Reducing Operational Costs Through Optimised Hybrid Propulsion Configuration on Fishing Vessels

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Abstract

Advances in maritime science and technology have brought significant developments to fishing vessels, particularly in the use of oil-fuelled engines and electronic equipment supported by onboard generators. However, the operation of these engines produces vibrations that can affect the behaviour of fish under the vessel, potentially reducing fishing efficiency when using nets or fishing rods in open waters. This study examines the use of a Hybrid Electric Vehicle (HEV) propulsion system, which allows vessels to operate using internal combustion engines or electric motors. As the importance of efficiency and performance increases, propulsion systems must be redesigned to support hybrid operations. Computational Fluid Dynamics (CFD) modelling was used to simulate and identify the most effective and efficient propulsion design. Field data and simulation results show that the use of a conventional DongFeng S 1125 engine results in operating costs of IDR 170,000.00, while the hybrid system reduces these costs to IDR 64,700.00. These findings highlight the potential of HEV systems to improve energy efficiency and significantly reduce operating costs in small-scale fishing operations.

Keywords: Propulsion system, fishing vessel, hybrid propulsion system, Computational Fluid Dynamics (CFD) simulation

1. INTRODUCTION

Fishing vessel operating patterns are an important aspect of the fishing industry that affects operational efficiency and business sustainability. Factors such as vessel type, fishing gear, fishing location, and environmental conditions must be considered holistically in order to design optimal operating patterns (Fathanah, 2013). Existing studies provide important insights for developing more efficient and sustainable fishing vessel operational strategies. Hybrid propulsion systems on fishing vessels are an innovative solution to improve fuel efficiency and reduce greenhouse gas emissions in the fishing industry. Various studies have been conducted to explore the application of this system on both small and large fishing vessels. A study by Kim et al. (2022) analysed the environmental benefits of electric hybrid propulsion systems on fishing vessels in Korea. Through empirical experiments and simulations using MATLAB/Simulink, it was found that hybrid systems can significantly reduce fuel consumption and CO_2 emissions compared to conventional diesel systems. Another study by Ma'arif et al. (2025) reviewed the development of hybrid and electric propulsion technology in fishing vessels. They used VOSviewer software to analyse publication trends and found that although some fishing vessels have adopted hybrid propulsion systems, there is still a lack of understanding of the full benefits of this technology. Additionally, a study by Dong et al. (2018) discussed the design and life cycle cost analysis of hybrid and pure electric propulsion systems for lobster fishing vessels. The results showed that both propulsion system designs could reduce greenhouse gas emissions and provide significant life cycle cost savings compared to conventional diesel propulsion systems. In general, the application of hybrid propulsion systems on fishing vessels shows great potential in improving operational efficiency and reduce environmental impact. However, further research is still needed to address the technical and economic challenges in its implementation.

With the ongoing modernisation of the maritime sector, fishing vessels have undergone significant technological advances (Yasim et al, 2021). Many vessels are now equipped with diesel engines and various electronic systems powered by onboard generators. While this technology improves functionality, it also generates mechanical vibrations that can disturb fish beneath the vessel. This disturbance can affect the success rate of common fishing methods, such as nets and longlines, especially in open water environments (Tran & Kim, 2023).

In response to these challenges, this study explores the potential application of hybrid electric vehicle (HEV) propulsion systems on fishing vessels. HEV systems enable dual-mode propulsion by combining traditional fuel-powered engines and electric motors, offering greater flexibility, improved energy efficiency, and reduced operational noise and vibration. However, the integration of HEV technology requires a re-evaluation of existing propulsion system designs to ensure compatibility and optimal performance. To assess the feasibility and performance of hybrid propulsion configurations, this study utilises Computational Fluid Dynamics (CFD) modelling. CFD simulations are used to evaluate hydrodynamic performance and identify the most effective and efficient propulsion system design for fishing vessel applications. The main objective is to contribute to the development of sustainable, high-performance fishing vessels that minimise environmental impact while supporting the economic livelihoods of Indonesian fishermen.

