Analysis of The Design of Changing The Main Engine From a Diesel Engine to an Electric Engine on a Fishing Vessel

Dimitry Rizal Ramadhani[1], Erifive Pranatal[2]
[1,2]Naval Engineering, Institut Teknologi Adhi Tama Surabaya, Surabaya

Email: [1]dimitririzal@gmail.com, [2]erifive@itats.ac.id

Received: 2024-05-18 Received in revised from 2024-06-12 Accepted: 2024-06-19

Abstarct

Fishing vessels in Indonesia conventionally use diesel engines as their main propulsion engine. However, the use of diesel engines has quite a bad impact on the surrounding environment. So the latest innovations using alternative energy are needed. One of them is the use of electric engines as a replacement for diesel engines in the ship's main propulsion engine. The use of this electric machine will have a friendly impact on the environment. Apart from that, you don't need to spend a lot of money to maintain this electric machine. We can see this by comparing the ship's thrust requirements with maximum speed.

Keywords*: Electric machines, Electrical energy; Fishing ships*

1. Introduction

Ships are sea transportation that are widely used for certain purposes. The type of ship is determined by the cargo carried. This time the type of ship used for research is a fishing boat. From the journal Where these fishing boats still use fossil or diesel energy propulsion engines. Fishermen still have difficulty getting fossil or diesel energy sources due to the scarcity of supply and the distance from urban areas. Therefore, one solution that can be provided is to replace the fossil or diesel energy drive engine with an electric drive engine [1].

Ships generally have power plants that are driven by several engines, including diesel engines, steam and gas turbine engines. according to the journal, this generator drive engine is used to convert primary energy (fuel) into generator drive mechanical energy (rotary power) and converted again into electrical energy [2]. Apart from that, we can get electrical energy from sunlight which is absorbed using solar panels. Indonesia is located on the equator, which makes solar energy available throughout the year. and also in the journal solar energy has a potential of 4.8 Kwh/m² which can benefit Indonesia to use it as a source of electrical energy [3].

New renewable energy is still considered less economical and less efficient technology. This is understandable because the availability of fossil energy sources is still sufficient today. According to what is in the journal, renewable energy will be really needed in the future considering the limitations of fossil energy sources [4]. Indonesia has great potential to develop renewable energy. and in the journal, in the future renewable energy is very strategic considering the environmentally friendly and sustainable nature of renewable energy [5]. One of the obstacles in terms of distribution of energy sources is the long distance between islands, making it inefficient [6]. However, an alternative solution is to utilize the surrounding natural resources, for example the use of sea breeze using windmills, sea water currents and sunlight which are managed as sources of electrical energy [7].

In the ship production process, it is necessary to pay attention to materials and designs that suit the marine characteristics of the area. The ship is designed as a fishing vessel that can be used to operate fishing equipment. This ship is made from FRP (Fiber Reinforced Plastic) material, Fiberglass is a material that has quite affordable economic value and is easily available [8]. In the ship design process, fiberglass material is used for the skin of the ship, while the ship frame uses steel to make it stronger to weather big waves [9]. The location of the ship's engine must comply with regulations to maintain safety. This electric driving machine has a high level of risk, because it is very sensitive to water which can cause short circuits and fires. Strict supervision of ship production is needed to ensure safety when sailing. And the design of the ship must comply with the regulations determined by the BKI (Biro Classification Indonesia) agency and be seaworthy [10].

Boats, which are the only transportation used by fishermen, still have difficulty providing the necessary fuel. However, it also has a negative impact on the surrounding environment. So an innovation is needed that can provide a solution for fishermen so that they don't get confused when going to sea and also don't damage the surrounding environment. Converting a diesel engine to an electric one is a good innovation where the energy source is easy to obtain and the energy output does not damage the environment. The material factor for producing affordable ships is an additional point. So converting diesel ship propulsion engines into electric propulsion engines is an innovation that is very beneficial for fishermen and the surrounding environment.

2. Method

Research objects are an important role played by researchers in the form of people, places, objects and so on. The object of this research was carried out at the Banyuwangi area shipyard and its fishing vessels. With shipping routes in the waters of Banyuwangi, Bali and Nusa Tenggara.

2.1 Data Collection

In accordance with the object of this research, the main thing that needs to be known is the main size of the ship. The purpose of this is so that we can know the appropriate ship design. According to the type, the following are the main sizes of fishing vessels that have been determined in Table 1.

