et al.,* [3] research compared two engines with 6.5 HP and 9 HP. The 6.5 HP engine power is capable of producing a top speed of 7.57 knots at 1690 rpm with a gasoline consumption of 2.87 liters/hour and the 9 HP engine power is capable of producing a top speed of 8.96 knots at 2500 rpm with a gasoline consumption of 4.40 liters/hour. At this speed level, the boat tends to run parallel to the water and experiences heavy concentration at the stern of the boat. So, the boat tends to form an angle of 30^0 to the waterline [4].

Based on the results of these studies, it can be explained that the greater the fuel consumption of gasoline, when the rpm increases. According to a previous study by Vishawakarma and Kumar [5], the greater the change in engine speed, the greater the impact on the speed, so that the amount of compressed fuel increases. The main problems of the gasoline engine are high exhaust emissions, high fuel consumption, and the low life time of using the gasoline engine when the boat is operating. Research weaknesses on previous study by Boretti [6] defined that gasoline engine can be solved by developing an electrical engine. Utilization of electric engines and batteries that have been developed to date can be used as the main energy source in fishing boats.

According to a previous study by Letafat *et al.,* [7], utilization of electrical engines to reduce exhaust emissions by using a hybrid system on ships/boats. Hybrid system research on a passenger boat with a capacity of 20 passengers with a boat power of 42.10 kWh/day which is supplied from the onboard PV system, battery, and generator mounted on the stern of the boat. With the boat specifications LOA = 12 m, BOA = 4.8 m, draft (D) = 0.5 m, the boat can only operate for 8 hours a day. This is due to the uneven distribution of the load, so that the boat is limited in operation [8]. A previous study by Reabroy *et al.,* [9] related to the placement of electrical engines was carried out on boats with the specifications LOA = 4 m, BOA = 1.2 m, LWL = 3.2 m, draft (D) = 0.417 m, having EPS electrical energy. The results of this study indicate that the maximum speed of the EPS system can only reach 5 knots within 1 kilometer.

Another research previous study by Sunaryo and Imfianto [10], the use of electrical engines on tourist boats is adjusted to the design of the boat and the number of passengers. Semi-trimzaran hull model boat, specifications LOA = 5.8 m, BOA = 1.8 m, drfat (D) = 0.12 m, the boat requires an average power of around 4 kw. The results of this study indicate that the number of batteries used is a cylinder cell battery of 144 cells, a total weight of 10 kg. Results of previous research by Ibrahim *et al.,* [11] regarding Plug-in Hybrid Electric Recreational Boats (PHERB) powertrains, explains that the simulation results show that motorbike fuel consumption decreases with increasing motor power under conditions of the same battery capacity and engine power. This phenomenon shows that the simulation results also show that electricity and fuel consumption are contradictory one another.

The implementation of the electrical engine in previous studies positioned the ship's propulsion components and the steering wheel at the stern of the ship. This causes differences in the distribution of boat loads. Research about hybrid technology on previous studies by Nasirudin *et al.,* [12], defined the use of hybrid technology still has some weaknesses; (a) the amount of load increases, (b) the distribution of the load is uneven, (c) the value of the total resistance on a large boat hull. According to Kurniawan [13], this condition is affected by the inaccuracy of the installation of the energy supply system and the engine as the propulsion system on the ship. Some aspects of these weaknesses are due to inappropriate boat design and propulsion systems [14].

On scope research on previous study by Aliffrananda *et al.,* [15] explained placement of the battery and the main propulsion engine at the rear / stern, causing the concentration of the load on the rear. This phenomenon can cause trim on the boat. Trim is the difference between fore draft and rear draft. Research about trim on boat previous study by Matafi *et al.,* [16] defined that trim can be expressed as both positive and negative, including even keel, trim by the head and trim by the stern. The greater the torque given, the boat will tend to lift and form an angle to the surface of the water. This phenomenon causes resistance in the keel of the ship [17]. This causes the engine performance to produce greater ship thrust so that the fuel requirements are also greater. According to a previous study by Giraldo-Pérez *et al.,* [18], the amount of resistance exposed to the hull of the boat becomes greater. This can cause the boat to experience a decrease in speed and increase fuel consumption.

