INTECHBIZ2025
International Conference on Industrial Technology and Business

Analysis of Engine–Propeller Mismatch and Performance of Colt L300 Engine on Polbeng II Vessel

Jamal[1], Firdaus[1], Hardiyanto[1], Fazrian[1], Easwind Nasution[2]
[1] Department of Naval Architecture, Politeknik Negeri Bengkalis, Bengkalis, Indonesia
[2] Ship Design and Construction Company, CV Vikram Fiber Glass, Siak, Indonesia
jamal@polbeng.ac.id

Abstract

Polbeng II is a research vessel owned by Politeknik Negeri Bengkalis, designed with a target speed of 12 knots. However, despite being equipped with a 74 HP diesel engine, the vessel was unable to achieve this speed, indicating an engine–propeller mismatch. This study analyzes the propulsion system using an engine–propeller matching approach through engine power calculations, open water propeller analysis, and numerical simulation. The results show that at 12 knots, the required power is 15.59 HP, while the matching calculation yields 18.59 HP. Both values are far below the available engine power of 74 HP, yet the vessel still failed to reach its design speed. Further analysis suggests that the Colt L300 engine installed as the main propulsion system does not operate optimally, and its actual performance may not correspond to the specified technical capacity..

Keywords : Colt L300, Polbeng II Vessel, Engine Propeller Matching

1. INTRODUCTION

Research vessels play a crucial role in supporting scientific investigations and data collection across various disciplines, particularly in marine studies. As the largest archipelagic country in the world, with more than 17,000 islands, Indonesia possesses vast marine resources. However, much of this potential remains underexplored and underutilized. To optimize marine research and ensure sustainable resource utilization, the availability of efficient and effective research vessels is essential (Kusuma & Rahman, 2019). In practice, many research vessels operating in Indonesia face several challenges, such as suboptimal performance, low fuel efficiency, and limited maneuverability in diverse marine environments. One of the most critical aspects influencing these factors is the ship's propulsion system, which plays a vital role in ensuring operational efficiency, speed, fuel economy, and maneuverability (Molland, Turnock, & Hudson, 2017).

Polbeng II is a research vessel owned by Politeknik Negeri Bengkalis, designed to support marine research activities with a design speed of 12 knots, according Fig 1. However, field observations and prior studies indicate that the vessel fails to achieve its design speed despite being equipped with a 74 HP diesel engine, according Fig.2and Table 1. This condition suggests a possible mismatch between the engine power and propeller requirements, commonly referred to as an engine–propeller mismatch. Such a mismatch can result in several operational issues, including increased fuel consumption, engine overloading, reduced propulsion efficiency, and even potential propulsion system failure (Carlton, 2018).

Therefore, a comprehensive study of the Polbeng II propulsion system is necessary, particularly focusing on the engine–propeller matching aspect. This process is essential to ensure that the engine power output corresponds effectively to the propeller's ability to generate thrust (MAN Energy Solutions, 2020). Through this analysis, it is expected that the actual performance of the Polbeng II propulsion system can be evaluated, while also providing technical recommendations to optimize vessel performance in the future. The objective of this study is to analyze the compatibility between the engine power and propeller characteristics of the Polbeng II research vessel. Furthermore, this study aims to determine the optimum operating point, where the engine and propeller achieve effective matching, thereby contributing to improved propulsion efficiency and overall vessel performance.

Fig. 1. The Polbeng II Vessel

(a) (b)

Fig. 2. Main engine of the Polbeng II vessel, (a) *Colt L300 engine, (b) Name tag Colt L300 engine.*

Table 1. Colt L300 engine specifications

Specification	Description
Engine Type	*4-cylinder Diesel (4PI)*
Number of Cylinders	*4*
Power Output	*72 PS*
Engine Displacement	*4.0 L (approx. 4000 cc)*
Maximum Power	*74 HP*

2. METHOD

This study employs a quantitative approach based on numerical analysis, consisting of two main stages: ship resistance analysis and engine–propeller compatibility analysis (engine–propeller matching).

