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Theoretical Evaluation of Fuel Consumption in Fishing Vessel Machinery

Rizqi Ilmal Yaqin [1)*], Riski Anjaska[1)], Bobby Demeianto[1)], Juniawan Preston Siahaan[1)]

[1)] Department of Ship Machinery, Politeknik Kelautan Dan Perikanan Dumai, Dumai 28826, Indonesia
[*)] Corresponding Author: r.ilmalyaqin@politeknikkpdumai.ac.id

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Abstract

Fuel serves as a crucial element in the operations of fishing businesses employing boats. Presently, the usage of fuel in ships remains significant, yet it lacks thorough mathematical and theoretical assessment. This research aims to evaluate, both mathematically and theoretically, the fuel consumption of fishing vessels during their fishing endeavors. The study involved observations of various aspects, such as engine types, fuel types, and fuel flow, on fishing vessels. Fuel consumption was computed based on operational hours and RPM (Revolutions Per Minute) of diesel engines onboard ships. The findings revealed that engines with identical loads exhibited varying fuel consumption rates due to differences in cylinder volume. Additionally, fuel consumption increased with higher RPM. Fluctuations in fuel consumption during fishing operations were attributed to adjustments made by vessels according to environmental and situational factors. Theoretical and mathematical analyses indicated that several factors, including operational hours, RPM, and cylinder volume, influence fuel consumption in diesel engines of fishing vessels. This study's significance lies in providing insights into the theoretical and mathematical aspects of predicting fuel consumption in diesel engines utilized in fishing vessels.

1. Introduction

Fishing vessels are sea transportation used by fishermen in fishing operations [1]. Many fishing vessels still use diesel engines to drive the ship's machinery. A diesel engine is a machine with good durability and effectiveness in operating for a long time [1], [2]. Nevertheless, the use of diesel engines cannot be separated from fuel consumption. Fuel oil (in Indonesia called BBM) is vital component in fish production or fishing business activities. The large or small amount of fuel consumption is influenced by several factors, including operating time, ship size, engine use, and fuel type [4] . On the other hand, the continuous use of fuel will result in wastage, increasing the ship's total operational costs. This condition is because the fuel used in fishing vessels is the highest cost, up to 70% of the ship's operational costs, so the need for fuel in operations must be considered. Therefore, several ship companies that use diesel engines as machinery on board need to pay attention and consider it during fishing operations so that fuel is not wasted [5].

Several studies have been carried out on fuel calculations in diesel engines and onboard machinery. One of them, Uloli et al. [6], examined fuel use in diesel engines using mathematical equations. As a result, fuel consumption in diesel engines can be calculated, but other factors from fuel consumption in diesel engines are not yet known. On the other hand, research from Bialysotcki et al. [7] states that fuel requirements for ship engines can be predicted with a mathematical approach. Modeling of several algorithms is used in estimating fuel needs based on factors that influence it, including displacement, ship shape, and type of propulsion. Meanwhile, calculating fuel consumption using ASTM-IP requires the specific gravity of the type of fuel [1]. The calculation of fuel consumption, if technically calculated, can be used by considering the ship's engine power and operating hours [10]. However, the main engine and the ship's auxiliary engine influence the fuel consumption on board. Therefore, the difference in calculating fuel consumption for the main engine and auxiliary engines are distinguished by the factors of engine power and the use of diesel engines [12]. Technical comparison calculations have been done by comparing the calculation of theoretical equations and the amount of fuel used on board. The result of the calculation depends on the engine rotation speed, which affects the speed of the ship and the number of operating hours used [13]. Other research on the results of calculating the fuel consumed by ships can be made in a linear regression so that an upward trend and a significant increase in the ship's diesel engine power can be seen [14], [15]. So that in calculating the fuel requirements for the next voyage.