Based on the description of the problem and developments in the scope of electric engine research, in designing an electric fishing boat a feasibility strategy is needed in terms of manufacturing by evaluating the design, the magnitude of the hydrostatic force and the resistance when the boat is in operation. The research carried out can contribute to the development of knowledge to determine the feasibility of converting conventional boats into electric boats. The feasibility improvement was carried out by modeling an electric fishing boat on Maxsurf software, then the boat model was evaluated based on the hydrostatic force and resistance generated while the boat was operating. Hydrostatic force analysis and resistance simulations in boat design are simulated at several variations of 1 knot, 3 knots and 5 knots to obtain minimum power as a reference in determining propulsion components.

2. Methodology

The research methodology used simulation method with a direct approach to the size and speed of the boat on maxsurf software. Early research on the use of electrical engines on fishing boats was carried out in three strategies to get feasilibity electrical fishing boat ; (1) observe and calculate the main dimensions of a conventional fishing boat to get the parameters for making an electric fishing boat, (2) boat model design; modeling a fishing boat in the Maxsurf Modeller software to determine the hydrostatic force on the boat and (3) the resistance of the boat model; simulate the resistance experienced based on the parameters in the Maxsurf Resistance software to analyze the resistance on the boat with Wyman method.

2.1 Observe and Calculate

The fishing boats that are often used by fishing communities have a pointed tip with a V-shaped boat body, in Figure 1. The boat operates with a petrol engine that is directly connected to the propeller drive system. Some of the main sizes of fishing boats are in Table 1.

Fig. 1. Gasoline engine fishing boat

Table 1
Main Dimensions of the Boat

Parameter	Value (m)
LoA	3 – 4
B	0,75 – 0,8
H	0,5
T	0,2

2.2 Design Process

The boat design is modeled using the maxsurf modeler software based on the main size of the ship. The boat modeling stages include (a) determining the size of the boat, (b) designing the boat, (c) calculating the hydrostatic force experienced by the boat. Some of the boat's main parameters include: LoA (Length Over All) is the overall length of the ship measured from the bow (front) to the stern (back); LwL (Length Water Line) is the length of the hull that touches the water surface; Beams (B); is the width of the hull measured from the left to the right side of the hull skin; Depth (H) is the height of the ship's body measured from the bottom of the hull to the surface of the ship's superstructure; Water Draft (T) is the distance between the bottom of the hull and the waterline.

2.3 Resistance Simulation Process

Determination of boat resistance is simulated with maxsurf resistance software with reference to the results of the boat model in the previous simulation. The modeling stages to determine the resistance of the boat, include (a) determining the design of the boat, (b) determining the parameters of the resistance, (c) determining the speed variations of 1 knot, 3 knot, and 5 knot, (d) analyze the resistance of the boat model simulate with Wyman method.

3. Results

3.1 Evaluation of Hydrostatic Force

The modeling of the pakura boat using the maxsurf modeller software is shown in Figure 2. Based on the results of the modeling on the maxsurf software, it shows the suitability of the main dimensions of the model and the shape according to the boat in real conditions in Table 2. In Figure 2 it shows the model of the pakura boat with the baseline shape. There are the main lines of the design results, namely the waterline (DWL) and the waterline line (WL). Research using maxsurf software was also carried out by Budiman *et al.,* [19], with a focus on hull variations on boats. Maxsurf software can analyze the resistance received by the boat while operating. The DWL line is a reference that is determined by adjusting the draft height on the pakura boat, which is 0.2 m. While the WL 1, WL 2 and WL 3 lines are simulated water level lines that can be reached when the boat is operated.