Draft Determination

The determination of the vessel's draft was carried out using two approaches: (i) Case 1 (Weight Calculation Method): The draft was estimated based on the principle of buoyancy, where the vessel's total displacement weight was calculated by summing up the weight of the hull, machinery, equipment, and payload. The resulting displacement was then related to the hydrostatic properties of the hull to determine the corresponding draft (Lewis, 1988). (ii) Case 2 (Draft Survey Method): A draft survey was conducted by measuring the vessel's actual draft at several reference points (forward, midship, and aft). Corrections for trim and water density were applied to obtain the actual displacement and corresponding draft. This method provides an empirical validation of the weight-based calculation. The combination of both methods ensures that the draft estimation is both theoretically consistent and practically validated through direct measurement.

Ship Resistance Analysis

The resistance of the Polbeng II research vessel was analyzed using the Savitsky (Planing) method and slenderbody. This method is specifically developed for planing hulls operating at medium to high speeds and is therefore suitable for evaluating the resistance characteristics of Polbeng II, which has a design speed of 12 knots. Total resistance calculations were performed based on the Savitsky formulation (Savitsky, 1964; Bertram, 2012) using a numerical approach to determine the total resistance and power requirement at various operating speeds.

Engine–Propeller Matching Analysis

The next stage involved evaluating the compatibility between the engine and the propeller using the engine–propeller matching method. This method compares the engine power curve with the propeller power requirement (propeller law) to determine the optimum operating point (matching point) (Carlton, 2018; Molland et al., 2011). The specifications of the Colt L300 engine were used as input, while the open water propeller curve served as a reference to assess how efficiently the propeller absorbs the engine power

Analytical Approach

All calculations were conducted using numerical software and spreadsheets (Excel), allowing simulations under various operational conditions. This approach enables the assessment of whether the available engine power meets the propeller's requirements to achieve the design speed. Additionally, it helps identify the reasons why the vessel fails to reach its intended speed despite being equipped with a 74 HP engine (Lewis, 1988; ITTC, 2017). This methodology is expected to provide a comprehensive evaluation of the propulsion system performance of the Polbeng II vessel and to produce technical recommendations, including adjustments to propeller dimensions or engine performance, to achieve a more efficient and optimal propulsion system.

3. RESULT & DISCUSSION

Ship Draft

The determination of the ship's draft was carried out using two approaches, namely through the calculation of the vessel's construction weight (Case 1) and through a draft survey (Case 2). The calculation of construction weight serves as a validation to ensure that the draft survey results are accurate. Although there is a slight difference between the theoretical calculation and the draft survey, the discrepancy is minimal, indicating that the draft survey is reliable. Table 2 presents the draft calculation results obtained from both the construction weight method and the draft survey. The draft survey measurements show differences between the bow, stern, port side, and starboard side, as presented in Table 3. The average draft measurement obtained at the midship is 0.16 meters, as shown in Table 2. Furthermore, the draft height based on the construction weight calculation is presented in Table 4. The results in Table 4 represent the structural distribution illustrated in Figure 3.

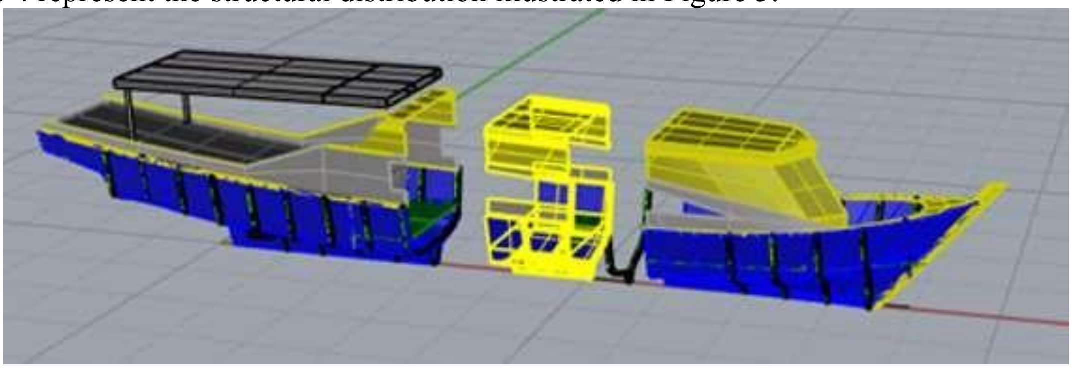

Fig. 3. Proses pembagian section berat konstruksi kapal

Table 2. Draft and Displacement Results of Polbeng II Research Vessel

Position of Draft Measurement	*Ship Draft Results*	
	Case 1	*Case 2*
Draf at Midhip	*0.15*	*0.16*
Displacement (Ton)	*0.7406*	*0.7879*

