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Planning of a Hybrid Propulsion System for Purse Seine Fishing Vessels in Mayangan, Probolinggo, East Java

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***Abstract*— The Mayangan Beach Fisheries Port (BFP) in Probolinggo City is a fishing port that was established using a combination of funds from the State Revenue and Expenditure Budget and Regional Revenue and Expenditure Budget of East Java province and Regional Revenue and Expenditure Budget of Probolinggo city. Equipped with basic and functional facilities to support various fishing activities, fishing vessels generally use a mechanical propulsion system driven by a diesel engine. The results of the government's decision to increase fuel prices by IDR 8,000/liter, were then supported by a survey which showed that fishermen needed as much as 110 liters of fuel for a journey of approximately one hour for one trip, with these conditions making fishermen, especially in the Mayangan district, Probolinggo very objection by increasing the price of fuel that will be used to go to sea, so that with the problems complained of by fishermen on the Mayangan coast, Probolinggo about rising fuel prices, this refers to researchers planning a hybrid propulsion system to reduce consumption of the use of fuel that will be used for purse seine fishing boats. The results showed that the main engine specifications for the Mitsubishi ship were 6D24-Mpt (A) with 228 Kw power, then the Yanmar Ytg 15 Tlv generator, while the electric motor specifications that would be used were Weg Tru Metric 132 Kw / 175 HP, as well as batteries for storing battery energy which had specifications J185-Agm Vrla Agm / Non-Spillable. The difference in fuel consumption in the conventional system and the hybrid system looks quite significant. Using a hybrid propulsion system can produce fuel savings of up to 30% when compared to using a conventional engine.**

Keywords—*Electric motor, fishing boat purse seine, hybrid propulsion system,*

I. Introduction

The coastal fishery area of Mayangan city of Probolinggo is located at 7° 43' 41" to 7° 49' 04" LS and 113° 10' to 113° 15' BT with an area of 56,667 Km². According to Regulation of the Minister of Marine Affaires and Fishery No. PER.08/MEN/2012 regulating Port for Fisheries, fishing ports are places consisting of land and surrounding waters with certain restrictions as places of government activities and fishery business activities that are used as places for fishing vessels to lean, dock, and unload fish equipped with vesselping safety facilities and fishery support activities [1].

Purse seine is a good fishing tool for coastal fisheries and offshore fisheries because of the shape of the tool which is specially designed for types of fish that live *schoaling* (hordes), and are close to the surface of the water [2]. To profit from the catch, fishing operators need to take risks in an expensive and complicated business. The fuel consumption of fishing vessels depends on the operational profile of the vessel and the method of fishing, but fuel costs can reach 20-30% of the total catch value [3]. Some of the main fishing methods and tools for commercial fishing used today are pure trawls, trawls, gill nets and ropes that are dilwith a fishing hook [4]

The operation of purse seine fishing gear is of course supported by various aids with the aim that the catch obtained is maximized. Fishing aids are tools used to facilitate the process of fishing with certain fishing gear. Examples of fishing gear that are commonly used are navigation tools, fishing aids and tools for collecting. Therefore, fish boats with purse seine type require quite a lot of power. In general , diesel engine use fuel oil. The availability of oil in Indonesia is decreasing. Based on data from the Ministry of Energy and Mineral Resources, from 2006 to 2015 oil reserves in Indonesia experienced a very significant decline [5].

This problem was reinforced by the news that there would be the abolition of subsidized fuel by the government [6]. This is widely felt by fishermen who are on the coast of Mayangan Probolinggo Java Timur. Many fishermen complain about the large cost of fuel incurred one way to sail. In an effort to optimize marine resources as stated in Presidential Instruction No. 1 of 2010 related to the acceleration of the implementation of national development priorities in the field of food security, the sea and the environment are energy supply sectors that can be utilized as well as wind, wave, current and solar energy [7].

Seeing these conditions, it is necessary to make a breakthrough to find solutions for fishermen so that they can escape the problem, and can escape the dependence on fossil fuels [8]. One alternative solution for fishermen

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to escape dependence on fossil fuels. A combination propulsion system between a *diesel* and a battery-supplied electric motor[9]. Energy storage here refers to batteries and was chosen because it is likely to store large amounts of energy at a reasonable cost compared toother storage methods [10].