Table 2
Main Dimensions after on Maxsurf Simulation

Parameter	Value (m)
LoA	3,49
B	0,8
H	0,5
T	0,2

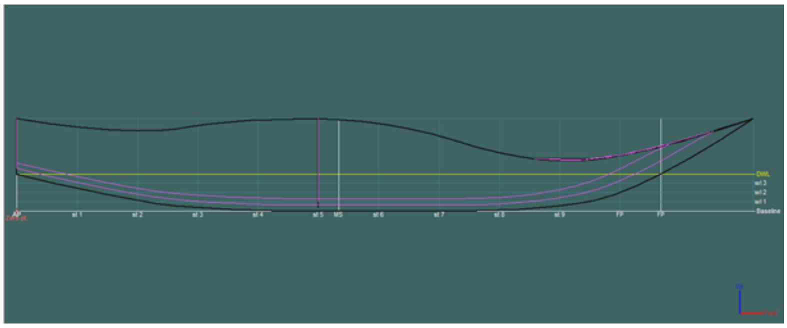
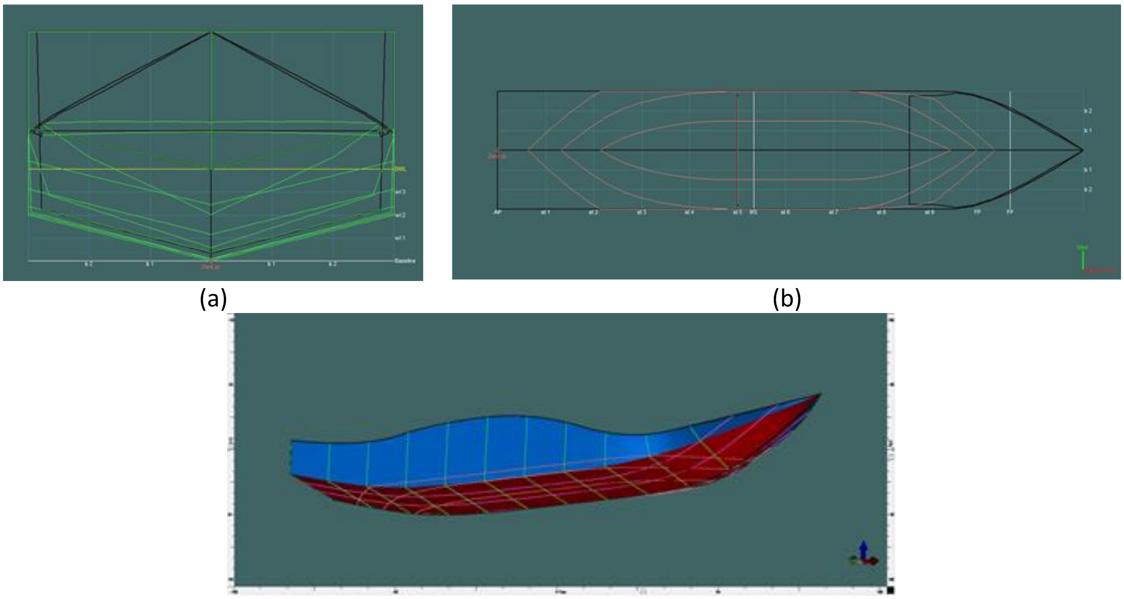


Fig. 2. Basline pakura boat design on maxsurf software

Figure 3(a) and Figure 3(b), show the waterline of the pakura boat model in the front and top views of the boat. WL 1 value (0.05 m); WL 2 (0.1 m); and WL 3 (0.15 m) shows the maximum height of seawater that can be taken into account when using a pakura boat. In Figure 3(c), shows the boat model in perspective. Based on the three figures, it can be explained that the pakura boat can be used to operate with due regard to the water limit.



(a) (b)

(c)

Fig. 3. Pakura boat design on maxsurf software; (a) body plan, (b) plan, (c) prespective

The hydrostatic force experienced by the pakura boat is shown in Table 3. The main parameters of the hydrostatic force include; displacement, volume (displaced), amidships draft, immersed depth, and wetted area. Displacement or the term sinking weight is the weight of the liquid displaced by the body of the ship which is below the surface of the liquid where the ship is located. In Table 3, it is shown that the total displacement is 301.5 kg, this shows the maximum weight that can be accepted by the boat. With the maximum weight of the namesake, the boat experiences a downward compressive force with an immersed depth of 0.2 m and a wetted area of 3.088 m^2.

Table 3
Hydrostatic at DWL after designed boat prototype

Parameter	Value
Displacement	301,5 kg
Volume (displaced)	0,294 m^3
Draft Amidships	0,2 m
Immersed depth	0,2 m
WL Length	3,499 m
Beam max on WL	0,8 m
Wetted Area	3,088 m^2
DWL	0,2 m
WL 1	0,05 m
WL 2	0,1 m
WL 3	0,15 m

The calculation of the weight received by an electric fishing boat is shown in Table 4. Based on the total weight available is 286,5 kg, the boat can be used to operate with a maximum weight limit of 301.5 kg. Configuring the placement of the battery and BMS is one of the strategies to get an even distribution of weight on the boat. By configuring the battery placement, the boat can run stably while operating. Based on the design that has been modeled and the hydrostatic force obtained based on the boat model, the strategy or planning that needs to be done is estimating the total load of passengers and propulsion components that can be loaded by an electric boat. The heavier it is, the more the fishing electric boat will sink to the maximum water level.