Table 3. Weight of Polbeng II Vessel per Station

No	*Frame*	*Area* (m^2)	*Thickness (m)*	*Volume* (m^3)	*Volume x Density Fiberglass (kg)*
1	*0-AP*	*4.224*	*0.005*	*0.02112*	*31.7*
2	*AP-1*	*3.989*	*0.005*	*0.019945*	*29.9*
3	*1-2*	*4.543*	*0.005*	*0.022715*	*34.1*
4	*2-4*	*10.468*	*0.005*	*0.05234*	*78.5*
5	*4-6*	*13.78*	*0.005*	*0.0689*	*103.4*
6	*6-8*	*8.858*	*0.005*	*0.04429*	*216.4*
7	*8-10*	*8.97*	*0.005*	*0.04485*	*67.3*
8	*10-12*	*8.697*	*0.005*	*0.043485*	*65.2*
9	*12-14*	*8.728*	*0.005*	*0.04364*	*65.5*
10	*14-16*	*4.572*	*0.005*	*0.02286*	*34.3*
11	*FP-forward*	*1.561*	*0.005*	*0.007805*	*14.4*
		Total weight (kg)			*740.7*

Based on the calculations performed, the obtained value of the vessel's lightweight tonnage (LWT) is 740.7 kg. To determine the ship's draft (T), the calculation was carried out using the vessel's construction weight through Equation (1) and (2). The draft calculation resulted in a value of 15 centimeters, equivalent to 0.15 meters.

$$\nabla = \frac{\Delta}{\rho} \tag{1}$$

$$T = \frac{\nabla}{\mathrm{L} \cdot \mathrm{B} \cdot \mathrm{Cb}} \tag{2}$$

Where ∇ denotes the displacement volume, Δ represents the displacement, ρ is the seawater density, T is the ship's draft, L is the ship's length, B is the ship's breadth (beam), and Cb is the block coefficient.

Ship Resistance

In this study, the resistance calculation was carried out under two different cases: Case 1 with a draft of 0.15 m and Case 2 with a draft of 0.16 m. The ship resistance was analyzed using the Savitsky planing method and the Slender Body method. The results of the ship resistance calculation are presented in Table 5.

The calculation of ship resistance at the Lightweight Tonnage draft (0.15 m) resulted in a resistance value of 11.71, while at the draft survey (0.16 m), the resistance was 12.21, with a difference of only about 0.50%. Visual observation confirmed that the ship's propeller blades were fully submerged (see Fig. 4), receiving a clean fluid flow without interference from the hull. This indicates that no significant turbulence or vortex occurred in the stern area.

Based on the resistance calculation using the Savitsky Planing method in the NUMERIK software, the resistance values of the Polbeng II vessel were found to be within a reasonable range for a high-speed craft (planing hull), with a Froude number of 0.72. The required engine power at a speed of 15 knots was calculated at 20.88 HP, which is very close to the results of a previous study using the Slender Body method, which estimated 26.64 HP. The difference of 5.76 HP (21.62%) demonstrates consistency and validates the model.

Therefore, no further modifications are required to the basic hull form, as the resistance performance is already efficient and aligned with the vessel's operational requirements.

Table 4. Ship Resistance Results of Polbeng II in Case 1 and Case 2

VS (knot)	*Case 1 (Draft = 0,1505 m)*				*Case 2 (Draft = 0,16 m)*			
	Savitsky Planing		*Slenderbody*		*Savitsky Planing*		*Slenderbody*	
	Tahanan (Kn)	*Daya Power (Hp)*	*Tahanan (Kn)*	*Daya Power (Hp)*	*Tahanan (Kn)*	*Daya Power (Hp)*	*Tahanan (Kn)*	*Daya Power (Hp)*
10	*0.71*	*7.68*	*0.94*	*10.06*	*0.75*	*8.02*	*0.97*	*10.46*
11	*0.82*	*9.99*	*1.06*	*12.91*	*0.85*	*9.99*	*1.10*	*12.87*
12	*0.92*	*11.71*	*1.18*	*15.07*	*0.96*	*12.21*	*1.22*	*15.59*
13	*1.05*	*14.58*	*1.34*	*1.69*	*1.09*	*15.19*	*1.39*	*19.31*
14	*1.15*	*17.76*	*1.48*	*22.83*	*1.20*	*17.93*	*1.53*	*22.79*
15	*1.26*	*20.04*	*1.62*	*25.87*	*1.31*	*20.88*	*1.67*	*26.64*