2. LITERATURE REVIEW

2.1. Propeller

According to Paulus Agung Hermowo, a vessel is defined as a watercraft of a specific shape and type, which can be propelled by wind, mechanical power, or other forms of energy. Vessels can also be towed or pushed, and this definition includes dynamically supported vehicles, submarines, as well as floating devices and static floating structures. A ship's propulsion system, commonly referred to as "propulsion," consists of a main engine or prime mover, propulsion devices (propulsors), and transmission components. Therefore, a propulsion system can be understood as a mechanical system that provides movement to a ship, including the main engine and related transmission elements. (Hernowo, 2008)

In the context of propeller design, the principles of hydrodynamics are very important—especially the concept of hydrofoils. These elements generate lift and drag forces. For a propeller or hydrofoil to function efficiently in a fluid medium, the lift force must exceed the drag force. Hydrodynamics involves the study of fluid flow around surfaces and is influenced by differences in flow velocity above and below the hydrofoil. Typically, the fluid on the upper surface of the hydrofoil moves faster than the fluid on the lower surface. This difference in velocity causes a difference in pressure, which ultimately generates lift.

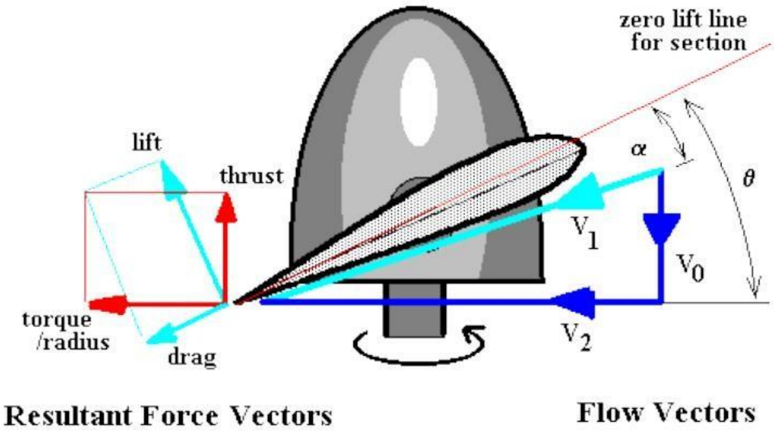

Figure 1. Lift force of a hydrofoil

2.2. Hybrid Propulsion System

A hybrid propulsion system on a fishing vessel is an integration of an internal combustion engine (usually diesel) and an electric motor, aimed at improving fuel efficiency and reducing exhaust emissions. The hybrid system configuration can be series, where the electric motor fully drives the propeller and the diesel engine only recharges the battery, or parallel, where both power sources work together to drive the propeller directly. Fuel efficiency can be calculated by comparing fuel consumption in conventional systems with hybrid systems. The formula is as follows:

$$\text{Fuel Efficiency (\%)} = \frac{\text{Conventional system FC} - \text{ hybrid system FC}}{\text{Conventional sytem FC}}\ x\ 100\%$$

Explanation:
FC : Fuel consumption

In general, the configuration of a hybrid propulsion system is as shown in the figure below.

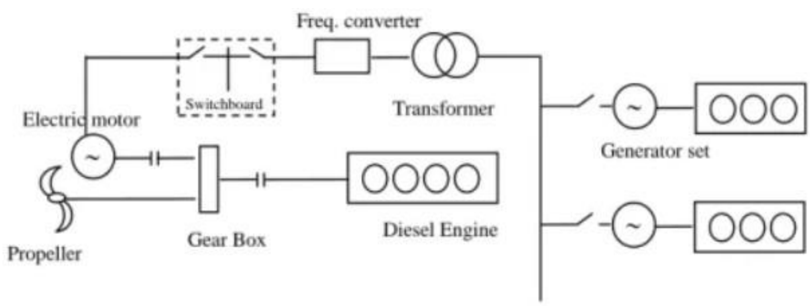

Figure 2. General configuration of a hybrid propulsion system
(Source: Andi Haris, et al. 2015)