2.2 Design of Electric Fishing Boat Building Designs

Design design is an initial stage in creating a new ship building to find out the shape of the ship before making it in 2-dimensional and 3-dimensional form. The ship is designed of course taking into account the ship's needs. The aim of this design is so that we can understand the overall shape of the ship's contents. The design of this electric engine fishing boat is different from conventional boat designs. This electric engine fishing boat has several additional components to help the performance of the electric engine. One of the components is a solar panel. Of course, the solar panels used have certain specifications according to the ship's needs. In this research, the ship design emphasized the light weight of the ship, making the ship easy to control. Apart from that, this ship is designed with additional components to support the electric engine in the form of solar panels and a control panel for the electric propulsion engine.

The following is a design for an electric fishing boat.

2.3 Determination of Electrical Machine Capacity

This fishing boat, which previously used a diesel engine, had a power of 90 HP (Horse Power). In this research, fishing boats that started out using diesel engines were converted to electric engines. The method used is to calculate the equation between the units HP (Horse Power) and kWh (Kilo Watt-H). The purpose of this calculation is so that we can know the amount of power needed in the driving engine [11].

The following is the calculation of diesel engine power to electric engine:

Diesel power = 90 HP

$$\begin{aligned} Pkw &= 0{,}7457 \times PHP \\ &= 0{,}7457 \times 90 \\ &= 67{,}113\ Kwh \end{aligned} \tag{1}$$

After the conversion is carried out, the diesel engine is converted to an electric engine. Using the unit change method or equation, it can be seen that the diesel engine of this fishing boat has a power of 90 HP (Horse Power) and after conversion to an electric engine it changes to 67.113 kWh.

Apart from that, it can also be seen how much power is released by the electric engine with a power of 67,113 kWh. Of course, the power produced by the electric engine provides a thrust which causes the ship to move. The following is a calculation of the amount of power produced by an electric machine with a power of 67,113 kWh :

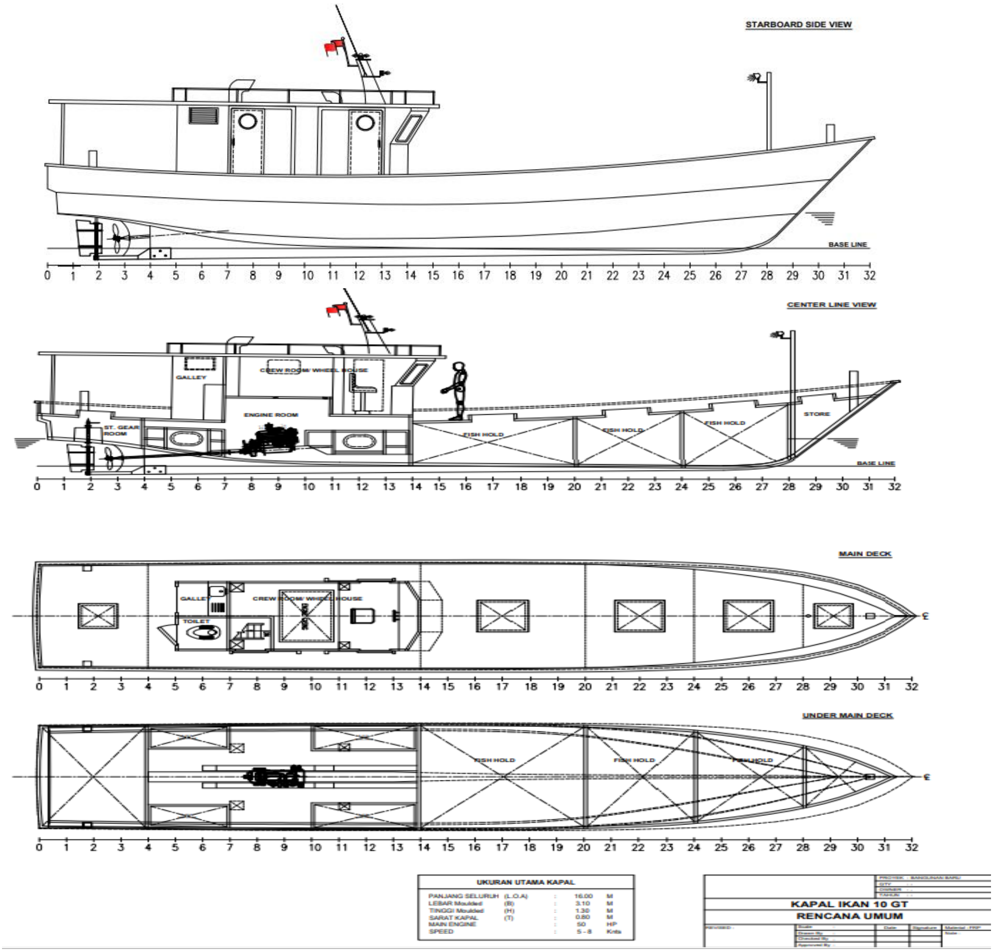

Figure 1. General Plan Design

Table 1. Vessel Size Data.