Table 4
Calculation of weight on a pakura boat

Parameter	Qty	Value (kg)
Person	2	190
Engine	1	23
Battery + BMS	1	10
Lifebouy	2	3,5
Boat	1	20
Fish	2	40
Total		286,5

3.2 Evaluation the Resistance of the Boat

Maxsurf resistance is basically what is used to predict the resistance of the hull shape on a boat. The use of maxsurf resistance is an application in boat design for breaking down barriers into legally compliant components different. Maxsurf resistance can calculate components resistance in the form of coefficients. In the boat resistance simulation, not all components' obstacles are available [20]. This is due to differences in the methods used, then the results obtained will differ based on the formulation applied. The total resistance is obtained from decreasing Fn (Froude number) which depends on the wave resistance component or residual resistance and Re (Reynolds number) depending on viscous resistance components [21]. Figure 4 shows the profile of resistance that occur on the boat during operation. Resistance includes residual resistance and frictional resistance.

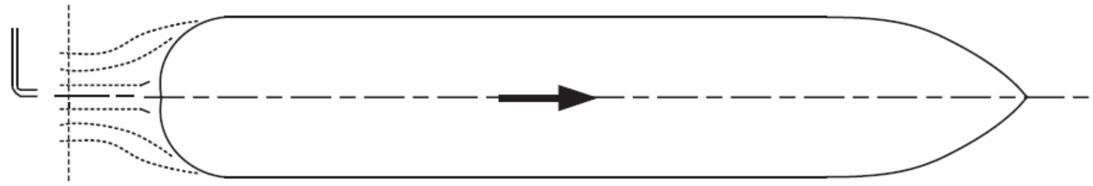


Fig. 4. Pakura boat design on maxsurf software; (a) body plan, (b) plan, (c) prespective

$$R_{TM} = R_{FM} + R_{RM} \quad (1)$$

By using the Froude method, the resistance coefficient of a full scale ship can be calculated from the results of boat model experiments, with the resistance coefficient equation

$$R_T = R_F + R_R \quad (2)$$

Two dimensional analysis method on the boat above does not adequately reflect the contribution of the shape or contour of the three dimensional boat hull to viscous resistance. The total resistance on a 3D shaped boat is the sum of three components, including; friction resistance (R_F), form resistance (R_{FO}), and free surface resistance (R_W) [22].

$$R_T = R_F + R_{FO} + R_W \quad (3)$$

$$R_{FO} = kR_F$$

$$R_T = (1 + k)R_F + R_W \quad (4)$$

$$(1 + k) = \frac{R_T}{R_{FO}} \quad (5)$$

Assuming that $R_{RM} = aFn^n$ in general ($Fn < 0.2$), so the total resistance formula that occurs in Eq. (6) is as follows

$$R_T = (1 + k)R_F + aFn^n \quad (6)$$

Boats operating at sea will form waterline waves that follow the shape of the boat body. The normal profile shape that occurs while the boat is operating is shown in Figure 5. Meanwhile, the simulation results of an electric fishing boat on Maxsurf resistance with varying speeds are shown in Figure 6. In Figure 6 the simulated boat operates with speed 1 knot (Figure 6(a)), 3 knot (Figure 6(b)), and 5 knot (Figure 6(c)). With these variations in speed, the boat can operate properly by paying attention to the shape of the resulting seawater waves.