2.3. Fuel consumption

Fuel consumption on fishing vessels is greatly influenced by several factors, such as engine power, operating time, fuel type, and engine efficiency. Several general formulas are used to calculate fuel consumption on fishing vessels:

- *General Formula for Fuel Consumption Based on Power*

Fuel consumption on fishing vessels can be calculated using a basic formula that links the power required and the efficiency of the vessel's propulsion system.

$$Fuel\ consumption\ = \frac{BHP\ x\ t}{Engine\ Efficiency\ x\ SFC}$$

Explanation:

BHP (kW)	:	Power required to propel the vessel at a certain speed.
t (hours)	:	The duration of time the vessel is in operation.
Engine Efficiency	:	The percentage efficiency of the engine used in the ship's propulsion system (e.g., diesel engine).
SFC (kJ/kg)	:	Energy produced per kilogram of fuel used

- *Specific Fuel Consumption (SFC)*

For diesel engines on ships, fuel consumption can be calculated using Specific Fuel Consumption (SFC), which indicates the fuel efficiency of the engine per unit of power produced. The formula is:

$$SFC\ = \frac{Fuel\ consumption\ (kg/hour)}{Power\ Produced\ (kW)}$$

- *Fuel Consumption of Hybrid Systems on Fishing Vessels*

On vessels with hybrid propulsion systems, fuel consumption will depend on the proportion of diesel engine and electric motor usage. The calculation formula is:

$$Hybrid\ Fuel\ Consumption = Fuel\ comsumption\ X\ (1 - Electric\ Motor\ Usage\ Fraction)$$

3. METHOD

The method used in this study was to conduct an empirical calculation analysis of the fuel requirements of fishing vessels using conventional propulsion systems and hybrid systems, using a comparison vessel that is already in operation. The steps to be followed in carrying out this activity are illustrated in the flow chart in Figure 6.