Dimension	***Range***
Length Over All (LOA)	17 meter
Length Water Line (LWL)	14,5 meter
Bread (B)	4 meter
Hight (H)	1,4 meter
Draft Water (T)	0,8 meter
Coofisien Blok (Cb)	0,55
Main Engine	90 House Power
Volume Speed (VS)	6 – 9 Knot

$$T = \frac{5250 \times HP}{N} = \frac{5250 \times 90}{2000} = 236{,}25\ Nm \quad (2)$$

After looking at the calculations above, it can be concluded that the maximum power produced by this 67,113 kWh electric machine is 236.25 Nm.

2.4 Determination of Ship Endurance

Loadings on a ship are ship components that are powered by electrical energy sourced from the ship's auxiliary engines or the ship's generator [12][13]. Of course, this is a necessity for ships when operating. So it is necessary to recalculate how many components the ship needs and the amount of power for these components. The goal is to find out the total electrical power required by the ship. Therefore, the following is the total load on the ship:

Table 2. Ship Loading Components

Equipment	*Amount*	*Power (kWh)*
Lighting and stop kontak	15	34,10
Nautical, communication, safety	35	20,17
Refrigeration compressor	1	0,03
Water pump	2	0,024
Drive engine	1	67,113
TOTAL	51	121,437

2.5 Determination of Battery Capacity

A battery is a device used to supply electricity needs. In this research, a battery is needed that meets the ship's specifications. In accordance with the calculated needs of the ship, a battery with a power capacity of 121,437 kWh is required. Later, this battery will fill the ship's needs when operating. All supporting components on the ship, including the ship's propulsion engine, will be powered by electricity from the battery.

2.6 Determination of EBT capacity

New Renewable Energy (NRE) is energy that comes from natural processes. Examples of new renewable energy sources include solar energy, wind, water currents, biological processes and geothermal energy. The benefits of NRE can encourage sustainable economic growth. Utilization of NRE is a breakthrough in providing abundant sources of electrical energy. Of course, sophisticated technological processes can convert natural energy sources into electrical energy.

In this research, one of the NREs used is solar heat. Using a solar panel device that can convert solar heat energy into electrical energy, so it is an advantage to be able to supply electrical energy produced by solar panels which are sourced from solar energy. And the use of electrical energy on this ship is not entirely dependent on the availability of energy sources in the battery. However, it can be helped through solar panels which can produce electrical energy naturally.

2.7 Design and Planning of Electric Fishing Boats

After carrying out the planning design at the initial stage and determining the components needed for the ship. So the design planning is carried out again to determine the location of the components according to their function. Where at the beginning of the design, which is the initial planning of the fishing boat before it is converted to an electric engine. This stage is also the final stage in the production process. So this design is more detailed than before. Of course the design is made in accordance with ship regulations regarding safety in operation.

In figure 3.2 is a fishing boat design that has been modified to use an electric engine from the previous diesel engine. It is designed in such a way as to place electric ship components where there are solar panels placed on a canopy above the ship's deck at the stern. Place the battery in the engine room next to the engine and the control panel. This has been taken into account by looking at efficiency that does not cost too much during production and looking at the safety of the ship when operating.

2.8 Simulation on Ship Design

After the ship is completed and has been launched, trials will be carried out on the ship and will be attended/witnessed directly by the owner and supervisor. One of the trials carried out on ships is Sea Trial or sailing trials which must be carried out in accordance with the provisions of the contract between the owner and the shipyard and after the results of the Mooring Trial are good and accepted by the owner.

