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Optimization of Engine and Fishing Gear Selection Based on Vessel Characteristics in Selambai Fishers Village, Bontang City

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Abstract**—** Small-scale fisheries constitute the dominant fishing sector in Indonesia and play a crucial role in sustaining coastal livelihoods, particularly through vessels of ≤5 GT operated by traditional fishing communities. However, fleet configuration covering hull dimensions, engine power, and fishing gear selection is often determined by fishers' experience and economic considerations rather than technical assessment, resulting in operational inefficiency, elevated fuel consumption, and declining productivity. This study aims to analyze the suitability of fishing vessel characteristics with installed engine power and fishing gear used by fishers in Selambai Fishers Village, Bontang, East Kalimantan, in order to identify whether current fleet configurations align with technically optimal design and power requirements. Primary data were collected through field measurements of principal vessel dimensions (length, L; breadth, B; depth, D), structured interviews with fishers regarding engine specifications and gear practices, and hydrodynamic resistance simulation using Maxsurf Resistance software. Vessel dimension ratios (L/B, L/D, B/D) were evaluated against established naval architecture reference standards to assess hull suitability for specific fishing gear categories, while engine power requirements were determined based on effective horsepower (EHP) and shaft horsepower (SHP) calculations derived from Holtrop resistance predictions across a range of operating speeds. The results show that the surveyed fishing vessel exhibits principal dimension ratios of L/B = 5.07, L/D = 10, and B/D = 1.97, indicating a hull form suitable for passive fishing gears that require high transverse stability, such as handline, squid jigging, gillnet, and collapsible traps, rather than for gear types demanding higher maneuverability or towing capacity. Hydrodynamic analysis further identifies an optimal operational speed range of 6–7 knots, corresponding to a power requirement of approximately 60–65 HP; deviation from this range through inappropriate engine selection is shown to correspond with increased fuel consumption and reduced overall performance efficiency. These findings provide a technical basis for aligning engine power and fishing gear selection with actual hull characteristics in small-scale fishing operations.

*Keywords***—** Small-scale fishing vessel, engine optimization, vessel dimension ratio, fishing gear suitability.

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I. INTRODUCTION

Small-scale fisheries (SSF) are the backbone of Indonesia's capture fisheries sector, involving crucial contributions to livelihoods, food and nutrition security, and the well-being of coastal communities, with 2.5 million households in Indonesia involved in SSF production despite persistently high poverty rates and vulnerability to environmental change [1]. Vessels of ≤5 GT dominate this fleet and are the primary livelihood source for coastal communities such as Selambai Fishing Village in Loktuan, Bontang City, where household economies depend heavily on squid and fish capture using small boats powered by outboard engines. Capture fisheries in Indonesia are predominantly supported by small-scale fishing fleets, particularly vessels of ≤ 5 GT, which serve as the primary livelihood source for coastal communities and play an essential role in national food security [1**2**]. This vital contribution is evident within the traditional fishing community of Selambai Fishing Village in Loktuan, Bontang City, where most household economies rely on squid and fish capture activities using small boats powered by outboard engines. However, the utilization patterns of vessels and fishing gears in this area demonstrate considerable inconsistency, as fishers frequently switch fishing gears and select engines based mainly on affordability and inherited experience rather than on technically measured power requirements [2**3**]. Such practices potentially lead to operational inefficiency, increased fuel consumption, and reduced catch productivity. However, the utilization patterns of vessels, engines, and fishing gears in Selambai show considerable inconsistency: fishers frequently switch gear types and select engines based on affordability and inherited experience rather than on technically measured power requirements.

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This inconsistency is not unique to Selambai. A similar mismatch has been empirically documented at Palabuhanratu Fishing Port, where a comparison between existing engine power and theoretical power requirements found that most small-sized boats were fitted with oversized engines, and fishers tended to carry 62.1% more fuel than the theoretical requirement because of the use of larger engines and the need to bring spare fuel [2]. A related study on seine net boats in the same port confirmed that fuel consumption varies substantially across gear types and engine ages even within a single fishing ground, indicating that empirical, boat-specific power calculation rather than intuition is needed to control fuel costs [3]. These findings suggest that the pattern observed in Selambai reflects a broader, largely unaddressed problem across Indonesia's small-scale fishing ports: engine selection is treated as a matter of price and habit rather than of naval architecture.