Based on several studies on mathematical and theoretical calculations in predicting fuel use on fishing vessels, much has not been done, even though this finding is essential in calculating operational costs in the industrial world, especially in

the fishing vessel industry. The highest operational costs of sea transportation, especially ships, are fuel costs [16] . condition will also trigger the price of fishery products and other matters related to the economy. This problem needs special attention to handle it. Therefore, this research aims to theoretically and mathematically analyze the fuel requirements of fishing vessels during fishing operations. The novelty of this study presents ways and techniques for calculating fuel requirements by showing the results of a comparison of the factors that can technically affect fuel requirements on board. This research contributes to providing scientific information in predicting fuel theoretically using mathematical equations. So that the world capture fisheries industry can save money by manipulating the factors that influence it or can calculate fuel consumption according to the needs of the sailing day.

2. Methods

2.1. Data Collection

The research focuses on determining the parameters for fuel consumption in fishing vessels operating in Batam City, Riau Archipelago, Indonesia. Specifically, the study targets fishing vessels equipped with purse seine fishing gear and having a Gross Tonnage (GT) of 152. These vessels are powered by a main engine with 365 HP, manufactured by Nissan, alongside two generator engines, one with 340 HP and another with 217 HP, both manufactured by Mitsubishi. The fuel utilized is diesel fuel, specifically type B30, known for its environmentally friendly characteristics, which is commonly preferred in fishing vessel. The calculation of fuel consumption under operating conditions of fishing vessels relies on various classifications that serve as parameters for assessing fuel consumption patterns. These classifications are identified based on previous research findings, emphasizing the importance of considering specific conditions for fuel consumption in fishing vessels [17].

a. Engine-generated rotation rate (RPM)
b. Machine operating conditions during ship activity
c. The engine type of the Engine used on the ship

In collecting fuel consumption data, the parameters that will be investigated are the rotations per minute (RPM) of the Engine used, the specifications of the diesel engine, and the operating hours of the Engine used. These parameters become material in data processing which is used in analyzing and evaluating based on theoretical calculations.

2.2. Calculation of fuel consumption

Calculating the theoretical fuel consumption required several stages in the analysis. These stages are

1. Measurement of parameters that affect fuel consumption
2. Calculate the effective power of a diesel engine
3. Calculate the effective pressure of a diesel engine
4. Calculating fuel consumption based on specific fuel consumption

Hermawan et al. [2] propose that fuel consumption can be determined through measurements employing instruments. To calculate the specific fuel requirements accurately, knowledge of effective pressure is essential, alongside understanding the effective power generated by the engine during operation. The calculation of the diesel engine's effective power can be conducted using the following equation [13].

$$N_e = \frac{\pi/4 \times D^2 \times P_e \times s \times n \times i}{60 \times 75 \times z} \quad (1)$$

Where $N_e$is the effective power (HP), P_e is the average effective pressure (kg/cm^2), D is the cylinder diameter (mm), s is the piston stroke (mm), n is the motor speed (RPM), i is the number of cylinders and z is a constant value of 1 for 2 strokes and 2 for 4 stroke motors. In producing effective power, it is also necessary to calculate the effective pressure. To determine the effective pressure of the motor P_e, by taking power and full rotation of the motor, you can use the following equation [13].

$$P_e = \frac{T_e \times 60 \times 75 \times z}{\pi/4 \times D^2 \times s \times n \times i} \quad (2)$$

Where P_e is the average effective pressure (kg/cm^2), T_e is the motor power (HP). A mathematical theory is needed in fuel calculations that relate to the specific fuel consumption produced by diesel engines. In this study, specific fuel consumption theory is used to analyze the fuel consumption amount. The theory of specific fuel consumption is the ratio between the fuel consumed at a particular time and the power produced by a diesel engine. The theory of fuel consumption can use the following equation [8], [13].

$$B = \frac{b_e \times n_e}{\rho} \quad (3)$$

Where B is the specific fuel consumption, b_e is the fuel consumption (liters), and ρ is the density of Diesel fuel.