Sailing trials are official trials consisting of:

- Ship Speed Trial
- Test the ship's maneuvering capabilities
- Trial of the ship stopping suddenly and reversing
- Test the turning radius of the ship

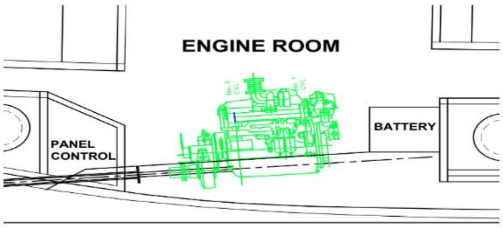

Figure 2. Design of an Electric Fishing Boat

- Test the durability of the main engine and auxiliary engines
- Testing of communications and navigation equipment

The results of the sailing trials must be stated in an official sailing trial report and accompanied by a Minutes of Sailing Trials. If during sailing trials something happens that does not meet the provisions of the technical specifications and contract, the shipyard must repair and perfect or carry out sailing trials again before the ship is handed over to the owner.

All materials, machines, tools and equipment used to build this ship and which will be installed on this ship are of good quality and for use on ships (marine use). The process of making and installing equipment on this ship is carried out carefully and perfectly by skilled personnel who are experienced in the shipbuilding process. Done using good tools and according to the type of work the shipyard has.

If there is a failure during testing, it will return to the first design stage. There may be a calculation error in the design. After improvements have been made to the design, the stage of determining the machine and its components is also readjusted until the testing stage is said to be successful.

2.9 Results and Conclusions

The conclusion of this thesis is the use of an electric engine as a ship propulsion engine using the method of converting a 15 GT fishing boat which previously used a diesel engine into an electric engine with a fixed ship design. Then suggestions will be put forward that are in accordance with the results of the work on this final assignment.

3. Results and Discussion

3.1 Main Ship Dimensions

The main size of this fishing boat corresponds to the size of previous boats that use diesel engines. So when converting to an electric engine, the size of the ship will remain the same but the main engine will be changed from a diesel engine to an electric engine.

Table 3 are the main sizes of fishing vessels:

Table 3. Main Dimensions Ship

Dimention	units
Lpp	17 meter
Lwl	15,45 meter
B	4 meter
H	1,4 meter
T	0,8 meter
Vs	9 knots = 4,630 m/s

Apart from the main size data of the ship, other data in Table 4 is obtained from the Hydrostatic Curve:

Tabel 4. Hydrostatic Curve Data

Hydrostatic data	Units
Koefisien block (Cb)	0,348
Koefisien prismatic (Cp)	0,741
Koefisien midship (Cm)	0,5
Koefisien bidang air (Cwp)	0,865
Volume displacement (Δ)	30,664 meter ^{3}
Displacement (∇)	31,431 ton

3.2 Main Machine Electrical Power Requirements

The main engine of this fishing boat basically uses a diesel engine which has a power of 90 HP. Where the specifications are In-Line, Water-cooled, 4-Stroke, and also has 6 cylinders. Apart from that, the rotation per minute is 2000 Rpm. If the power produced by a previous diesel engine of 90 HP is converted, then the House Power (HP) unit is changed to Kilo Watt (Kw). The following is the calculation for the HP to Kw conversion.

$$
\begin{aligned}
P_{kw} &= 0{,}7457 \times Php \\
&= 0{,}7457 \times 90 \\
&= 67{,}113\ kWh
\end{aligned}
\tag{3}
$$

In accordance with the calculations above, it can be concluded that the power produced by a diesel engine that has been converted to an electric engine is 67,133 kWh. This value will be a reference for the use of electric engines which have been calculated according to the operational needs of the fishing vessel.

The amount of power required by a ship is determined by the amount of resistance of the ship. The speed of the ship according to our wishes along with the weight of the ship's cargo will determine the amount of resistance of the ship. What needs to be paid attention to is the method for calculating the ship's power requirements using the Naval Architectur Vol II SV Aa Harvald "Resistance and Propulation of Ships" method. This method will determine the amount of power and matching propeller, including Effective Horse Power (EHP), Delivered Horse Power (DHP), Shaft Horse Power (SHP), Brake Horse Power (BHP) and Trusht Horse Power.