The technical tools required to correct this mismatch already exist and are well established in the ship design literature. Regression-based resistance and power-prediction methods, most notably the Holtrop, Holtrop–Mennen, and Savitsky methods have been validated for small and medium-sized fishing vessels, allowing designers to estimate hull resistance and the corresponding engine power needed for a given hull form and speed with reasonable accuracy compared to model-test data [4], [5]. Yet in traditional boatyards such as those serving Selambai, vessels are built without applying these calculations; engine selection is instead driven by market availability and price. The consequence is a fleet in which engines are frequently mismatched to hull characteristics, producing elevated fuel consumption, suboptimal transit speed to fishing grounds, and degraded maneuverability precisely when catch and cost efficiency matter most.

Beyond fuel and speed inefficiency, this mismatch has direct safety implications. Fishing gear loaded, stowed, or hauled onboard alters a vessel's center of gravity and can trigger heeling or listing moments that are, in many operational conditions, as significant as those produced by wind and waves [6]. Small vessels are particularly exposed to this risk because their limited freeboard and displacement leave little margin for error when loading conditions change during a trip. A recent case analysis of a small dredge fishing boat capsizing found that cargo loaded during hauling produced a list and trim angle of 15.4° and –6.5° respectively, exceeding the 15-degree threshold for initial stability and leading directly to capsizing, underscoring how gear-handling practices not just hull design determine whether a small vessel remains safe at sea [7]. For Indonesian small fishing boats specifically, operability analyses under varying loading conditions have shown that stability and seakeeping performance are highly sensitive to how weight (fuel, catch, and gear) is distributed onboard [8], reinforcing that engine, hull, and gear decisions cannot be evaluated in isolation from one another.

Fishing gear configuration also independently shapes operational efficiency. In general, passive gears such as hooks, traps, and pots require substantially less fuel per kilogram of catch than towed gears, and improving gear selection is recognized internationally as one of the most effective low-cost pathways to reducing fuel intensity in small-scale fisheries [9]. This means that gear choice and engine/hull compatibility are two levers of the same problem fleet efficiency yet they are almost never analyzed together in the context of Indonesian small-scale fisheries research, which tends to treat naval architecture, engine sizing, and gear technology as separate disciplinary concerns.

While engine-power suitability [2], [3] and hull resistance prediction methods [4], [5] have each been studied for Indonesian and international fishing vessels, and while vessel stability under fishing-gear loading has been examined separately [6], [7], [8], no published study has integrated hull-resistance-based power calculation, empirical engine suitability assessment, and fishing-gear efficiency analysis into a single, site-specific framework for ≤5 GT vessels in an artisanal fishing community such as Selambai. Existing Indonesian case studies (e.g., Palabuhanratu) focus on engine–hull suitability alone, without linking the results to gear-specific operational and safety outcomes, while stability studies rarely connect their findings back to engine and hull optimization recommendations that fishers can practically act on. This study addresses that gap by combining (i) theoretical hull resistance and power requirement calculation, (ii) empirical assessment of existing engine–hull suitability, and (iii) evaluation of fishing gear configuration and its influence on efficiency and stability, using Selambai Fishing Village as a case study. The resulting integrated approach is intended to generate practical, technically grounded recommendations for fuel-efficient, productive, and safe small-scale fishing operations, offering a replicable model for other ≤5 GT fishing communities across Indonesia's coastal regions.

II. METHOD

A. Study Area and Research Period

This study was conducted in May 2025 in Selambai Fishers Village, Kuala, Bontang, East Kalimantan Province, Indonesia. The research focused on evaluating the suitability of engine power and fishing gear selection relative to local vessel characteristics. The detailed methodology is outlined below.