The analysis revealed that the most crucial parameter is the number of operating hours for both the main engine and the generator engine utilizing diesel fuel. Additionally, the RPM speed parameter for the diesel engines of both the main engine and the generator engine is monitored periodically. During the observation, these parameters are compared across

different trips (or voyages), ensuring that the comparison of operating hours for each trip is directly comparable to fuel consumption.

3. Results and Discussion

3.1. Case study of fishing vessel fuel systems

Fishing vessels are ships fishermen use to fish in the ocean. Fishing vessels are used to go to the fishing ground from the port. The type of fishing vessel of research is a fishing vessel with purse seine fishing gear. Where the fishing area is in the Riau waters area, this fishing vessel has various machines to assist in activities in carrying out fishing activities. The main engine of this ship uses a diesel engine, so it has excellent power in propulsion the ship and good resistance in 24-hour operation [2], [18]. The main engine is the main component of the ship's propulsion system [3], [19]. Observation images of the main engine used by this ship can be shown in Figure 1. As for the main engine's specifications, the observations' results can be shown in Table 1. Based on the main engine image, it can be seen that the number of cylinders used in a diesel engine is 10 cylinders. In general, the main engine has an engine rotation value that is constantly changing (dynamic) depending on the ship's speed.

Figure 1. The main engine of a fishing vessel

Table 1. Main engine specifications for fishing vessels

Specification	Information
Engine Type	Diesel Engine 4 Strokes
Brand	NISSAN RE 10
Type	V 10
Engine Power	370 PS (364,9HP)
Step Volume	18.884 cc
Cylinder	10 Cylinder
Bore x Stroke	135 x 132 mm
Fuel	Diesel Fuel
Starting system	Electric
Fuel Consumption	-

In addition to the main engine, machines, namely generators, use diesel fuel as fuel to drive the engine. The observation results show that the generator used in fishing vessel. The Vessel's generator supplies electrical energy used for lighting and navigation on board [3]. The generator is driven using a diesel engine as its propulsion engine. The observation results show that the generator propulsion engines used on fishing vessels are shown in Figure 2. The specifications of the generator propulsion engines used are shown in Table 2 and Table 3. Based on the observation results, it can be seen that the first and second generator propulsion diesel engines have a total of 8 cylinders and 6 cylinders in a row. Generally, a diesel engine as a generator drive has a relatively constant engine rotation value.

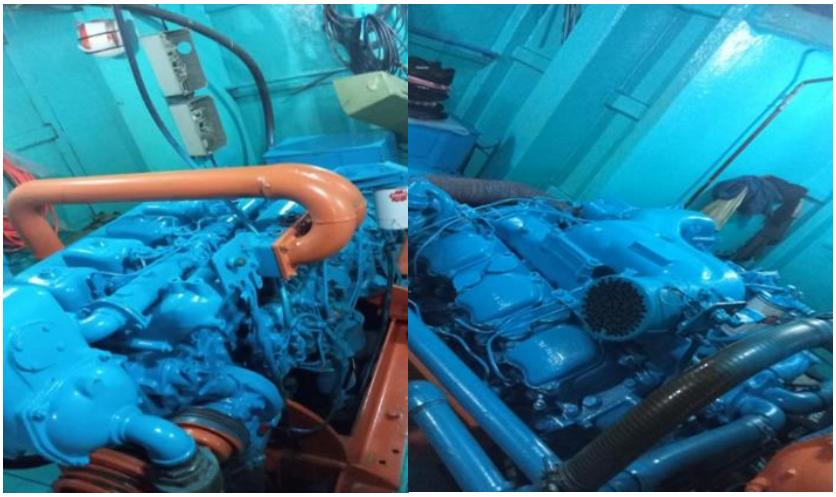

Figure 1. The first and second generator driving engines

Table 1. The specification of the first diesel generator engine on a fishing vessel

Specification	Information
Engine Type	Diesel Engine 4 Strokes
Brand	MITSUBISHI 8DC 11
Type	V 8
engine power	340 HP
step volume	11.592 cc
Cylinder	8 Cylinder
Bore x Stroke	142 x 130 mm
Fuel	Diesel Fuel
Starting system	Electric
Fuel Consumption	-