a. Calculation of Wet Surface Area

$$
\begin{aligned}
A_{BT} &= Cross\ Area\ of\ Bulb\ in\ FP \\
&= 10\% \times B \times T \times Cm \\
&= 0
\end{aligned}
$$

$$
S = L(2T + B)Cm^{0,5}\left(0{,}4530 + 0{,}4425\ Cb - 0{,}2862\ Cm - 0{,}003467\frac{B}{T} + 0{,}3696\ Cwp\right) + 2{,}38\frac{A_{BT}}{C_B}
$$

$$= 46{,}713$$

$$
A_{Rudder} = C_1 \times C_2 \times C_3 \times C_4 \times \frac{1{,}75 \times L \times T}{100}
$$

$$= 0{,}238$$

$$
S_{Bilge\ Keel} = L_{Keel} \times H_{Kell} \times 4
$$

$$= 17{,}268$$

$$
\begin{aligned}
S_{app} &= \text{Total wetted surface of appendages} \\
&= S_{Rudder} + S_{Bilge\ keel} \\
&= 17{,}560
\end{aligned}
$$

$$
\begin{aligned}
S_{Tot} &= Watted\ surface\ of\ bare\ hull\ and\ appendages \\
&= S + S_{app} \\
&= 64{,}220
\end{aligned}
\tag{4}
$$

b. Total Force Calculation

C_A (Correlation Allowance)

$$C_A = 0{,}006(LWL + 100)^{(-16)} - 0{,}00205$$
$$= 0{,}006(15{,}39 + 100)^{(-0{,}16)} - 0{,}00205$$
$$= 0{,}0008$$

W (Weight)

$$W = \rho \times g \times \nabla$$
$$= 308{,}336\ N$$

R_{Total}

$$R_T = \frac{1}{2} \times \rho V^2 \times S_{Tot}[C_F(1+k) + C_A] + \frac{R_W}{W} W$$
$$= 2530{,}622\ N$$

$R_{Total} + 15\%\ (margin)$

$$= 2{,}190\ kN = 2910{,}215\ N \tag{5}$$

c. Effective Horse Power (EHP) Calculation

$$F_n = \frac{V_S}{\sqrt{g.L}}$$
$$= \frac{4{,}630}{\sqrt{9{,}81 \times 17}}$$
$$= 0{,}35153$$
$$EHP = \frac{R_T \times V}{1000}$$
$$= \frac{2910{,}215 \times 4{,}630}{1000}$$
$$= 13{,}473\ Kw \tag{6}$$

d. Thrust Horse Power (THP) Calculation

THP $= \frac{T \times V_A}{1000}$

T $= \frac{R_T}{(1-t)} = \frac{2910{,}215}{(1-0{,}25)} = 3882{,}875$

$V_A = V \times (1 - W) = 4{,}630 \times (1 - 0{,}01722003) = 4{,}5498$

$V_V = (1 + K)C_F + C_A = 0{,}00368392$

W $= 0{,}3C_B + 10C_VC_B - 0{,}1$

$= 0{,}3(0{,}348) + 10(0{,}00368392) - 0{,}1$

$= 0{,}01722003$

t $= (0{,}5 \times C_P) - 0{,}12$

$= (0{,}5 \times 0.741) - 0{,}12$

$= 0{,}25$

$\eta h = \frac{1-t}{1-W}$

$= \frac{1 - 0{,}25}{1 - 0{,}01722003} = 0{,}76263256$

THP $= \frac{3882{,}275 \times 4{,}5498}{1000} = 17{,}667\ Kw$ (7)

e. Delivered Horse Power (DHP) Calculation

DHP $= {THP}/{\eta_p}$

$\eta_O = 0{,}55$

$\eta_r = 0{,}98$

$\eta_p = \eta_O \times \eta_R$

$= 0{,}55 \times 0{,}98$

$= 0{,}539$

DHP $= \frac{17{,}667}{0{,}539} = 32{,}777$ (8)

f. Shaft Horse Power (SHP) Calculation

SHP $= DHP/\eta_B\eta_S$

$\eta_b\eta_s = 0{,}98$

SHP $= \frac{32{,}777}{0{,}98} = 33{,}446\ Kw$ (9)

g. Brake Horse Power (BHP) calculation

$$BHP = SHP/\eta_T$$

$$\eta_T = 0,975$$

$$BHP = \frac{33,446}{0,975} = 34,303\ Kw \quad (10)$$

h. Maximum Continuous Rating (MCR)

The power generated from the main engine continuously reaches maximum level limits and safe conditions. So you can know the electrical power requirements of the main engine according to your needs.

$$\begin{aligned} MCR &= BHP\ \times (1 + MD)\ /\ (1 - MS) \\ &= 34,303 \times (1 + 0,5)\ /\ (1 - 0,15) \\ &= 42,374\ Kw = 57,612\ HP \quad (11) \end{aligned}$$

$$\begin{aligned} \text{Generator Power} &= 24\% MCR \\ &= 10,170\ Kw \quad (12) \end{aligned}$$

3.3 Fishing Ship Sailing Routes

The distance of the shipping route will determine the time the ship travels at maximum ship speed. This fishing ship will start its voyage from the port of Banyuwangi to the designated fishing area. To determine the time taken, the distance of the ship's sailing route when operational and the maximum speed of the ship are needed. The following is a picture of the fishing boat shipping route see Figure 3.