B. Data Collection

Primary data were collected through direct field measurements and structured interviews. Vessel dimensions including length (L), breadth (B), and depth (D) were measured using a roll meter. Field observations and interviews were conducted to obtain existing data regarding engine specifications and fishing gear currently used by fishers. Respondents were selected using a purposive sampling technique, with criteria including being an active fisher and holding a leadership role within the local fishing groups in Selambai Village. A structured questionnaire comprising closed-ended questions was distributed to assess fishermen's perceptions concerning the effectiveness, ease of operation, and impacts of fishing gear use on catch productivity and the marine environment. The questionnaire also included Likert-scale items to evaluate agreement levels related to operational performance and sustainability considerations.

C. Fishing Vessel Engine Power Analysis

The analysis of ideal engine power requirements (Powering Analysis) was carried out following the principles of Naval Architecture (PNA, Vol. II), beginning with the estimation of total hull resistance (RT) using the Holtrop method [8], expressed in Equation (1):

$$R_T = R_F(1 + \mathrm{k1}) + R_{APP} + R_W + R_B + RT_R + R_A$$

Where:
RF = Frictional resistance (ITTC–1957 formulation)
1+k1 = Form factor
RAPP = Appendage resistance
RW = Wave-making and wave-breaking resistance
RB = Bulbous bow resistance
RTR = Transom resistance
RA = Air resistance

Effective Horse Power (EHP) represents the required power to move the vessel at a given speed and is computed using Equation (2) [9]:

$$\mathrm{EHP} = \mathrm{RT\ dinas} \times V_s\ \mathrm{dinas} \quad (2)$$

Wake fraction (w) and Thrust deduction factor (t) were calculated using empirical formulations proposed by Taylor [10], as shown in Equations (3)–(4):

$$w = 0{,}5 \times cb - 0{,}05 \quad (3)$$

$$t = k \times w \quad (4)$$

Speed of Advance (VA), representing flow velocity into the propeller region, was calculated as follows [11]:

$$VA = (1 - w) \times Vs \quad (5)$$

Delivered Horse Power (DHP) was obtained from Equation (6), based on propulsive coefficient (PC) [12]:

$$DHP = EHP/PC \quad (6)$$

The propulsive coefficient was computed using Equation (7):

$$PC = \eta h \times \eta rr \times \eta o \quad (7)$$

Propeller–hull efficiency (ηh) was calculated using Equation (8):

$$PC = \eta h \times \eta rr \times \eta o \quad (8)$$

Shaft Horse Power (SHP) was estimated based on mechanical transmission losses of approximately 2% [13], using Equation (9):

$$SHP = DHP/\eta s \quad (9)$$

Finally, Brake Horse Power (BHP), representing actual power output from the engine shaft, was calculated using Equation (10) [14]:

$$BHP = DHP/\eta Gear \quad (10)$$

D. Analysis of Fishing Gear Suitability

A descriptive quantitative approach was used to evaluate the compatibility between vessel characteristics and the fishing gears utilized. The main vessel dimensions (L, B, D) were used to compute the ratios L/B, L/D, and B/D, which were compared with standard references for Indonesian traditional fishing vessels [15].

TABLE 1.
STANDARD RATIO OF VESSEL DIMENSIONS ACCORDING TO FISHING OPERATION METHODS IN INDONESIA

Metode operasi	L/B	L/D	B/D
Static gear	2,83 – 11,12	4,58-17,28	0,96-4,68
Encircling gear	2,60 – 9,30	4,55 – 17,43	0,56 – 5,00
Towed/Dragged gear	2,86 – 8,30	7,20 – 15,21	1,25 – 4,41
Multipurpose gear	2,88 – 9,42	8,69 – 17,15	0,53 – 6,09

The ratios were interpreted to determine whether the vessel design adequately supports fishing gear operation. The results formed the basis for recommendations regarding vessel design improvements or fishing gear adjustments to enhance operational performance and safety.