In addition to reducing fuel use, the diesel and electric motor combination propulsion system is cheaper in terms of maintenance, and has a more flexible drive system setting. So using this hybrid propulsion system is the right and effective solution to reduce fuel consumption on *purse seine* vessels [11-13].

II. METHODS

This research has several stages that must be carried out. The stages referred to in this study are as follows:

A. *Problem Identification*
Conducted to answer from the problem in the background of the research where this research contains problems complained by fishermen on the coast of Mayangan Probolinggo about rising fuel prices.

B. *Literature Study*
At this stage, it is carried out to get a summary of the basics of existing theories, as a reference and various information that can be a support.

C. *Collecting Data*
This research uses the object of a *purse seine* fish boat obtained from one of the fishermen in the coastal fishery area Mayangan Probolinggo, East Java, based on the main data of the vessel to be used. From the data obtained in the field data collection process, the next step is to calculate vessel resistance and hybrid propulsion system components such as *main engines*, generator sets, batteries, fuel consumption, and electric motors

D. *Determination of Propulsion Specifications*
After obtaining the necessary data, the next step is to determine the propulsion component. From the data analysis that has been carried out, a specification of the *components* of the hybrid propulsion system will be obtained that will be used for *purse seine* fishing vessels.

Here's the research flowchart looks like, as shown in figure 1.

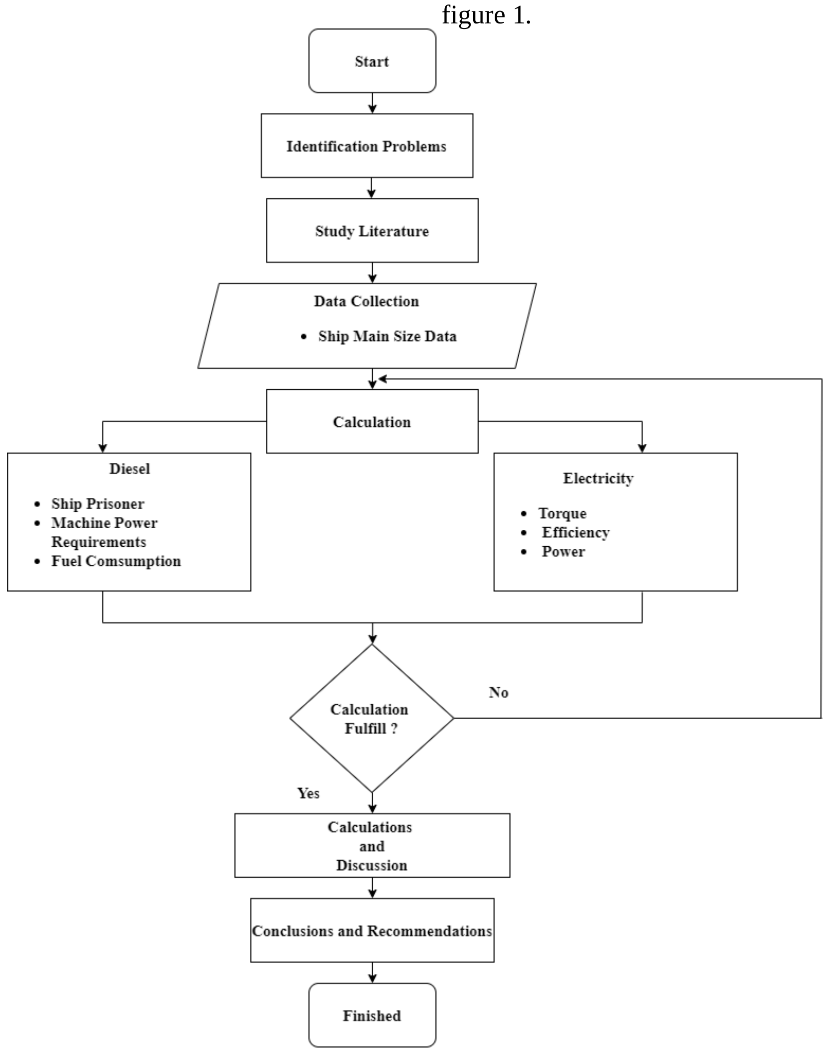

Figure. 1. Research Flow Chart

III. RESULT AND DISCUSSION

A. *The Main Data of the Vessel*

Aftergoing through the selection of several vessels it is further determined how much power needs will be used on the vessel.