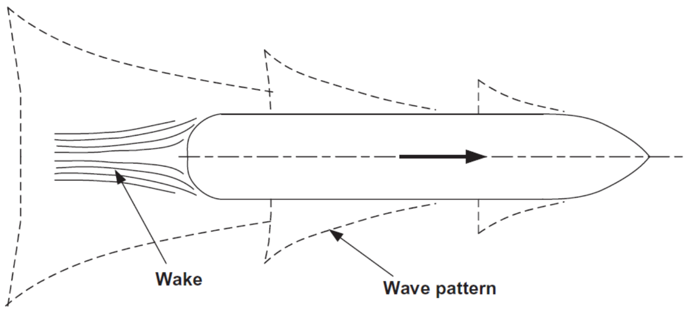
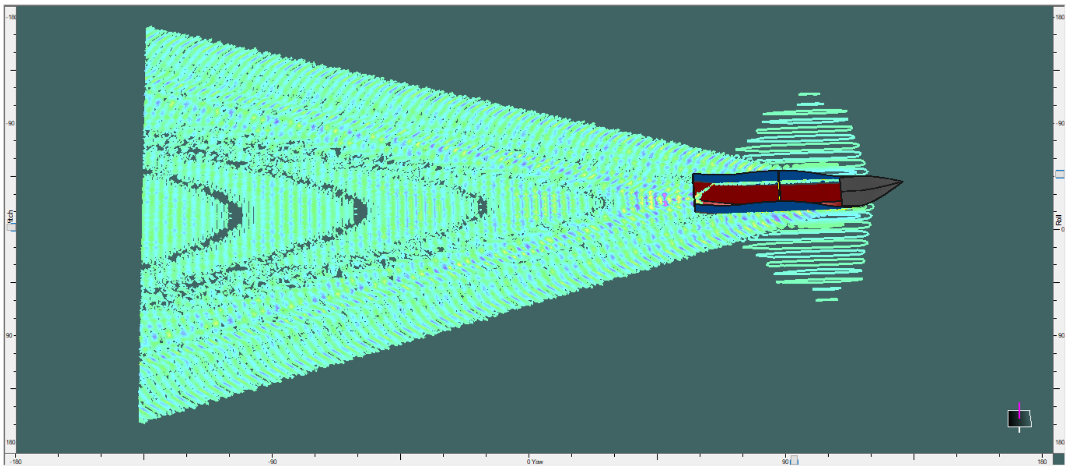
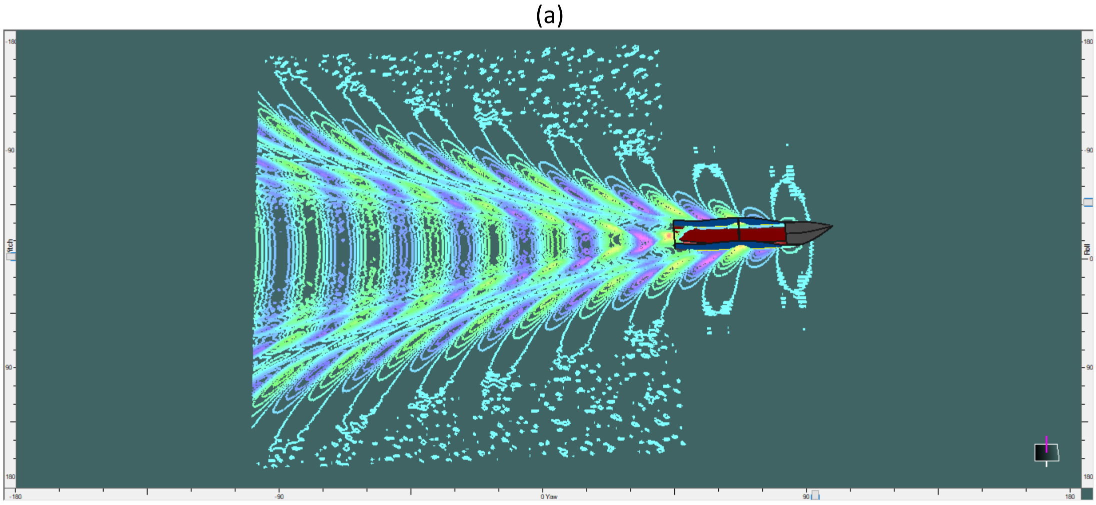


Fig. 5. Wave lines and normal water flow on the boat body and propeller

Based on Figure 6, you can see the profile of sea water waves produced when the boat is operating. Sea waves will get bigger as speed increases. This will have an impact on increasing frictional resistance and the resulting waves. As a result, the boat will tend to require more power. The wave profile simulation results are in accordance with the resistance and power calculation simulations in Table 5. The feasibility of an electric fishing boat requires attention and consideration of the operating speed of the boat, this is because electric fishing boats use an electric motor as a driving force which cannot be directly exposed to water splashes.