III. RESULTS AND DISCUSSION

The hydrostatic and hull-form data for the sampled fishing vessel reveal a block coefficient (C_b) of 0.436 and a prismatic coefficient (C_p) of 0.705, indicating a relatively fine, slender displacement hull with moderate fullness. Such hull characteristics are typical of fishing vessels optimized for moderate speed and maneuverability, offering acceptable resistance and reasonable seakeeping performance when operated under normal coastal conditions. This hull-form geometry suggests that the vessel is suited for light to medium fishing gears, rather than heavy or large-volume gears like purse-seine or trawl nets that demand larger blockiness and carrying capacity [20].

The waterplane area coefficient (Cwp) of 0.847 denotes a sufficiently broad waterplane for a vessel of this size, which correlates with acceptable transverse stability under static loading conditions. Combined with the moderate draft amidships (1 m) and wetted surface area, these properties promote efficient propulsion at displacement speeds and lower fuel consumption a desirable trait for small-scale coastal fishing operations. Literature on hull-form influence on fishing-vessel performance emphasizes that such slender but stable hulls strike a balance between wave-making resistance and frictional drag, making them well-suited for light gear operations, especially handlines and vertical jigging.

Moreover, recent research on hull stability shows that small fishing vessels with modest block and mid-ship coefficients similar to those observed here have lower vulnerability to "pure loss of stability" under both calm and wave conditions, provided the vessel's weight distribution (including gear loads) remains symmetrical and within calculated load limits. This implies that for the sampled vessel, maintaining balanced gear placement and avoiding heavy lateral loads is critical, especially when deploying squid-jigging rigs or setting traps.

Based on these hydrostatic characteristics and supported by the cited literature, the most appropriate fishing gear for this vessel includes handline / vertical jigging (for squid or reef fish) and collapsible pots/traps (bubu). These gears impose relatively low structural loads, require minimal deck space, and allow for manageable catch volumes, aligning with the hull's capacity for safe and efficient operation. Heavy gear like purse-seine, large nets, or heavy trawl rigs are discouraged because the slender hull would incur excessive wave resistance and stability risk under such high loads [21].

In operational terms, using LED lights for squid-jigging combined with manageable numbers of jigs (for instance, 150–300 units) distributed symmetrically along the deck would minimize heel and trim distortion while maintaining effective catch potential. The vessel's low displacement and fine hull form support efficient movement between fishing grounds without excessive fuel use, which is critical in small-scale artisanal fisheries.

Overall, these findings reinforce the conclusion that gear selection must be aligned with hull geometry and hydrostatic capacity. For vessels with the measured characteristics, gear configurations emphasizing low structural load, high maneuverability, and balanced weight distribution deliver the best performance offering operational efficiency, fuel economy, and improved safety for fishing crews.

TABLE 2.
THE CALCULATION OF HYDROSTATICS

Measurement	Value	Units
Displacement	13.15	t
Volume (displaced)	12.828	m^3
Draft Amidships	1	m
Immersed depth	1	m
WL Length	10.902	m
Wetted Area	35.882	m^2
Waterpl. Area	24.937	m^2
Prismatic coeff. (Cp)	0.705	
Block coeff. (Cb)	0.436	
Max Sect. area coeff. (Cm)	0.621	
Waterpl. area coeff. (Cwp)	0.847	
LCB length	4.867	from zero pt. (+ve fwd) m
LCF length	5.057	from zero pt. (+ve fwd) m
Immersion (TPc)	0.256	tonne/cm
MTc	0.184	tonne.m
L	14.26	m
B	2.76	m
H	1.5	m
D	1	m

The results of resistance and powering analysis using the Holtrop–Mennen method demonstrate a progressive increase in total ship resistance as vessel speed increases. At speeds below 2 knots, resistance values remain negligible (0–0.1 kN), indicating minimal hydrodynamic load at low displacement speeds. This trend aligns with the general principle that small displacement fishing vessels experience low resistance in early Froude number ranges due to dominant viscous forces over wave-making components [22].