The dimensions of the main sizes of vessels can be seen in Table 1. Experimental research is needed to verify and validate other studies such as simulation research [14-16]

TABLE 1.
THE MAIN SIZES OF FISH BOATS

Parameter of Vessel	Values	Unit
Length (Lwl) / Length (Lpp)	16.6 m / 16.5	m
Width	5.0 m	m
Height	3.0 m	m
Laden	1.5 m	m
Speed	8.0 Knots	knots
Block Coefficient	0.51	

B. *Model Building*

Hull model manufacturing uses line plan data from existing vessels. Remanufacturing of vessel models is also necessary for the calculation of the resistance of the vessel's body with the help of *software.* Figure 2 shows the shape of the *purse seine* vessel model which still uses a general (conventional) drive system designed using *AutoCAD software.*

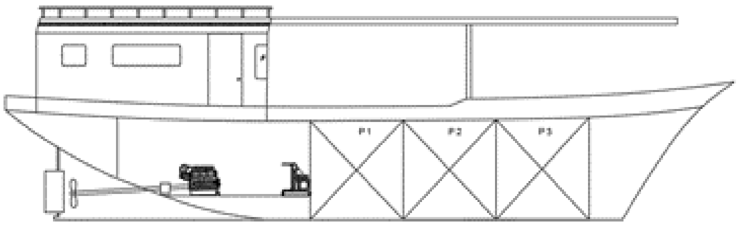

Figure. 1. Design *Purse Seine* vessel conventional machine

Then figure 3 shows the shape of the *purse seine* vessel model that has used a hybrid propulsion system and modeling made using *AutoCad software*.

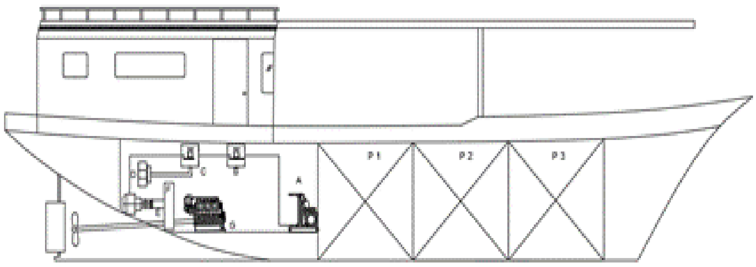

Figure. 3. Design *Purse Seine vessel hybrid* engine

To convert an image from two dimensions to three dimensions requires *a* tool, namely the maxsurf modeller. In the process of changing the image from two dimensions to three dimensions, a general arrangement drawing of the purse seine fish boat is needed so that the two-dimensional image can be changed. Because after being made into 3 dimensions the vessel will be used as material for testing how much resistance is obtained on the vessel. The shape of the purse seine vessel that has been made into three dimensions can be seen in figure 4.

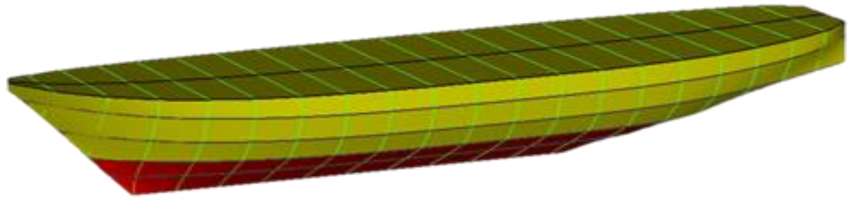

Figure. 4. Modeling of the hull using *Maxsurf*

C. *Calculation of Vessel Resistance*

This method uses manual calculations and uses the maxsurf resistence method holtrop [17-18]. To determine the engine power required for a vessel, it is necessary to calculate several components such as effective Hourse Power (EHP), delivered horse power (DHP), thrust horse power (THP), brake horse power service continue rating (BHPscr) and brake horse power maximum continue rating (BHPmcr). By calculating these components, it can be found what kind of engine is suitable for *a purse seine* vessel. In determining the magnitude of the vessel's resistance in this calculation using the Holtrop method. Calculation of ship resistance by simulation was also carried out in several cases [19-22].