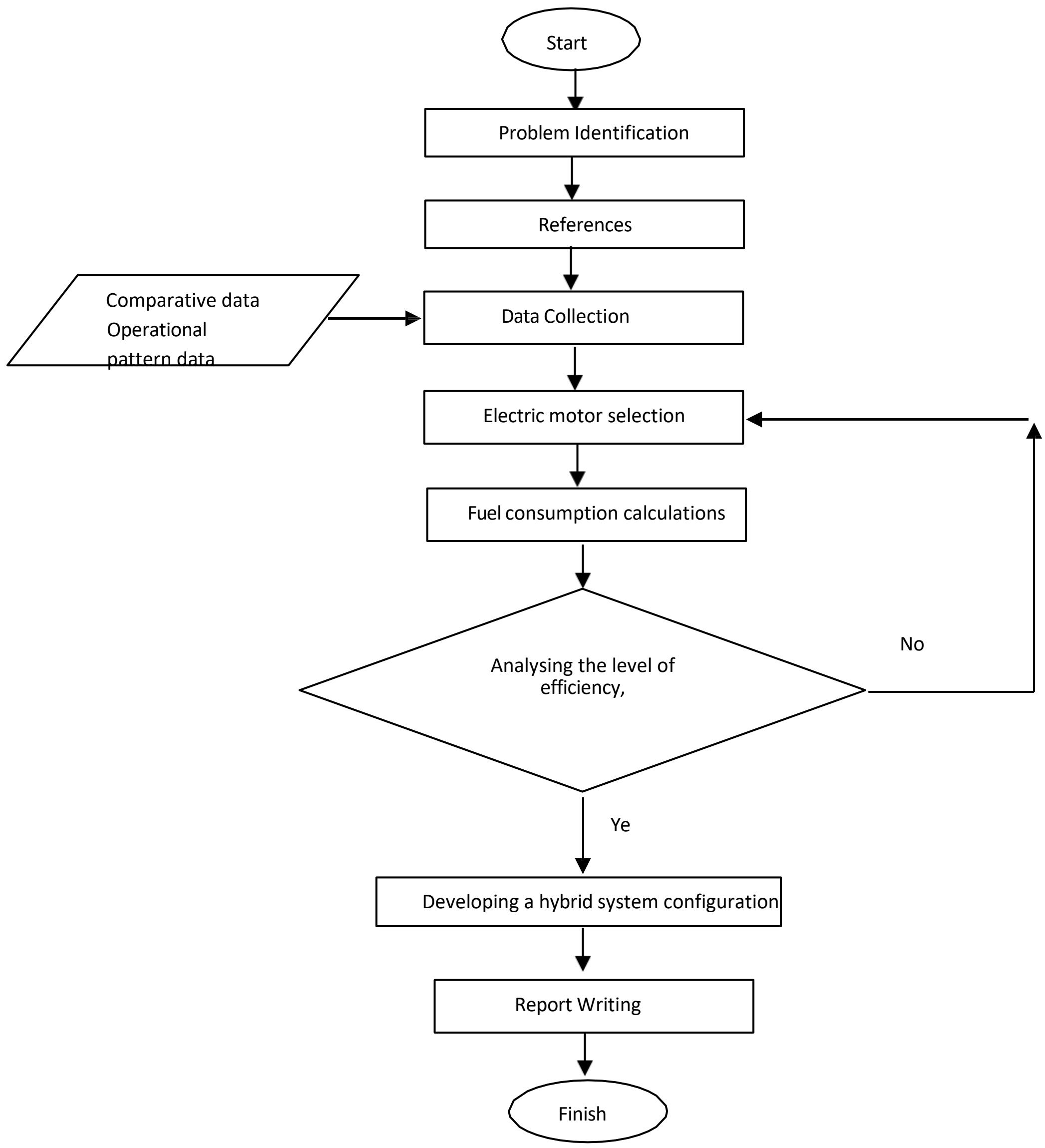

Figure 3. Flow chart

This research was conducted on fishing vessels operated by a group of fishermen in Muntai village, Bengkalis district. This research involved calculating the suitability of the engine-propeller, which will later be installed or paired with an electric motor. The dimensional data of the fishing vessel is as follows:

Main Dimensions of the Vessel	
Total Length	: 8.2 m
Beam	: 1.6 m
Height	: 2.0 m
Depth	: 0.8 m
Engine power	: 100 PS / 100 HP (Mitsubishi 4D30)
Propeller diameter	: 0.5 m

4. RESULTS & DISCUSSION

4.1. Selection of the hybrid system

The validation described above is crucial for accurately determining the actual engine power requirements. Furthermore, this validation plays an important role in the decision-making process for selecting the most suitable propulsion system in a hybrid configuration. At this stage of the research, an Engine Propeller Matching (EPM) analysis was conducted on a ship model that had been developed previously in prior research. The purpose of this analysis was to determine the appropriate relationship between engine output and propeller characteristics to ensure optimal propulsion efficiency. Using Computational Fluid Dynamics (CFD) simulation, the total hydrodynamic resistance of the ship was calculated and found to be 2082.55 N under the specified operating conditions.

To overcome this resistance and achieve a cruising speed of 10 knots, a Dong Feng diesel engine was selected. The engine used is a single-cylinder S1125 type engine, with a cylinder diameter of 125 mm and a stroke of 120 mm. This engine is capable of producing 20.87 kW (equivalent to 28 HP) of Brake Horsepower (BHP) at Maximum Continuous Rating (MCR), operating at 2200 revolutions per minute (RPM), and has a total weight of 240 kg.

As part of efforts to develop a more efficient and environmentally friendly propulsion system, a hybrid propulsion system modification was implemented. This involves the integration of an electric motor into the propulsion system. The decision to implement a hybrid configuration was based on several technical considerations, including the need to minimise the vibrations generated by the propulsion system, as well as the suitability of the engine's power output at a low operating speed of 5 knots with the power input required for the propeller to operate efficiently at that speed.

Based on these considerations, an electric motor with a power output of 3 horsepower (HP) was selected. The motor, manufactured by AllianceMotori, operates at a rotational speed of 2800 RPM and is considered suitable for providing additional propulsion power in low-speed sailing conditions.