A significant rise in resistance begins near 3 knots (FnL ≈ 0.15), with a calculated resistance reaching 0.2 kN and corresponding power demand of 6.156 HP. The rapid increase becomes more pronounced beyond 4 knots, where resistance reaches 0.4 kN and power increases to 19.27 HP, indicating stronger wave-making effects as the hull approaches the critical Froude region (Fn = 0.3–0.4). Research on displacement fishing vessels supports this hydrodynamic behavior, demonstrating sharp resistance escalation near semi-planing transition zones [21].

The optimal operational speed range can be identified between 5–6 knots (FnL = 0.24–0.30), where required power ranges from 35–58 HP. Beyond this range, power increase becomes disproportionate to speed gains, for example at 8 knots, resistance reaches 4 kN, requiring 83.18 HP, indicating operational inefficiency. Similar findings were reported by [20], showing that most traditional small fishing vessels achieve maximum fuel-efficiency at 60–70% of designed power output.

From the performance curve (Figure 3), the recommended installed engine power for the vessel is 40–60 HP, assuming operation within the efficient hydrodynamic envelope (5–6 knots). Installing power above 80 HP would reduce fuel efficiency without significant speed gain and increase operational cost, consistent with conclusions by [4], who emphasized the economic and energy inefficiency of excessive engine capacity in small fishing vessels.