Table 2. Specifications of the second generator diesel engine on fishing vessels

Specification	Information
Engine Type	Diesel Engine 4 Strokes
Brand	MITSUBISHI 6D16
Type	4 Strokes
engine power	220 PS (HP)
step volume	6.391 cc
Cylinder	6 Cylinder
Bore x Stroke	118 x 115 mm
Fuel	Diesel Fuel
Starting system	Electric

In supplying fuel to the engine, the support system is essential in flowing fuel from the main or daily tank to the diesel engine combustion chamber [21], [22]. Observation results from several diesel engines used as ship propulsion and generator propulsion obtained that the fuel support system is relatively the same. The fuel system is one of the most critical systems in a diesel engine as a fuel supply for the main engine and auxiliary engines driving the generator–the main components contained in the fuel system in the engine room sources of Vessel include Fuel tanks, separators, fuel distribution pumps, fuel filters, injection pumps, and injector pumps [23]. The fuel system schematic can be shown in Figure 3.

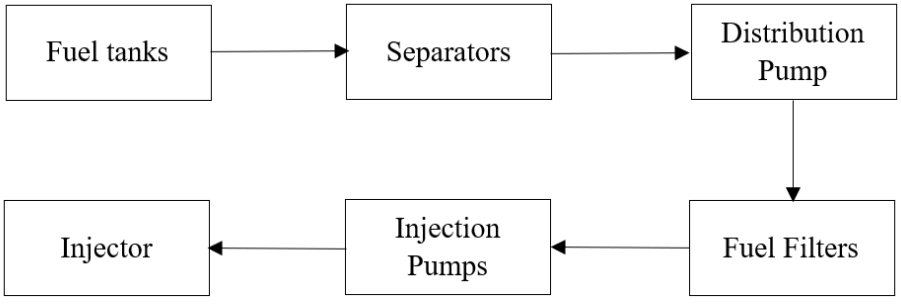

Figure 2. Fuel system block diagram

3.2. Comparison of diesel engine RPM with fuel consumption

Diesel engines are machines that have advantages in fuel efficiency. However, these advantages need to be reviewed against using RPM factors in shown Figure 4. The fuel consumption rate results from directly recording the RPM value when

the diesel engine operates. Mathematically the value of fuel consumption can be obtained from the RPM factor. Comparison of diesel engine RPM values to fuel consumption on fishing vessels. There are three variations of RPM used in diesel engines. RPM variations affect the rate of fuel consumption. Based on the results of recording and analysis, in the fishing vessel main engine fuel consumption in stationary vessel conditions with RPM 600 is 20,51 (Liters/Hour), while in the fishing operation setting conditions, RPM 1300 fuel consumption is 44,44 (Liters/hours). Moreover, when the ship is on a long journey, the main engine runs at a maximum speed of 1400 RPM with a fuel consumption of 47,86 (liters/hour). Main engines of fishing vessels consume the highest amount of fuel during fishing operations by consuming as much as 47,86 (liters/hour) of fuel. The picture described shows that the form in increasing the number of engine rotations, the greater the required fuel consumption [24], [25]. Fuel consumption increases when the engine speed increases in value. This is because the more significant the engine speed, the more fuel the combustion process in the combustion chamber will require. This is given that the engine's rotation is the number of revolutions per minute, which means that as the number of revolutions increases, the amount of fuel consumption used in one minute is also more significant [26]. The effect of engine RPM significantly affects the consumption of fuel used; therefore, several studies suggest suggesting more efficient use of RPM so that fuel consumption is more efficient [17].