This fishing boat will sail to the waters of the southern part of Nusa Tenggara Island. Where, if seen from the maps, the distance traveled is 150 km from the port of Banyuwangi. So using physics formulas you will get the time the ship takes when sailing when going home and going.

$$\text{Range} = kecepatan\ (V) \times Waktu\ (t)$$

$$150\text{ km} = 4,630 \frac{m}{s} \times t$$

$$t = \frac{150}{4,360} = 8,9\ Hour \quad (13)$$

So from the calculations above, it can be seen that the fishing boat's travel time when sailing submerged is 8.9 hours with a distance of 150 km and a speed of 4,630 m/s.

3.4 Determining Battery Capacity

Batteries are used as the main source of electrical energy to supply the ship's main engine needs. The battery is designed to suit the needs of the main engine. Determine the battery capacity according to power requirements and the duration of operation of the main machine.

Battery capacity = MCR x Traveling time
= 42,374 x 8,9
= 377,12 kWh (14)

From the calculations above, it can be seen that the battery capacity required for the main engine with a power requirement of 42,374 kWh and operational time is 377.12 mAh.

3.5 Fishing Boat Design

3.6 In this fishing boat conversion design, it is in accordance with the design of the fishing boat before conversion. However, there is an additional design for the battery compartment in the engine room. The following is the design used:

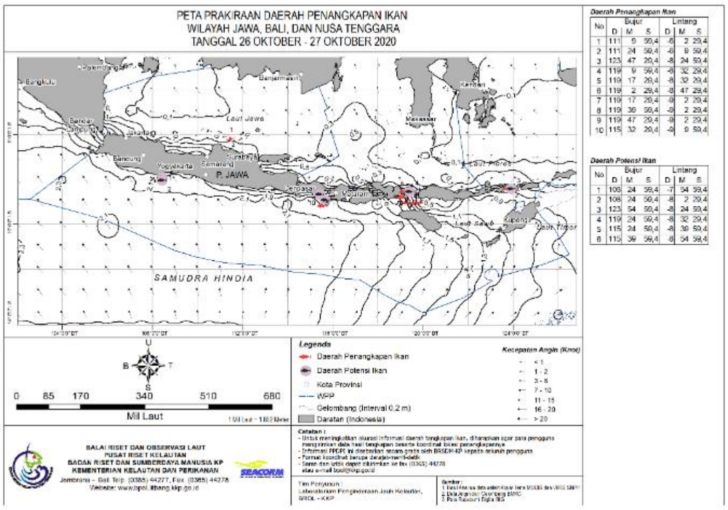

Figure 3. Regional Water Map of Java, Bali and Nusa Tenggara.