The calculation procedure uses the following formula:

$$R_T = (1 + k1) + R_{APP} + R_W + R_B + R_{TR} + R_A \quad (1)$$

Where:

RF = Swipe resistance under ITTC-1957
(1 + k1) = Form factor
RAPP = Additional resistance of prominent shape
Rw = Wave resistance
RB = *Bulbous bow* resistance
*R*TR = Water-immersed transom resistance
RA = Vessel model correlation resistance

Therefore, from the known data, the size of the prisoners can be calculated using the holtrop method as follows.

$$R_T = R\,(1 + k1) + R_{APP} + R_W + R_B + R_{TR} + R_A \quad (2)$$
$$= 1.0299\,(1.28) + 0 + 20.5484 + 0 + 0 + 0.4551$$
$$= 20.321772 \text{ kN}$$

TABLE 2.
VESSEL RESISTANCE BASED ON *MAXSURF RESISTANCE*

Speed (Knots)	Holtrop Holtrop Resistance (kN)	Power (kW)
0	-	-
0,6	0,1	0,17
0,9	0,1	0,067
1,2	0,3	0,176
1,8	0,7	0,626
2,1	0,9	0,977
2,7	1,4	0,927
3,0	1,6	2,519
3,9	2,4	4,719
4,2	2,6	5,589
4,8	3,1	7,549
5,1	3,3	8,654
5,7	3,8	11,207
6,0	4,1	12,691
6,9	5,3	18,693
7,2	5,8	21,656
7,8	7,1	28,325
8,0	7,6	31,612

Table 2 is a calculation calculation using *maxsurf resistance* software. *Maxsurf* resistance can be used to make predictions and estimates on vessel resistance. Once a prediction of the vessel's resistance is found and the amount of power capable of overcoming the resistance, a graph of the comparison between the resistance and the speed of the vessel as shown in figure 5.

In addition, maxsurf resistance will make the shape of the wave flow pattern that hits the hull. With the presence of these tools it can be clearly seen how the shape and contour of the hull is as shown in figure 6.

The ship's resistance it self is an estimate of the effective power required to keep the ship moving at the speed for which it was designed. A ship moving forward at a certain speed experiences drag from the action of a fluid whose direction is opposite to the ship's motion.

Ship resistance is denoted by the letter R. Barriers acting on ships are usually denoted by RT or called total resistance.