(a)



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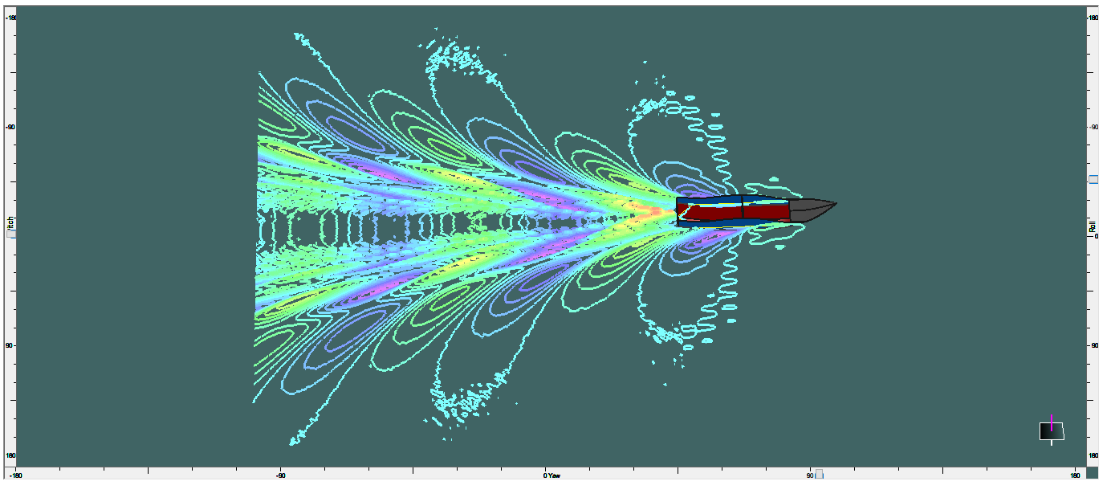


(c)

Fig. 6. Sea wave profile when the boat is operating; (a) 1 knot, (b) 3 knots, and (c) 5 knots

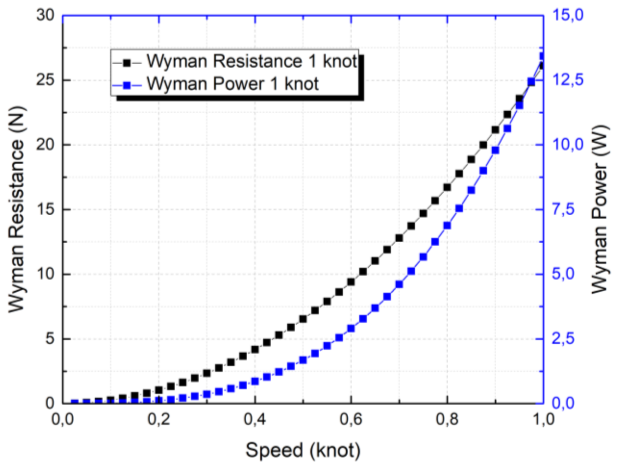
Utilization of the pakura boat as a prototype of an electric fishing boat can be used by paying attention to resistance and power. Based on Table 5, it can be seen that the amount of resistance and the power required for the electrical engine to move the boat during operation. In this research, the Wyman large resistance and Wyman power methods are used to determine the power requirements required when the boat is operating. The simulation results show that the maximum speed is 1 knot, the boat receives a resistance of 26.11 N and a power of 13.43 W; maximum speed of 3 knot, receiving a resistance of 234.98 N and a power of 362.66 W; maximum speed of 5 knot, received a resistance of 652.73 N and a power of 1678.97 W.

Based on the simulation results on the pakura boat model, it can be explained that there is an increase in resistance and power required along with an increase in speed when the boat is operating. According to a recent study by Laamena and Taihutu [23], research that is in line with these results is hydrostatic calculations to determine displacement on ships. Ships with a total weight of 25.67 tons, resulting in drag and power values of 4.96 kN and 23.004 kW at a ship speed of 9 kN and an increase of 7.45 kN and 35.003 kW at a ship speed of 10 kN. Another research by Anugrah and Al-Fath [24] that shows an increase in resistance to speed is on catamarans with main dimensions of LoA 60 cm, B = 30 cm, H = 15, T = 6 cm. The results showed that the ship experienced a linear increase of 0.5 m/s (0.46 N), 1 m/s (1.6 N), 1.5 m/s (3.18 N), 2 m/s (4.92 N), and 2.5 m/s (6.89 N).