Figure 4. Electric Motor

Fuel requirement calculations were performed using operational pattern data obtained from interviews, which indicated that fishermen require 8 hours for a single fishing trip. The total time of 6 hours is derived from the 2-hour journey to the fishing location, 1 hour for setting the nets, 2 hours waiting, 1 hour for hauling the nets, and 2 hours for the return journey. Using this operational pattern, the fuel requirements for a fishing vessel using a conventional propulsion system are shown in the graph in Figure 5 below.

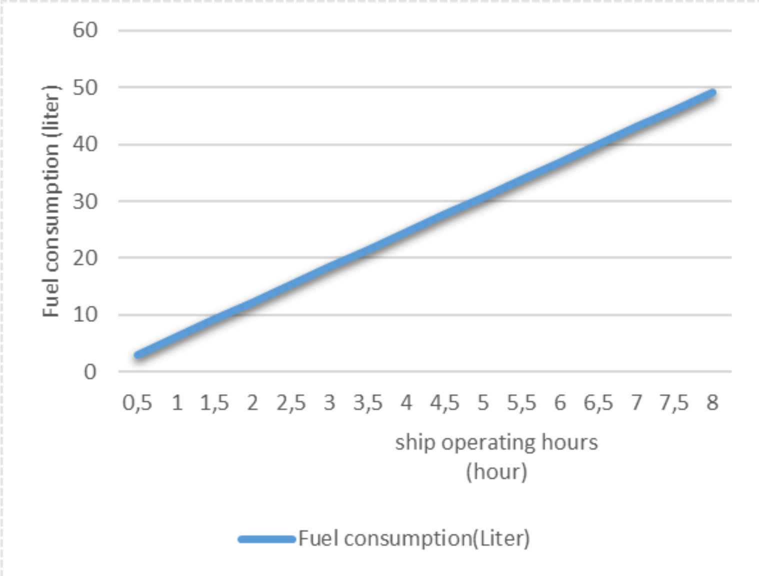

Figure 5. Graph showing fuel consumption of ships with conventional propulsion systems

Meanwhile, modifying the propulsion system to a hybrid system will result in a reduction in fuel consumption. The extent of the reduction in fuel consumption depends on how often the process of switching from the fuel-powered engine to the electric motor occurs. The pattern of reduction in fuel consumption is shown in Figure 6 below:

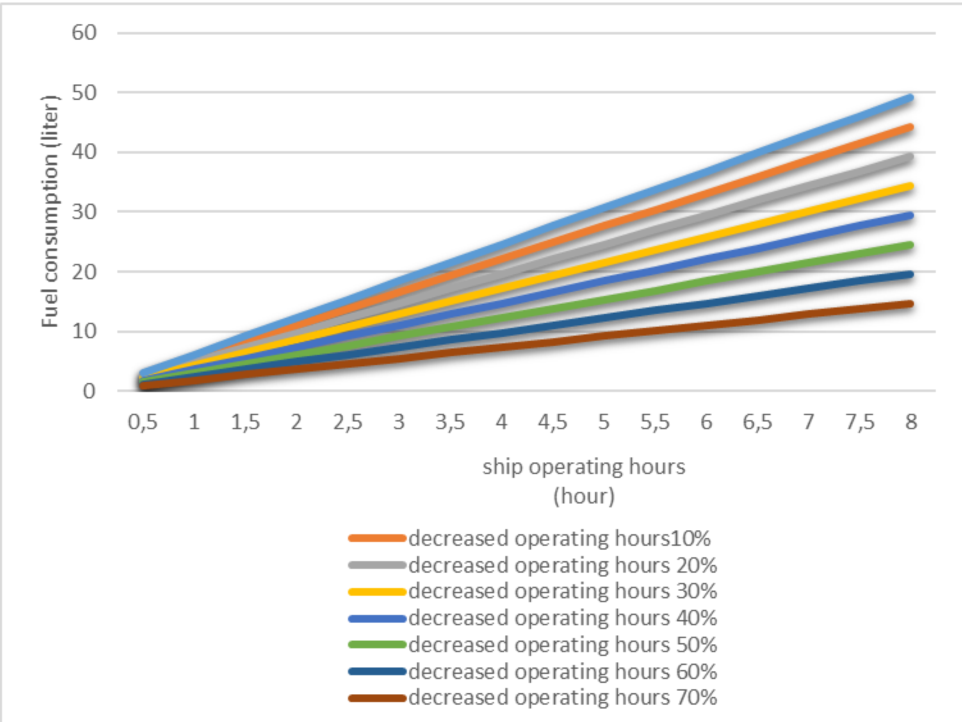

Figure 6. Graph of fuel consumption for ships with hybrid propulsion systems

4.2. **Reduction in operational costs**

Replacing the previously used 100 PS engine with a 28 HP engine is very effective and efficient in reducing costs. This can be seen from the difference in size and weight, where the 28 HP engine is lighter but still maintains the same speed, so that the weight saved can be allocated for fish cargo. In addition, fuel consumption with a 28 HP engine is lower because its Specific Fuel Consumption (SFOC) value is smaller than that of a 100 PS engine.

In addition to meeting engine requirements, fuel consumption can also be optimised through the application of a hybrid propulsion system, as shown in Table 2.

Table 1. Survey of operational cost conditions

Item	Diesel Engine	Electric Motor	Unit
SFOC	250		g/kWh
Density	0.85		kg/L
Fuel price	6800		Rupiah per litre
	8		Rupiah per gram
Distance (round trip)	10		Nautical miles
	18.52		km
Electricity price		1500	Rupiah/kWh

Note : 1 Day Condition (Round Trip): consumes 20 litres of diesel in 8 hours

Based on Table 2, an initial survey has been conducted. The survey results show that a vessel with a length of 14 metres and a maximum speed of 10 knots, equipped with a Mitsubishi 4D30 engine, consumes 35 litres of diesel fuel for one trip per day covering a distance of 5 nautical miles. On the other hand, a similar survey conducted at a different location using a vessel of the same length and engine type showed fuel consumption of only 20 litres per trip per day for the same distance of 5 nautical miles. These findings are important reference data for estimating operational costs. Therefore, the fuel consumption value of 20 litres per trip per day was adopted as the basis for further calculations, as listed in Table 2.

Table 2. Operational Costs

Item	Diesel Engine	Electric Motor	Unit
Round trip conditions			
Speed	10	10	Knots
	18.52	18.52	km/h
Time (round trip)	1	1	Hours
Engine power	20.8	20.8	kW
Diesel consumption	5200	5200	gram
	6,118	6,118	litre
Fuel price	41,600	41,600	Rupiah
Standby Condition			
Fuel Requirements	18,882		Litres
	16,050		gram
Engine power		2.2	kW
Time		7	Hours
Fuel/electricity cost	128,400	23,100	Rupiah
Total price	170,000	64,700	Rupiah

From Table 3, the difference in cost between conventional engine propulsion systems and hybrid propulsion systems can be observed, calculated based on a full day's round trip operation with a consumption of 20 litres of fuel in 8 hours of operation at sea. The fuel cost for the conventional engine propulsion system is IDR 170,000.00, while the hybrid propulsion system only requires IDR 64,700.00. Based on this cost difference, the hybrid propulsion system is highly recommended.

5. CONCLUSION

Based on this study, it can be concluded that the recalculation of the propulsion system resulted in the selection of a Dong Feng S1125 engine with an output power of 28 HP. In modifying the hybrid system, several factors were considered, including the vibration generated by the propulsion system, the engine output power, and the compatibility between the engine power and the power required by the propeller. As a result, a 3 HP electric motor was selected as the secondary propulsion source. The implementation of this hybrid system configuration has proven to offer more optimal operational cost reductions.

In addition to operational cost savings, it can be concluded that the hybrid propulsion system effectively reduces operational costs. The conventional engine propulsion system incurs a cost of around IDR 170,000.00, while the hybrid system reduces this cost to only IDR 64,700.00.

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