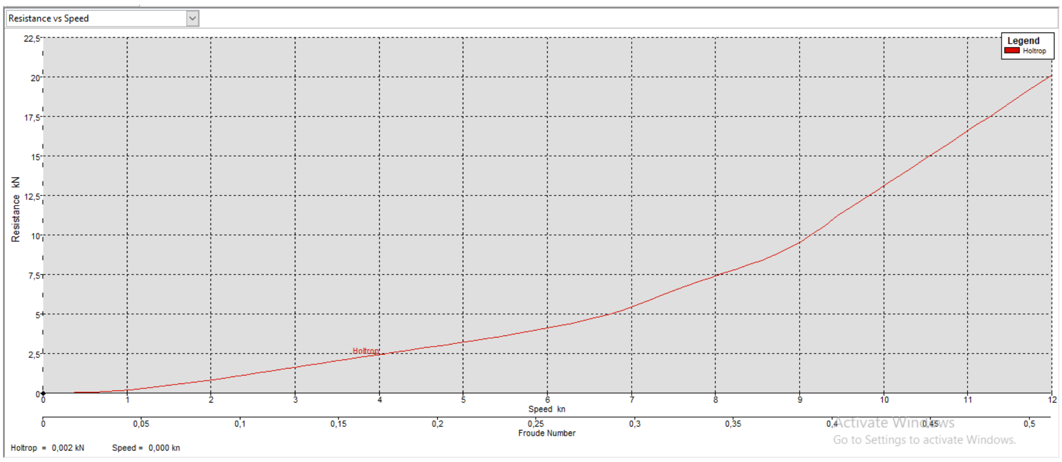

Figure 2. Drag vs Speed

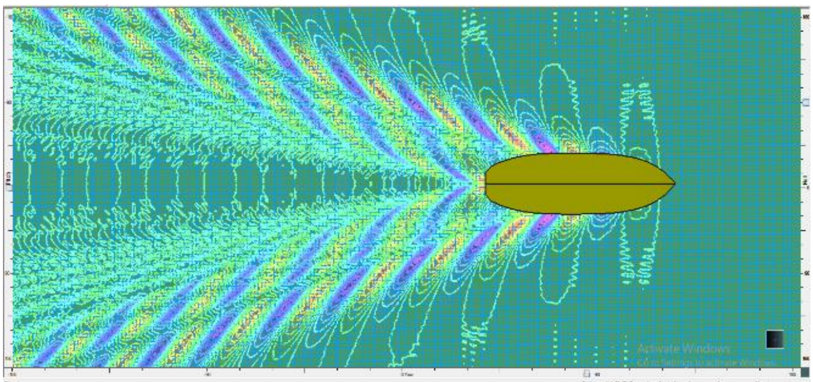

Figure 3. Wave Flow Contours of the vessel

D. *Calculation of the Selection of the Main Engine of the Vessel*

To perform the calculation to determine the engine power needed to support the vessel that will operate, a calculation will be obtained using the following formula.

1) Effective Horse Power (EHP)
EHP = RT_{Dinas} x Vs =....... Kw (3)
Where:
$RT_{Service}$ = $R_{T\ Vessel}$ While Sailing (22.3 kN)
Vs = Vessel speed (4,115 m/s)
EHP = 22.3 x 4,115
= 91,764 kW
= 123,057 HP

2) Delivery Horse Power (DHP)
DHP = Ehp : Pc =........ Kw (4)
Where:
DHP = 91.764 : 0.415
= 221.11 hp / 164.88 kw

3) Thrust Horse Power (THP)
Where:
THP = 123,349/0.672 (5)
= 183,555

4) *Shaft Horse Power* (SHP)
SHP = DHP / 100% - 2% = 98 % (6)
= 221.64 / 98 %
= 226.16 HP

5) Brake Horse Power (BHP)
BHPscr = SHP / ηG (7)
= 226.16 / 0.98 HP
= 230.77 HP / 172.08 Kw

6) BHPmcr = BHPscr / 0.80 (8)
Where:
= 230.77 / 0.80
= 288.4625 HP
= 215.1063 kW

E. *Calculation of Electrical Load on Fish Vessels*

TABLE 4.
VESSEL'S ELECTRICAL LOAD

Space	Equipment	Quantity	Power	Total Power
Deck	Lamp	8	1524	
Wheelhouse	Socket	2	632.7	
Machine	auxiliary machine	1	632.7	
				1417,8

Table 4 shows that the total electrical power requirement in *purse seine* vessels is 1417.8 Watts or 14,178 kW. The total power requirement is the result of the summation of all electrical components on the *purse seine* fish boat. Because the total power released by 1417.8 exceeds the strength of the main alternator, it is necessary to replace the alternator according to existing needs, where the selection of the alternator is exaggerated by 20% so that the *life time* of the alternator is more display. Then it is obtained alternator as follows.

F. *Electric Motor Power Calculation*

To be able to find out how much power the electric motor is used to meet the needs, calculations can be made. From the 165 HP power obtained from the calculation with the holtrop method, 15% is added for sea trial conditions, so that the power needs of the new are obtained as follows:

$$P = 165 \times 1.15$$
$$= 5.29 \text{ HP}$$
$$P = 189.75 \text{ HP} / 95\% \qquad (9)$$
$$= 199.7 \text{ HP}$$

From the data above, a reference can be used as a selection of electric motor specifications as a propeller drive for *purse seine* fish boats. The specifications of the electric motor that will be used in this planning to drive the propeller are as shown in table 6.

TABLE 6.
SPECIFICATIONS OF THE ELECTRIC MOTOR

Specification	Description
Brand	WEG TRU METRIC
Power Output	132 kW / 175 HP
Speed	1800 RPM
Voltage	460 V
Current	:203 A
Efficiency	96.2
Pf	0.85

G. *Battery Capacity Calculation*

To be able to find out how many batteries are used to meet the needs of an electric motor, the following calculations can be made.
Known:
Total energy consumption: 12863.4 Watts
Operating time: 12 hours
Total energy consumption: 12863.4 Watts x 12hours (10)
: 15436 Wh or 15.436 Kwh
AH: Total Energy Consumption x Operational Time : (V x DOD) (11)

Where:
V = Battery voltage
AH = Hourly battery electric current
DOD = *Depth of discharge*
Known:
AH: (15,436 Kwh x 1 Day) / (48V x 0.95) (12)
AH: 15,436 Kwh / 45.6 V
AH: 330 Ah

To accommodate the energy generated from the generator that will be used to drive the electric motor, it is determined to use a 200 AH battery as many as 2 batteries so the total battery capacity is 400 AH as shown in table 7.