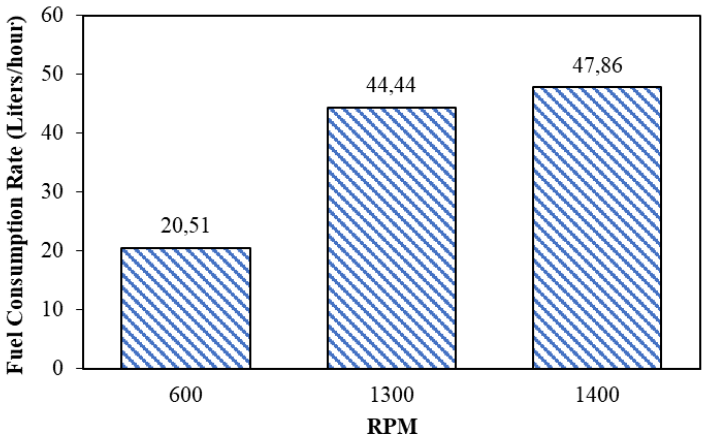

Figure 3. Comparison of RPM with the rate of fuel consumption

3.3. Comparison of types of diesel engines with fuel consumption

The type of diesel engine on the machinery on board has different characteristics. The characteristic shown by the naked eye is the type of machine used. This type of engine is one of the differences in fuel consumption. Figure 5 shows a comparison of the rate of fuel consumption used by various types of diesel engines. This comparison was made on the type of engine driving the generator so that it has constant RPM when operating [27], [28] Figure 5 shows the different types of diesel engines, namely types 6d and 8d, with respect to the fuel consumption rate, but the generator load used is relatively the same value. The mathematical calculations show that the 6dc generator engine has an average fuel consumption rate of 18,56 (Liters/Hour), while the 8dc generator engine has an average fuel consumption rate of 55,23 (Liters/Hour). The fuel consumption rate of 8dc propulsion engine has a higher fuel consumption rate than the 6dc generator propulsion engine because the 8dc type propulsion engine has more cylinders than the 6dc generator propulsion engine. The volume of the diesel engine cylinder can affect the amount of fuel. Meanwhile, the volume of the cylinder itself depends on the size and number of cylinders [29] . This amount of fuel can cause internal combustion to produce mechanical energy. In addition to cylinder volume, the fuel consumption rate, in this case study, is also influenced by engine operating hours in fuel consumption to produce energy [12], [30]. These two factors are of particular concern in the operation of engines, especially generators that use diesel engines to drive their generators.

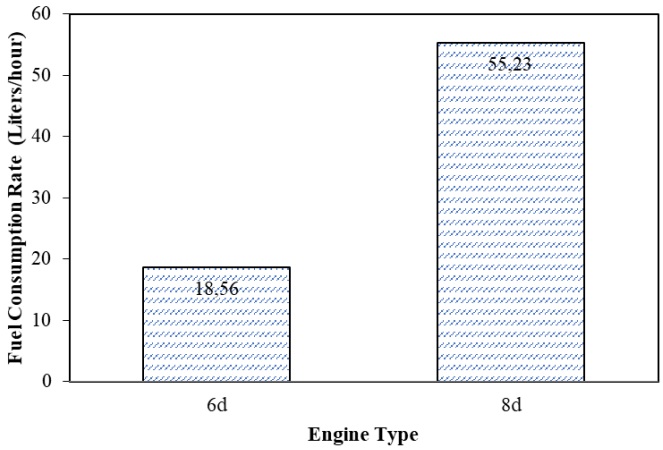

Figure 4. Comparison of engine type with fuel consumption rate

3.4. Fuel consumption on the main engine and generator engine

Measurement of fuel consumption is used to determine fuel requirements in a fishing operation. Figure 6 shows a graph of fuel consumption every day with a comparison of trip 1 and trip 2. Every day the consumption of materials used is different. Daily fuel consumption for trips 1 and 2 tends to have no fuel consumption pattern. This irregularity is due to the different operating hours and factors that affect fuel consumption, including RPM and operating hours [5], [31]. This factor is because every fishing activity goes to the fishing area. When the tool settings adjust to the circumstances and conditions of the environment every day, the use of the machine will not be the same as the previous activity. Therefore, in the fuel consumption graph, the consumption amount will be irregular every day.