Meanwhile, the engine installed on the Polbeng II vessel has a power output of 74 HP. This indicates a significant difference of 83.49% between the installed engine power and the actual power required at a speed of 12 knots. This discrepancy suggests that the engine capacity is far greater than the vessel's actual operational needs. Therefore, it can be concluded that the installed engine is more than sufficient to operate the vessel under its current operational conditions and still provides a substantial power reserve to accommodate additional loads or stronger currents. However, the resistance calculation also reveals that if the vessel's actual speed is limited to only 5 knots, the installed engine does not perform according to its specifications. This is consistent with the calculation showing that the vessel requires only 16 HP to reach a speed of 12 knots.

Fig. 5. Polbeng II Propeller Condition

Engine–Propeller Matching Analysis

The calculation of engine–propeller matching involves several parameters, including engine speed (n), effective power (PE), delivered power (PD), shaft power (PS), continuous service rating brake power (PB–CSR), maximum continuous rating brake power (PB–MCR), the determination of KT, KQ, and propeller efficiency, as well as the calculation of thrust, torque, and propeller load. To determine the rotational speed (n), the initial step is to calculate the engine speed at continuous rating (nengine), which is typically around 80–85% of the maximum RPM. Based on the calculation, the continuous engine speed (nengine) was obtained as 3570 rpm, in accordance with Equation (3). Once the engine speed (nengine) has been determined, the next step is to calculate the propeller rotational speed (npropeller) using Equation (4).

$$n_{\text{engine}} = 85\% \text{ x } n \tag{3}$$

$$Ppropeller = \frac{\text{[illegible]}}{\text{[illegible]}} \quad (4)$$

Where n represents the maximum engine rotational speed

Table 5. Engine and Shaft Rotational Data

Vs (knot)	*n engine (rpm)*	*Propeller (rpm)*	*Power Percentage*
10	*3150*	*1016*	*75%*
11	*3360*	*1084*	*80%*
12	*3570*	*1152*	*85%*
13	*3780*	*1219*	*90%*
14	*3990*	*1287*	*95%*
15	*4200*	*1355*	*100%*

The power calculation begins with the determination of Effective Power (PE) using Equation (5). Once the PE value has been calculated, the Delivered Power (PD) can be determined by considering the efficiency of the propulsion process, according to Equation (6). After obtaining the PD value, the Shaft Power (PS) can be calculated. Since the engine is installed amidships, a 3% power reduction is applied to account for transmission losses along the shaft.

$$PE = n \times v \quad (5)$$

$$P_D = \frac{\text{[illegible]}}{\text{[illegible]}} \quad (6)$$

$$P_c = \eta_O \times \eta_H \times \eta_{rr} \quad (7)$$

$$\eta H = \frac{(1 - t)}{(1 - w)} \quad (8)$$

$$t = (0,5 \times CP) - 0,12 \quad (9)$$

$$w = (0,5 \times CB) - 0,05 \quad (10)$$

Where η_O represents the propeller efficiency, η_H is the hull efficiency, η_{rr} denotes the propulsor effectiveness, t is the thrust deduction factor, w is the wake fraction, C_B is the block coefficient, and C_P is the prismatic coefficient.

Table 6. Value of Effective Power (PE)

Vs (m/s)	*RT (N)*	*PE (W)*	*PE (HP)*
5.144	*750*	*3858.00*	*5.17*
5.6584	*850*	*4809.64*	*6.45*
6.1728	*960*	*5925.89*	*7.95*
6.6872	*1090*	*7289.05*	*9.77*
7.2016	*1200*	*8641.92*	*11.59*
7.716	*1310*	*10107.96*	*13.55*

Table 7. Value of Delivery Power (*PD*)

VS	*PE (HP)*	*PD (HP)*
10	*5.17*	*7.98*
11	*6.45*	*9.95*
12	*7.95*	*12.26*
13	*9.77*	*15.08*
14	*11.59*	*17.88*
15	*16.00*	*24.68*

After calculating the Shaft Power (P_S), the Continuous Service Rating Brake Power (P_{B-CSR}) can be determined, accounting for a 2% power loss due to the gearbox efficiency (η_G) of 98%. To determine the installed engine power on the vessel, the Maximum Continuous Rating Brake Power (P_{B-MCR}) is calculated. The P_{B-MCR} value is typically 15% higher than P_{B-CSR}. After calculating the Shaft Power (PS), the Continuous Service Rating Brake Power (PB–CSR) can be determined, taking into account a 2% power loss due to the gearbox efficiency (ηG) of 98%. To establish the installed engine power on the vessel, the Maximum Continuous Rating Brake Power (PB–MCR) is calculated, which is typically 15% higher than PB–CSR.