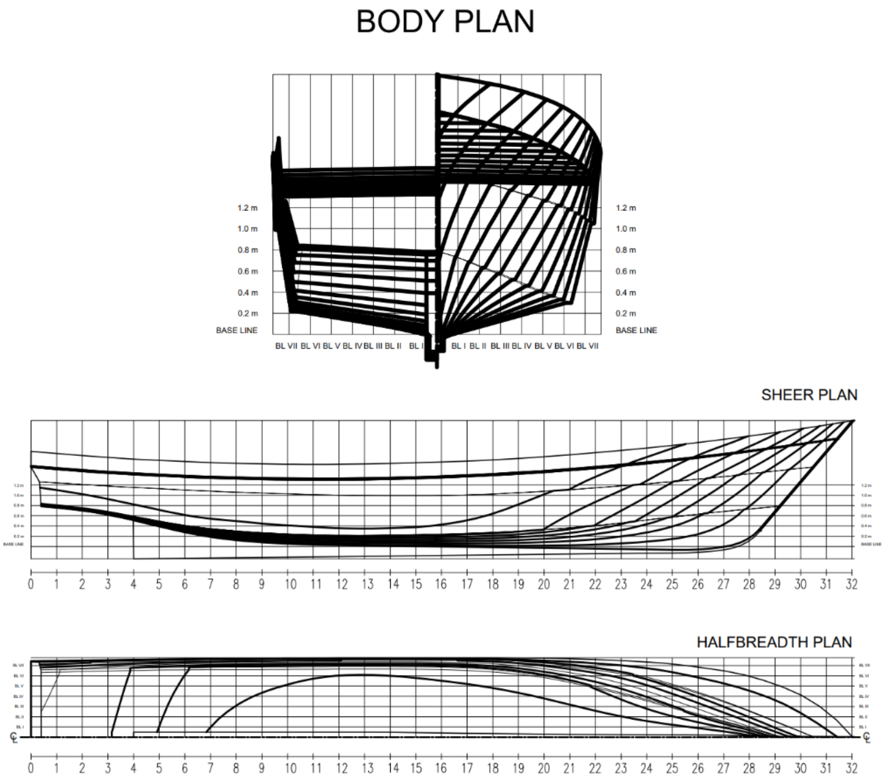

Figure 4. Fishing Boat Line Plan Using Electric Engines

The design above has been adjusted to the main size of the ship. By using the Auto CAD application and 3D modeling. The Lines plan (Figure 4) will later be tested for stability and resistance to determine its feasibility.

Apart from that, the design of the materials used in the body of this converted fishing boat uses FRP (Fibreglass Reinforced Plastic) which is reinforced with longitudinal and transverse reinforcements made from fiberglass blocks/frames filled with foam. The aim of using this FRP material is to make the ship feel light so that it will reduce the power requirement for the ship's main engine. Apart from that, this material is very easy and affordable to maintain. The method used in the process of making an electric fishing boat using FRP as the basic material

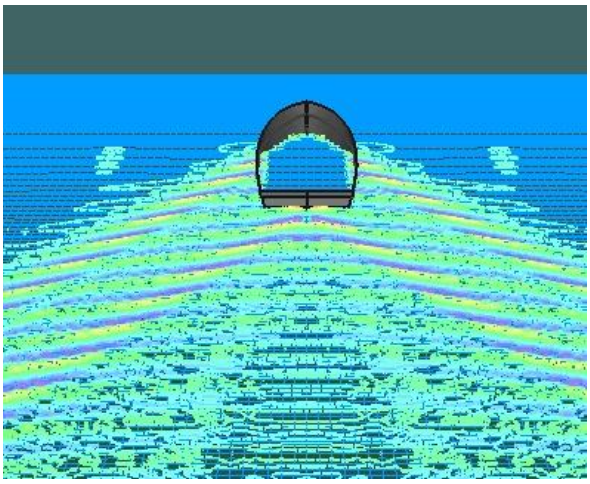

Figure 5. Results of Ship Redesign Trials

is the hand-lay up method. The following are the procedures for making a fish conversion boat using FRP materials:

1. Making a ship frame at a 1:1 scale using wood.
2. Installation of the ship's hull using plywood.
3. Lamination process, the process of attaching Wr and Matt fibers using liquid resin which is carried out repeatedly until a certain thickness.
4. Removal of mall frame and hull. This is done when the lamination process is dry.
5. Finishing process, caulking uneven fiber sections and painting the ship's body.

6. Trial Result

After the results of the converted ship design were finished, trials were carried out using the Maxsurf 3D modeling software. Where later the results of this trial will determine the feasibility of the ship design. If in the results of this trial an error occurs in the design, a complete recalculation of the ship design will be carried out. In this research, the results of the ship conversion design are as follows:

Figure 5 shows the results of design trials that have been successful and declared feasible. Furthermore, the results of this design will be applied directly in the field to build fishing boats using electric motors. After that, the second stage of trials was carried out, namely direct trials at sea.

Sea trials or sailing trials must be carried out in accordance with the provisions of the contract between the owner and the shipyard and after the results of the Mooring Trial are good and accepted by the owner. Sailing trials are official trials consisting of:

- Ship Speed Trial
- Test the ship's maneuvering capabilities
- Trial of the ship stopping suddenly and reversing
- Test the turning radius of the ship
- Test the durability of the main engine and auxiliary engines
- Testing of communications and navigation equipment

The results of the sailing trials must be stated in an official sailing trial report and accompanied by a Minutes of Sailing Trials. If during sailing trials something happens that does not meet the provisions of the technical specifications and contract, the shipyard must repair and perfect or carry out sailing trials again before the ship is handed over to the owner.