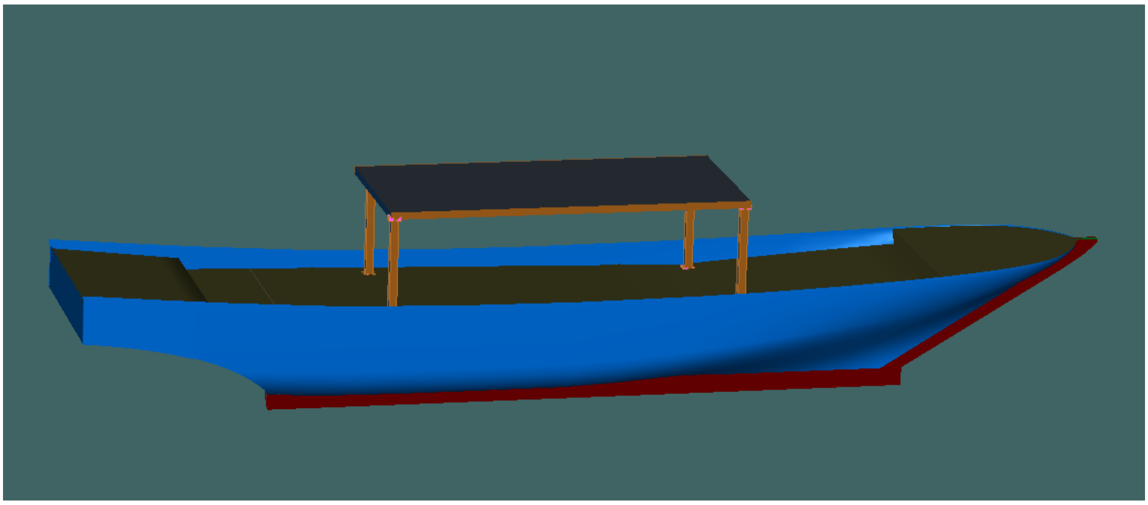

Figure. 1. 3 Dimensions model

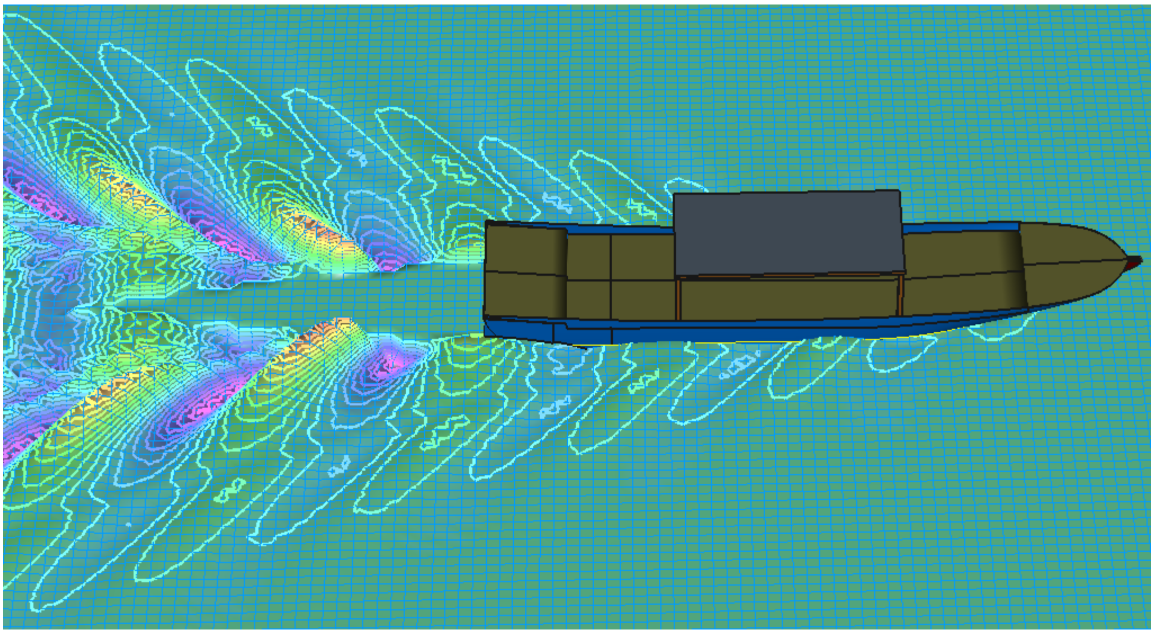

Figure. 2. Results of speed versus horsepower analysis with Maxsurf

TABLE 3.
POWER CALCULATION RESULTS BASED ON METHOD

Parameter	Method	Result	Unit
Total Resistance Total (RT)	Holtrop (1984)	21,300	kN
Effective Power (EHP)	RT x V_S / C	104,279	HP
Delivery Horse Power Capacity (DHP)	EHP / PC	238,84	HP
Shaft Efficiency (PC)	1 - 3%	0,97	-
Service Margin (SM)	15%	0,15	-
Brake Horse Power (BHP)	DHP/PC (1+\SM)	281,83	HP
BHP Ideal	Convert to kW	207,28	kW

TABLE 4.
SPEED AND HOLTROP POWER RESULT

Speed (kn)	Froude No. LWL	Froude Vol	Holtrop resistance (kN)	Holtrop Power (hp)
0	0	0	--	
0.25	0.012	0.027	0	0
0.5	0.025	0.054	0	0.003
0.75	0.037	0.081	0	0.009
1	0.05	0.108	0	0.026
1.25	0.062	0.134	0	0.06
1.5	0.075	0.161	0.1	0.15
1.75	0.087	0.188	0.1	0.371
2	0.1	0.215	0.1	0.792
2.25	0.112	0.242	0.1	1.468
2.5	0.124	0.269	0.2	2.505
2.75	0.137	0.296	0.2	3.954
3	0.149	0.323	0.2	6.156
3.25	0.162	0.349	0.2	8.834
3.5	0.174	0.376	0.3	11.627
3.75	0.187	0.403	0.3	14.003
4	0.199	0.43	0.4	19.272
4.25	0.211	0.457	0.4	21.071
4.5	0.224	0.484	0.5	25.703
4.75	0.236	0.511	0.6	33.771
5	0.249	0.538	0.7	35.253
5.25	0.261	0.565	0.8	35.591
5.5	0.274	0.591	0.9	41.465
5.75	0.286	0.618	1.1	50.847
6	0.299	0.645	1.4	58.41
6.25	0.311	0.672	1.7	61.668
6.5	0.323	0.699	2	61.388
6.75	0.336	0.726	2.2	59.753
7	0.348	0.753	2.5	58.998