Table 8. *Value of Shaft Power (PS)*

VS	*PD (HP)*	*PS (HP)*
10	*7.98*	*8.23*
11	*9.95*	*10.26*
12	*12.26*	*12.64*
13	*15.08*	*15.54*
14	*17.88*	*18.43*
15	*24.68*	*25.44*

Table 8. *Value of Continuous Service Rating Break Power (P_{B-CSR})*

VS	*PS (HP)*	*PB-CSR (HP)*
10	*8.23*	*8.40*
11	*10.26*	*10.47*
12	*12.64*	*12.89*
13	*15.54*	*15.86*
14	*18.43*	*18.80*
15	*25.44*	*25.96*

Table 9. *Value of Maximum Continuous Rating Break Power (P_{B-MCR})*

VS	*PB-CSR (HP)*	*PB–MCR (HP)*
10	*8.40*	*9.65*
11	*10.47*	*12.04*
12	*12.89*	*14.83*
13	*15.86*	*18.24*
14	*18.80*	*21.63*
15	*25.96*	*29.86*

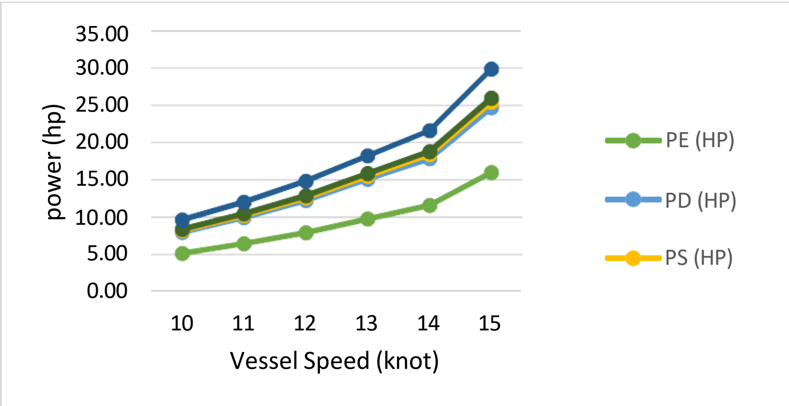

Fig. 6. Comparison of Power and Speed

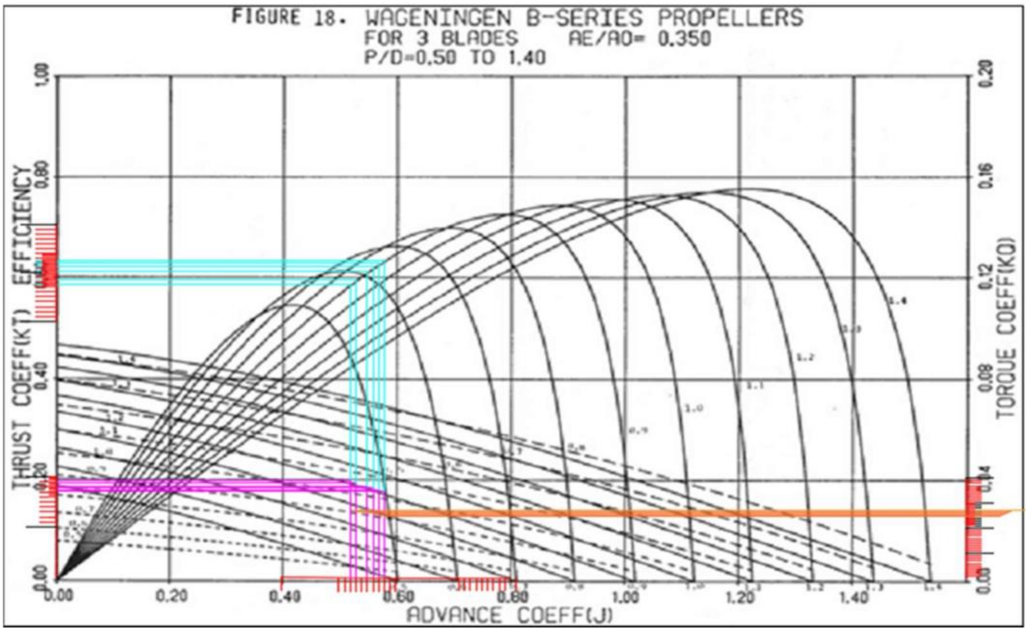

Fig. 7. *Open Water Propeller* B3-35 curve

The determination of KT and KQ values, as well as the propeller efficiency, can be obtained from the Wageningen B-series propeller charts. The charts are evaluated based on the P/D ratio, number of blades, and Ae/Ao ratio of the propeller used, referring to Figure 7 (Bernitsas, M. M., 1981). Subsequently, propulsion calculations are carried out to determine the values of each coefficient for the propeller according to Equation (11). Once the KT and KQ values are obtained, the thrust, torque, and propeller load can be calculated.

$$V_a = VS \times (1 - w) \tag{11}$$

Where the advance speed (Va) and the advance coefficient (J) can be determined after the wake fraction (w) has been established.

Table 10. Value of Reading of the B3-35 Propeller Chart result

vs (knot)	*va (m/s)*	*n (rps)*	*j*	*KT*	*KQ*	*η0 %*
10	*4.372*	*16.94*	*0.52*	*0.192*	*0.0274*	*57.8*
11	*4.810*	*18.06*	*0.53*	*0.188*	*0.0269*	*58.6*
12	*5.247*	*19.19*	*0.55*	*0.181*	*0.0263*	*60.2*