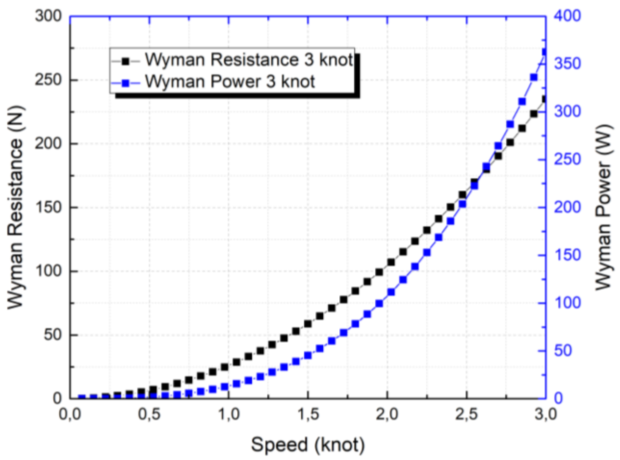
The phenomenon occurs when an electrical fishing boat that goes faster will produce greater thrust. The increase in thrust causes the bow of the boat to break the waves of sea water. That phenomenon is related with research by Prharsi *et al.,* [25], so that there is an increase in power and resistance received by the boat while operating. This can be proven in Figure 7 the graph of the relationship between resistance and power at variation of speed. Based on Figure 7, it can be explained that there is an increase in the required along with increasing speed. The results of the simulations that have been carried out can be the main reference in the strategy or design of electric boats, especially in selecting boat propulsion components, including the electric engine and batteries that will be used. The propulsion components of electric fishing boats must have capabilities above the power value produced in the resistance simulation [26]. Results of previous research by Jabar and Rahman [27] regarding Plug-in Hybrid Electric Recreational Boats (PHERB) powertrains, indicating that power flow analysis is used to determine size and capacity key components to achieve design specifications and requirements conventional ship and PHERB powertrain.

Table 5
Power-resistance comparison at various speeds

1 kn			3 kn			5 kn		
Speed (kn)	Wyman Resistance (N)	Wyman Power (W)	Speed (kN)	Wyman Resistance (N)	Wyman Power (W)	Speed (kN)	Wyman Resistance (N)	Wyman Power (W)
0,000	--	--	0,000	--	--	0,000	--	--
0,025	0,02	0,00	0,075	0,15	0,01	0,125	0,41	0,03
0,050	0,07	0,00	0,150	0,59	0,05	0,250	1,63	0,21
0,075	0,15	0,01	0,225	1,32	0,15	0,375	3,67	0,71
0,100	0,26	0,01	0,300	2,35	0,36	0,500	6,53	1,68
0,125	0,41	0,03	0,375	3,67	0,71	0,625	10,20	3,28
0,150	0,59	0,05	0,450	5,29	1,22	0,750	14,69	5,67
0,175	0,80	0,07	0,525	7,20	1,94	0,875	19,99	9,00
0,200	1,04	0,11	0,600	9,40	2,90	1,000	26,11	13,43
0,225	1,32	0,15	0,675	11,90	4,13	1,125	33,04	19,12
0,250	1,63	0,21	0,750	14,69	5,67	1,250	40,80	26,23
0,275	1,97	0,28	0,825	17,77	7,54	1,375	49,36	34,92
0,300	2,35	0,36	0,900	21,15	9,79	1,500	58,75	45,33
0,325	2,76	0,46	0,975	24,82	12,45	1,625	68,94	57,64
0,350	3,20	0,58	1,050	28,79	15,55	1,750	79,96	71,99
0,375	3,67	0,71	1,125	33,04	19,12	1,875	91,79	88,54
0,400	4,18	0,86	1,200	37,60	23,21	2,000	104,44	107,45
0,425	4,72	1,03	1,275	42,44	27,84	2,125	117,90	128,89
0,450	5,29	1,22	1,350	47,58	33,05	2,250	132,18	153,00
0,475	5,89	1,44	1,425	53,02	38,87	2,375	147,27	179,94
0,500	6,53	1,68	1,500	58,75	45,33	2,500	163,18	209,87
0,525	7,20	1,94	1,575	64,77	52,48	2,625	179,91	242,95
0,550	7,90	2,23	1,650	71,08	60,34	2,750	197,45	279,34
0,575	8,63	2,55	1,725	77,69	68,94	2,875	215,81	319,19
0,600	9,40	2,90	1,800	84,59	78,33	3,000	234,98	362,66
0,625	10,20	3,28	1,875	91,79	88,54	3,125	254,97	409,91
0,650	11,03	3,69	1,950	99,28	99,60	3,250	275,78	461,09
0,675	11,90	4,13	2,025	107,06	111,53	3,375	297,40	516,36
0,700	12,79	4,61	2,100	115,14	124,39	3,500	319,84	575,89
0,725	13,72	5,12	2,175	123,51	138,20	3,625	343,09	639,82
0,750	14,69	5,67	2,250	132,18	153,00	3,750	367,16	708,32
0,775	15,68	6,25	2,325	141,14	168,81	3,875	392,05	781,54
0,800	16,71	6,88	2,400	150,39	185,68	4,000	417,75	859,64
0,825	17,77	7,54	2,475	159,94	203,64	4,125	444,27	942,77
0,850	18,86	8,25	2,550	169,78	222,72	4,250	471,60	1031,10
0,875	19,99	9,00	2,625	179,91	242,95	4,375	499,75	1124,78
0,900	21,15	9,79	2,700	190,34	264,38	4,500	528,71	1223,97
0,925	22,34	10,63	2,775	201,06	287,03	4,625	558,49	1328,83
0,950	23,56	11,52	2,850	212,07	310,93	4,750	589,09	1439,51
0,975	24,82	12,45	2,925	223,38	336,13	4,875	620,50	1556,17
1,000	26,11	13,43	3,000	234,98	362,66	5,000	652,73	1678,97