Figure 7 shows the fuel consumption per trip used on fishing vessels, the difference in the amount of fuel consumption in trip 1 and trip 2 can be shown by the total fuel consumption in trip 1 of 18,379 (Kilo Liters), while for trip 2 of 18,524 (Kilo Liters). The difference in fuel consumption on the two trips is due to the difference in the number of days on each trip, so the difference in consumption is different. Besides that, the indication of the use of RPM and working hours used is one of the factors in calculating the amount of fuel consumption for each trip. So that theoretically and mathematically, the RPM factor, total cylinder volume, and operational hours are benchmarks for fuel consumption.

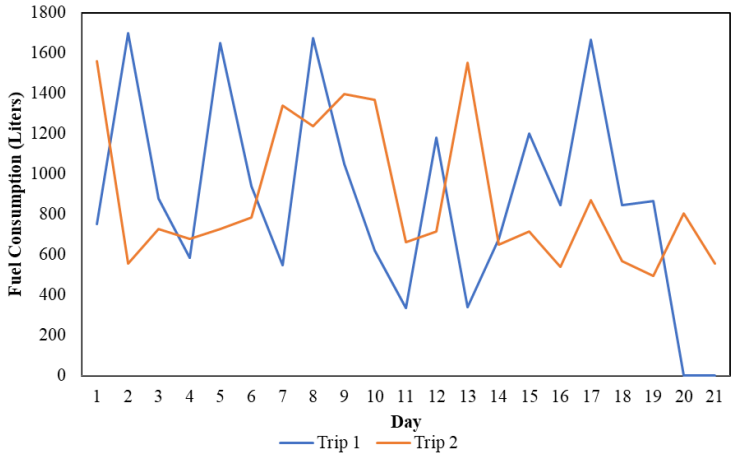

Figure 5. Consumption of engine driving motors on fishing vessels

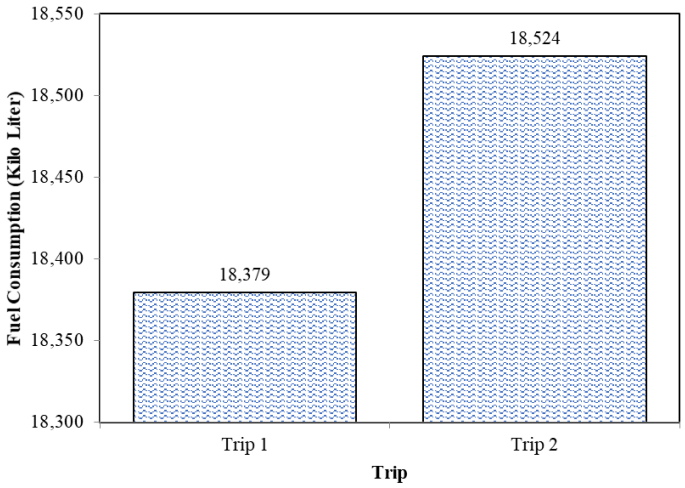

Figure 6. The difference in fuel consumption per trip

4. Conclusion

The purpose of this study is to evaluate the fuel consumption of fishing vessels during fishing operations mathematically and theoretically. The engine type factor, especially in the specification of the cylinder volume, is one of the factors that can increase the rate of fuel consumption. In addition, the higher the RPM used, the higher the fuel consumption rate used on fishing vessels. The comparison of daily fuel consumption on fishing vessels depends on erratic fishing activities. Comparison of fuel consumption on trips 1 and 2 of 18.379 (Kilo Liters) and 18.524 (Kilo Liters) respectively. Therefore, the influencing factors such as operating hours, rpm and the number of cylinder volumes need to be considered in operating the engine so that the engine is more efficient and effective. Information from the factors that need to be considered in regulating the consumption of engine fuel on ships becomes knowledge to increase the effectiveness and efficiency of fuel use in ship engines. The recommendation for further research is that theoretical calculations can be compared with other types of calculations according to standards and can be used as evaluation material to obtain trends in fuel use.

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