13	*5.684*	*20.32*	*0.56*	*0.178*	*0.0258*	*61.2*
14	*6.121*	*21.45*	*0.57*	*0.174*	*0.0252*	*62.1*
15	*6.559*	*22.58*	*0.58*	*0.170*	*0.0248*	*62.7*

Table 11. *Ship Propulsion at Speeds from 10 to 15 Knots*

vs (knot)	*RT (N)*	*T (N)*	*Q (Nm)*	*Ppropeller (HP)*
10	*750*	*3527,77*	*251,72*	*35,92*
11	*850*	*3930,20*	*281,18*	*42,80*
12	*960*	*4271,62*	*310,34*	*50,19*
13	*1090*	*4709,57*	*341,31*	*58,44*
14	*1200*	*5129,48*	*371,44*	*67,14*
15	*1310*	*5552,97*	*405,04*	*77,06*

The engine–propeller matching analysis was conducted to determine the matching point between the engine-generated power and the power absorbed by the propeller. To obtain the intersection graph, it was necessary to calculate both the engine and propeller power values as well as the maximum engine rotational speed. The required values had been obtained in the previous steps, including the engine speed, KQ, and the maximum PB–MCR of the vessel's engine. The calculation of the power absorbed by the propeller was performed considering a linear KQ value, where at an advance coefficient (J) of 0.81, KQ is 0.014. The PB–MCR power is linear from 0 HP at 0% of maximum engine speed (nengine), or 0 rpm, to 6.23 HP at 100% of maximum engine speed, which is 4200 rpm. The propeller speed (npropeller) is expressed based on the average gearbox reduction ratio of 1:3.1, resulting in a linear range from 0 rpm at 0% propeller speed to 977 rpm at 100% propeller speed, according Fig 8.

Table 12. *Engine–Propeller Power Matching Point*

% n	*nengine (rpm)*	*PB−MCR (HP)*	*npropeller (rpm)*	*KQ*	*Q (Nm)*	*Ppropeller (HP)*
60	*2520*	*17.91*	*813*	*0.0266*	*156.37*	*17.95*
61	*2562*	*18.21*	*826*	*0.0265*	*161.02*	*18.69*
62	*2604*	*18.51*	*840*	*0.0264*	*165.72*	*19.55*