4. Conclusion

The conclusion of this research is the electrical power requirement for the main engine is 57,612 Kw with a battery capacity of 377.12 kWh. Design from the drawing of line plans and general designs, data is obtained: Lwl=14,5 meter; Dwt 25,092 ton; and Midship Area, Am= 2,8 m². Operational costs when the ship is sailing: (i) A 90 HP diesel engine with 2000 liters of diesel fuel costs IDR. 12,000,000, (ii) An electric machine with a power of 377.12 kWh costs 544,388. So it can be concluded that the operational costs of ships when sailing are more economical using electric engines.

Acknowledgments

I would like to express my sincere thanks to all parties who have contributed to the completion of this research paper. First, I am extremely grateful to my lecturer, Erifive Pranatal, ST., MT., for her invaluable guidance, patience, and encouragement throughout the entire process. His insightful input and expertise have greatly enriched the quality of this research.
I also thank Nasyith Hanur Rohiem, ST., MT. and Novian Patria Uman Putra, ST., MT., for his assistance with the analysis and role in facilitating my research and interpretation of the data.

Reference

[1] I. M. A. Nugraha, “Penggunaan Pembangkit Listrik Tenaga Surya Sebagai Sumber Energi Pada Kapal Nelayan: Suatu Kajian Literatur,” J. Sumberd. Akuatik Indopasifik, vol. 4, no. 2, p. 101, 2020, doi: 10.46252/jsai-fpik-unipa.2020.vol.4.no.2.76.

[2] J. J. Handoyono, “Teknik Kelistrikan Kapal; Ahli Teknik Tingkat III,” Jakarta Buku Marit. Djangkar, 2017.

[3] H. Saksono, “Ekonomi Biru: Solusi Pembangunan Daerah Berciri Kepulauan Studi Kasus Kabupaten Kepulauan Anambas,” J. Bina Praja, vol. 05, no. 01, pp. 01–12, 2013, doi: 10.21787/jbp.05.2013.01-12.

[4] A. Hendrawan, “Konsep Kapal Dengan Tenaga Otec (Ocean Thermal Energy Conversion),” in Prosiding Seminar Nasional, 2019, pp. 101–105.

[5] A. Hendrawan, A. Sasongko, and others, “Analisis Zalir Kera Pada Pembangkit Listrik Tenaga Otec (Ocean Thermal Energi Conversion),” Saintara J. Ilm. Ilmu-Ilmu Marit., vol. 2, no. 2, pp. 19–26, 2018.

[6] A. B. Setyoko, E. S. Hadi, and U. Budiarto, “Analisis Optimasi Kebutuhan Daya Listrik Pada Kapal Penumpang Ro-Ro KM. Egon Dengan Metode Dynamic Programming,” J. Tek. Perkapalan, vol. 1, no. 2, 2013.

[7] D. Arisandi, “Sistem penggerak Hybrid (Mesin dan tenaga Surya) kapal ikan lambung Catamaran,” 2013.

[8] A. Baskoro and T. W. Pribadi, “Analisa Teknis dan Ekonomis Pembangunan Kapal Ikan Ukuran 10GT-20GT Konstruksi Fibreglass Reinforced Plastic (FRP) Sesuai Standar Biro Klasifikasi Indonesia,” J. Tek. ITS, vol. 7, no. 1, pp. G25--G30, 2018.

[9] I. Danajat, “Teknologi Alat Penangkapan Ikan,” Jakarta: Djankar, 2015.

[10] N. Nurhasanah and M. Helmi, “Kajian Pemanfaatan Serbuk Papan Sebagai Bahan Alternatif Campuran Resin Dengan Metode Pattern Hole Drying Untuk Perbaikan dan Perawatan Kapal,” INOVTEK POLBENG, vol. 8, no. 1, pp. 86–90, 2018.

[11] A. Wijaya and E. S. Koenhardono, “Analisa Teknis dan Ekonomis Sistem Propulsi Elektrik Pada Kapal Ikan 30 GT Tipe Purse Seine”.

[12] Santosa, P. I., and E. Pranatal. "Study of Catamaran Fishing Vessel Based on Solar Energy." Journal of Physics: Conference Series. Vol. 2117. No. 1. IOP Publishing, 2021.

[13] Santosa, P. I., and E. Pranatal. "Study of emission quantification in catamaran fishing vessels based on fossil energy." Journal of Physics: Conference Series. Vol. 1833. No. 1. IOP Publishing, 2021.