TABLE 7.
BATTERY SPECIFICATION

Specification	Description
Model	J185 - AGM
Battery	VRLA AGM
Material	Polypropylene
Voltage	12 V
Dimensions	380x176x367

H. *Electric Motor Efficiency Calculation*

Efficiency is defined as the comparison between output power and its input power. The output power is equal to the input power. Therefore, there are two variables, namely (output and input) to be able to find out the efficiency value, it is determined by the following formula:

$$\eta = \frac{P\ output}{P\ input} \times 100\ \% \qquad (13)$$

Where:
η = Efficiency (%)
P_{Output} = Output power (Watts)
P_{Input} = Input Power (Watts)

Known:

$$\eta = \frac{132}{150} \times 100\%$$
$$= 88\ \%$$

I. *Electric Motor Torque Calculation*

Torque is defined as a force used to move something with a certain distance and also a certain direction, therefore to be able to find out what the torque value is in a dc motor, it is determined by the following formula:

$$T = (5252 \times P) : N \qquad (14)$$

Where:
P = Power in units of HP *(HorsePower)*
T = Torque (Nm)
N = Number of revolutions per-minute (RPM)

5252 = Ais the determination value (Constant) for motor power in units of HP.

Therefore, from the data that has been known, it can be reducedto the torque value of the electric motor as follows.

T = (5252 x 175HP) : 1800Rpm (15)

T = 919100 : 1800

T = 510.6 Nm

The calculated per speed starting from 1 – 8 knots, the fuel value consumption as shown in table 8.

As for the calculation of the amount of fuel consumption for *a hybrid* engine at a maximum speed of 8.0 knots, it is as follows:

$Wfo = BHP_{me} . b_{me} . V_{s} . 10\text{-}6 . C$

$Wfo = 2237 . 178 . 8.0 . ^{10\text{-}6} . 1.05$

Wfo = 33.44 Tons

TABLE 8
CALCULATION OF FUEL REQUIREMENTS CONVENTIONAL MACHINES

Speed	Wfo (gr/kWH)
1	4. 85982
2	9.71964
3	14. 5794
4	19.43928
5	24.29910
6	29.15892
7	34.01874
8	38.87856

J. *Fuel Consumption Comparison*

To get the value of the need and use of fuel, calculations are carried out using the following formula:

Wfo = BHPme . bme . Vs . 10-6 . C (16)

Where:

Wfo = Main machine power

B_{me} = Mains engine fuel specifics

Vs = Speed

C = Backup correction

As for the calculation of the amount of fuel consumption for conventional engines at a maximum speed of 8.0 knots, it is as follows:

$Wfo = BHP_{me} . b_{me} . V_{s} . 10\text{-}6 . C$ (17)

$Wfo = 228 . 203 . 8.0 . ^{10\text{-}6} . 1.05$

Wfo = 38.87 Tons

If calculated per speed starting from 1 – 8.0 knots and the rotation of the electric generator is obtained fuel consumption as shown in table 9.

TABLE 9
CALCULATION OF FUEL REQUIREMENTS
HYBRID ENGINE

Speed	Wfo (gr/kWH)
1	4. 180953
2	8. 361906
3	12. 542859
4	16.723812
5	20.904765
6	25. 085718
7	29.266671
8	33.447624

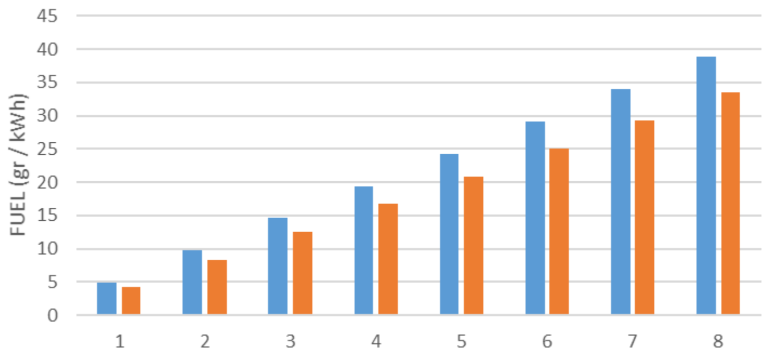

Figure 7. Fuel Consumption Comparison

From the figure 7, it can be seen clearly that the comparison of fuel consumption in conventional system and hybrid systems looks quite significant comparisons using hybrid systems resulting in fuel savings of up to 30% when compared to using conventional engines. With the reduction of fuel consumption in the diesel engine, it will affect the maintenance of the diesel engine. So that this propulsion system is highly recommended to be applied to fishing boats where this vessel requires high fuel consumption, so that if with the implementation of this hybrid propulsion system, it will benefit in terms of engine maintenance and can reduce fuel use.