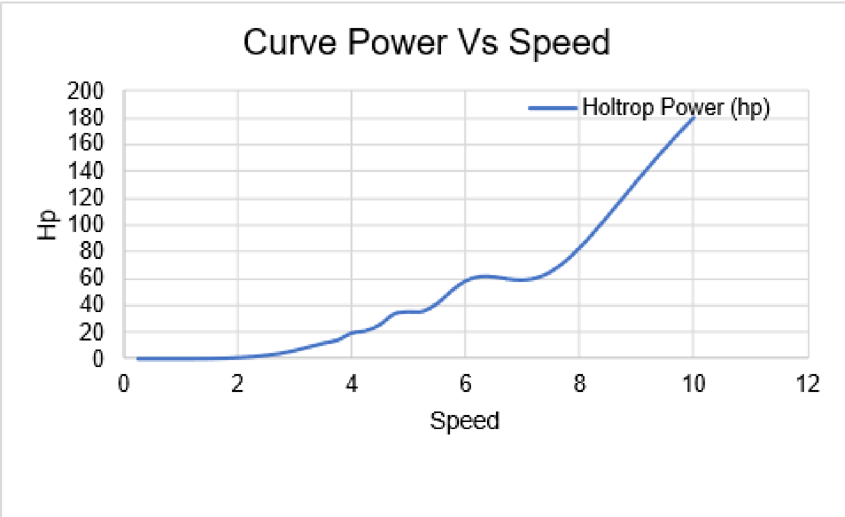

Figure 4. Speed and Hp Result

Considering typical fishing conditions in Bontang coastal waters, characterized by calm seas (<1 m wave height) and short steaming distances to fishing grounds, operational speeds above 6 knots are unnecessary. Therefore, gear types requiring high towing resistance such as trawl or seine nets are unsuitable. Instead, the vessel is mechanically more compatible with light gear, such as: Squid handline / vertical jigging with LED lights, Fish handline, Collapsible traps (bubu/lobster pots). These gears do not impose heavy drag loads and align with the hull's efficient operating range. [22] emphasize that gear weight and towing load must match hull hydrodynamic resistance to avoid stability and energy cost issues.

Thus, based on powering and resistance results, adopting mid-power engines (40–60 HP) combined with low-drag fishing gear supports enhanced operational efficiency, lower fuel usage, and improved economic returns for small-scale fishermen.

The analysis of principal dimension ratios shows that the studied fishing vessel has an L/B ratio of 5.07, an L/D ratio of 10, and a B/D ratio of 1.97. These values indicate that the vessel's hull form is relatively slender with moderate beam width compared to depth. According to [19], fishing vessels designed for handline operations typically fall within an L/B ratio range of 4–6, which supports good maneuverability, stability at low speeds, and reduced resistance in calm seas. Therefore, the observed L/B ratio demonstrates suitability for light gear fisheries such as handline and squid jigging, where vessel agility and position-holding ability are essential.

The L/D ratio of 10 suggests a relatively shallow hull configuration designed for sheltered coastal waters with short travel distances and low wave exposure. This aligns with characteristics reported by [23], who noted that handline boats operating in calm tropical inshore waters commonly employ L/D ratios between 9 and 12, balancing load capacity and adequate deck space for fishing operations. Such hull proportions are advantageous for operational activities in Bontang coastal waters, which are known to have generally calm sea states (<1 m significant wave height) due to protection from offshore island formations.

The B/D ratio of 1.97 indicates good transverse stability, necessary for vertical fishing activities where fishermen stand and work on deck. Previous studies show that a B/D ratio between 1.8 and 2.2 is recommended to maintain adequate stability while minimizing rolling motions for handline, trap, and squid jigging vessels [24]. This ratio also helps support additional equipment such as LED lamps used in squid fishing without compromising safety.