(a)



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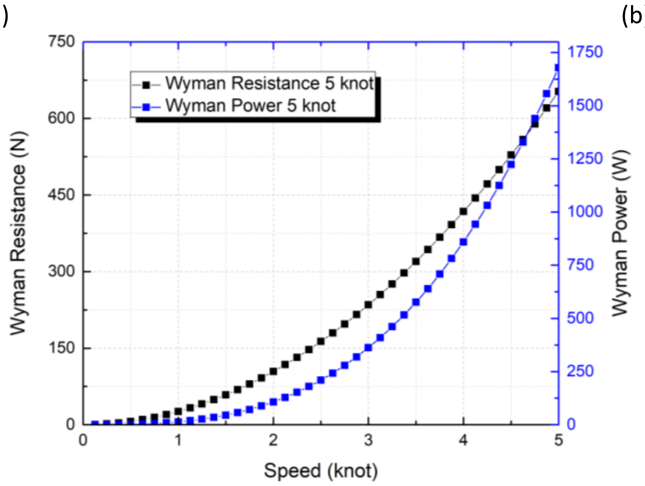

(c)

Fig. 7. Graph of Wyman resistance and Wyman power of the boat; (a) 1 knot, (b) 3 knot, and (c) 5 knot

Three main strategies to get feasibility electrical fishing boat; (1) boat design which is evaluated from the resulting hydrostatic force to determine the maximum total load, (2) simulation at speed variations which is evaluated from the amount of resistance received to determine the type and specifications of the boat's propulsion components, and (3) estimating electrical engine power as the main driving force for electric fishing boats. These three things are new in designing and making electric fishing boats that suit fishermen's needs for fishing. The model of electric fishing boat that will be made needs to pay attention and consider these two strategic aspects so that the boat can operate well at high speeds.

4. Conclusions

Utilization of the electric fishing boat as can be made by calculating and knowing the resistance and power requirements of the boat to operate. Modeling the simulation model of the electrical fishing boat in maxsurf modeller and maxsurf resistance software, can be used as a reference in designing the total weight of the boat load. In addition, the selection of boat propulsion components, including the electrical engine and lithium ion battery refers to the Wyman power obtained from the simulation at various speeds. Based on the modeling results, a model of an electrical fishing boat is obtained that corresponds to the dimensions of the main dimensions of the boat in real conditions. The electrical fishing boat model has a displacement of 301.5 kg, a draft amidship and immersed of 0.2 m, and a wetted area of 3.08 m^2. The resistance of the electrical fishing boat at various speeds was 26.11 N (1 knot), 234.98 N (3 knot); 652.73 (5 knot). Meanwhile, the amount of power needed by the electrical fishing boat to be able to operate against resistance is 13.43 W (1 knot); 234.98 W (3 knot); and 1678.97 W (5 knot). The resistance value of the boat and the operating power requirements have increased with increasing speed. There needs to be additional parameter observations to determine the stability of the electrical fishing boat.

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