K. *Disadvantages And Amendments Hybrid Propulsion*

Loss and loss is a comparison of the amount of energy produced by an element that shows how much loss and efficiency occurs in the system used.

Based on the equivalent of a combustion motor (conventional engine), the disadvantages consist of 4 types, namely:

1. *Propeller*
2. *Shaft*
3. *Gearbox*
4. *Main Engine*

Then the efficiency of conventional propulsion and hybrid propulsion as shown in figure 8.

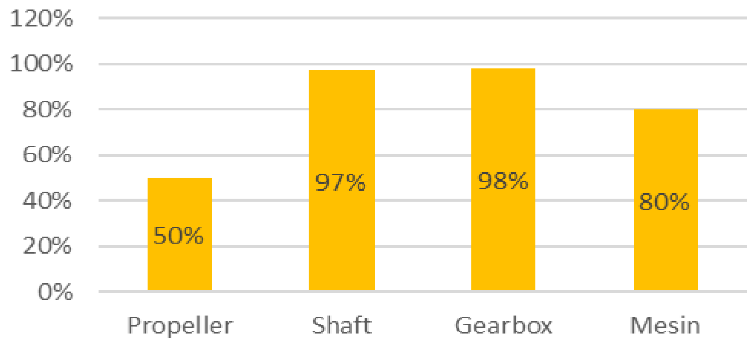

Figure 8. 4Conventional Machine Efficiency

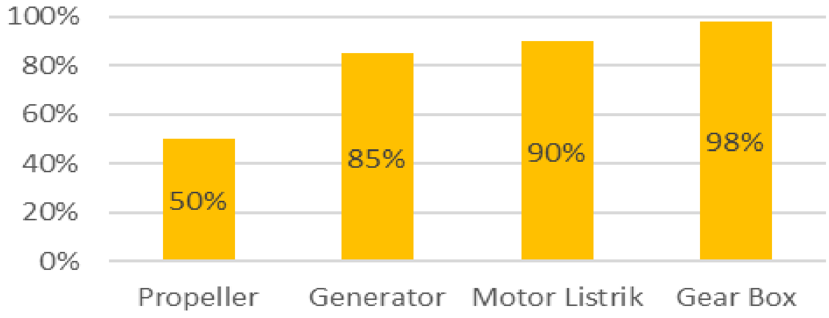

Figure 9. Hybrid Engine Efficiency

From figure 9, it can be determined the amount of effective power and power wasted by what percentage conventional propulsion effective power of 50%.

Meanwhile, in the calculation and graph of losses and amendments above, it can be determined the amount of effective power and power wasted what percentage. In *hybrid* propulsion the effective power is by 55%.

From the percentage above, it is proven that the efficiency of conventional propulsion and hybrid propulsion gets a difference that shows that *hybrid* propulsion is more efficient to use when compared to conventional propulsion which tends to have a lot of losses that occur in each component and plus fuel consumption is much more.

III. CONCLUSION

1. Based on the calculation results, a series hybrid system is obtained, where the stem propulsion is composed of all components that are connected in series, while for the calculation results of determining the specifications of the *hybrid* propulsion system, the main engine of the MITSUBISHI 6 D24-MPT (A) vessel with a power of 228 kW is obtained, then the YANMAR YTG 15 TLV generator, as for the specifications of the electric motor that will be used WEG TRU METRIC 132 kW / 175 HP, as well as batteries for storing energy batteries have specification J185-AGM VRLA AGM / *Non-Spillable*
2. The effect of the use of hybrid propulsion combined *diesel* and electric motor on fuel consumption can be seen clearly that the comparison of fuel consumption on conventional sistem and hybrid systems looks quite significant comparison using *a hybrid* system resulting in fuel savings of up to 30% if compared to using conventional machines.

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