Based on the evaluation of these principal dimension ratios, the vessel is structurally and operationally compatible with light stationary fishing gears, especially squid handline, vertical jigging, and collapsible traps rather than gears that impose significant towing forces. The combination of dimensional ratios and hydrodynamic performance indicates that the current hull form is optimized for low-speed fishing operations within sheltered waters, consistent with local fishing practices in Bontang Kuala.

The results of the Holtrop resistance analysis show that the required effective horsepower (EHP) increases gradually at operational speeds and reaches approximately 58–61 HP at a service speed of 6–6.5 knots, which represents the typical cruising range for squid handline fishing vessels operating in sheltered waters around Bontang Kuala. At the economic cruising speed commonly used by small-scale fleets (4–5 knots), the predicted engine power demand ranges from 19 to 35 HP. These findings indicate that the vessel requires a shaft power capacity within the range of 40–60 HP to ensure optimal propulsion performance under real operating conditions, considering transmission losses and mechanical efficiency.

Based on a standard propulsion efficiency assumption of $\eta s \approx 50–60\%$ for small traditional fishing vessels using conventional propeller systems [25], the calculated shaft horsepower (SHP) requirement suggests that an installed engine power of 60–80 HP would be appropriate to support maneuvering, head-current operations, and load variations during night fishing. This configuration aligns with the recommendation of [26], who stated that engine power 20–30% above EHP ensures safer operation and improves access to more distant fishing grounds without excessive fuel consumption.

Thus, the recommended engine capacity supports efficiency, fuel economy, and sustainable fishing productivity for small-scale fleets in Bontang, where fishing typically occurs at short-range coastal grounds (<12 nm) with calm sea characteristics.

When linked with the previously analyzed vessel characteristics, the vessel's hull ratios (L/B = 5.07; L/D = 10; B/D = 1.97) and displacement of 13.15 tons indicate suitability for gear types that require minimal towing load and prioritize maneuverability and static operation. Such dimensions are consistent with fishing vessels designed for handline, gillnet, and squid jigging operations [19]. Additionally, the Holtrop resistance analysis demonstrates an optimal power requirement of approximately 60–65 HP at 6–7 knots cruising speed, which aligns with the typical power range used for small-scale passive gear fisheries [27].

Based on both vessel performance and resource availability, the recommended fishing gears include squid jigging which matches the stability profile of the vessel and targets the abundant squid resource in Bontang waters, with increased efficiency when supported by LED lighting systems [28]. Bottom handline for demersal fish such as snapper and grouper due to selective and habitat-friendly characteristics. Gillnet for demersal species, which has been commonly practiced in the area and is technically compatible with the vessel's hull form and deck configuration.

IV. CONCLUSION

This study analyzed the suitability of fishing vessel characteristics, installed engine power, and fishing gear selection in Selambai Fishers Village, Bontang, East Kalimantan, to determine whether current fleet configurations align with technically optimal design. The vessel's principal dimension ratios (L/B = 5.07, L/D = 10, B/D = 1.97) indicate a hull form well suited to passive fishing gears requiring high transverse stability, such as handline, squid jigging, gillnet, and collapsible traps, confirming that the community's gear practices are broadly compatible with the available hull design. However, the hydrodynamic analysis reveals that optimal vessel performance requires an engine power of approximately 60–65 HP at an operational speed of 6–7 knots, and that deviations from this range commonly caused by engine selection based on affordability rather than technical calculation correspond with increased fuel consumption and reduced operational efficiency. These findings confirm that vessel engine gear suitability in Selambai is only partially met, with hull–gear compatibility being adequate while engine power selection remains the primary source of inefficiency. This study therefore recommends that fishers and local boatbuilders adopt hydrodynamic-based power calculations, rather than experience-based estimation, when selecting engines for ≤5 GT vessels, in order to achieve more fuel-efficient and productive small-scale fishing operations. The approach demonstrated here offers a replicable technical framework for similar small-scale fishing communities across Indonesia's coastal regions.

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