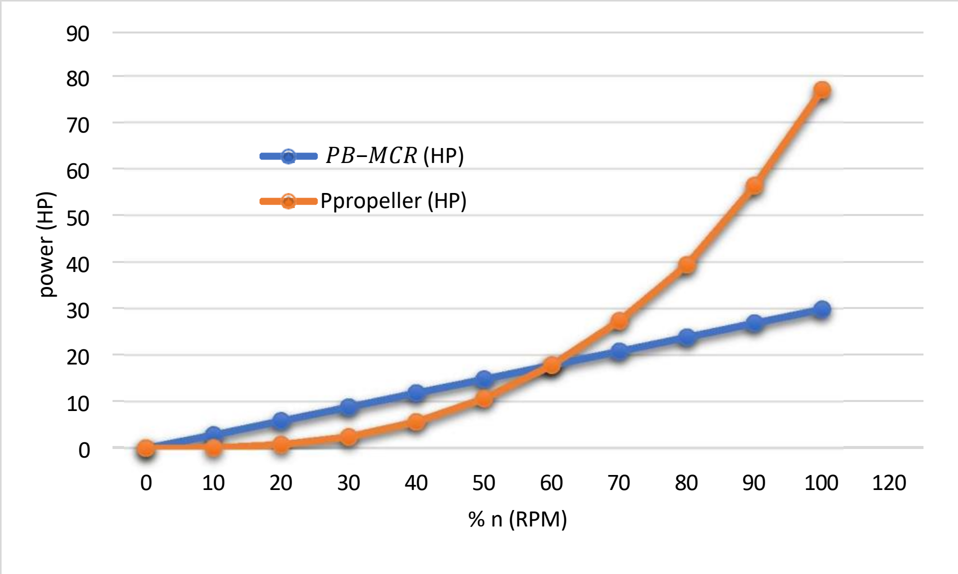

Fig. 8. Engine–Propeller Intersection

4. CONCLUSION

Based on the calculations, both from the engine power required to overcome ship resistance and from the engine–propeller matching analysis, it was determined that a speed of 12 knots requires only 16–20 HP. However, the available engine provides 74 HP, indicating that the installed engine specifications should be replaced with a marine-use engine, as the current engine is a land-use engine (designed for terrestrial vehicles) and is not intended for maritime operations. Furthermore, the gearbox reduction ratio needs to be evaluated and adjusted. An incorrect reduction ratio can result in a loss of torque or power transmission from the engine to the propeller. With a properly selected reduction ratio, the engine power can be transmitted more effectively to the propulsion system.

5. ACKNOWLEDGEMENTS

The authors would like to express their sincere gratitude to the Research and Community Service Center (Pusat Penelitian dan Pengabdian, P3M) of Politeknik Negeri Bengkalis for funding this research..

6. REFERENCES

Adji, S. W. (2005). Engine Propeller Matching. https://marinesistemengginering.wordpress.com/wp-content/uploads/2016/06/4-195-suryo-adji-engine-propeller-matching.pdf

Bernitsas. M.M, Ray. D, Kinley.P. (1981). KT, KQ and Efficiency Curves for the Wageningen B-Series Propellers. No237. Department of Naval Architecture and Marine Engineering College of Engineering The University of Michigan. Ann Arbor, Michigan 48109.

Bertram, V. (2012). Practical Ship Hydrodynamics (2nd ed.). Butterworth-Heinemann.

Carlton, J. (2018). Marine Propellers and Propulsion (4th ed.). Oxford: Butterworth-Heinemann.

ITTC – International Towing Tank Conference. (2017). Recommended Procedures and Guidelines: Resistance Test.

Kusuma, A., & Rahman, M. (2019). Performance analysis of Indonesian research vessels for marine exploration. Journal of Indonesian Naval Architecture, 5(2), 45–52.

Lewis, E. V. (Ed.). (1988). Principles of Naval Architecture: Resistance, Propulsion, and Vibration. The Society of Naval Architects and Marine Engineers (SNAME).

MAN Energy Solutions. (2020). Propulsion Systems and Matching Guide. Augsburg: MAN Energy Solutions.

Molland, A. F., Turnock, S. R., & Hudson, D. A. (2017). Ship Resistance and Propulsion: Practical Estimation of Ship Propulsive Power. Cambridge: Cambridge University Press.

Savitsky, D. (1964). Hydrodynamic Design of Planing Hulls. Marine Technology, 1(1), 71–95.

Schneekluth, H., & Bertram, V. (1998). Ship Design for Efficiency and Economy. Butterworth-Heinemann.