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Investigating The Engine Propeller Matching Of Triple Screw Ro-Ro Passenger Ship

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Abstract. The conversion of a Ro-Ro Vehicle Carrier into a Ro-Ro Passenger Ship. in compliance with PERMEN RI Number PM 62 of 2019. necessitates the use of at least two main engines. This study evaluates the performance of the C5-75 and MAU4-65 propellers to assess their efficiency. At a speed of 21 knots. the C5-75 propeller achieves an efficiency (ŋ) of 0.66 in clean hull conditions and 0.655 in rough hull conditions. The MAU4-65 propeller shows an efficiency of 0.646 in clean hull conditions and 0.653 in rough hull conditions. The Engine Propeller Matching (EPM) only a 12640 kW main engine indicates optimal operation at 109 rpm (clean hull) and 112 rpm (rough hull). Added 2 auxiliary main engine 1040 kW engines operate at 1577 rpm (clean hull) and 1597 rpm (rough hull). These findings highlight the propeller's performance and the required engine settings to achieve the desired speed after conversion.

Keywords: Propeller Efficiency, Engine Propeller Matching (EPM), Ro-Ro Ship Conversion.

1. Introduction

The regulation of the Minister of Transportation of the Republic of Indonesia Number PM 62 of 2019 concerning Minimum Service Standards for Crossing Transportation Article 1 paragraph 3 requires passenger ships to have at least 2 (two) main engines. The ship to be discussed in this paper is a Ro-Ro (Roll On-Roll Off) Vehicle Carrier that converted to a Ro-Ro (Roll On-Roll Off) Passenger. The change of ship types makes the addition of engines a necessary consideration for enhancing speed, efficiency, and navigational capabilities. This conversion not only fulfills the requirements but also drives innovation in engine technology.

Engine selection refers to Break Horse Power (BHP), which is the total engine power generated from the fuel combustion process, subtracting the mechanical losses, including the power requirements for the ship's sailing, sea margin, and engine margin [9]. In the selection of the main engine must consider fuel consumption to find the minimum consumption and the right DP,L (Delivered Power, Load) [12]. The rotation of the engine must be adjusted to the gearbox so the propeller can work optimally and no cavitation occurs due to the formation of nuclei bubbles that burst on the propeller.

Power from an engine is transmitted to the propeller producing thrust (t) that propels the ship forward. [3]. The emergence of the difference between the forward ship speed (Vs) and the speed of the water through the propeller results in the appearance of a wake (w). The wake contributes to increased resistance and drag on the ship. As the ship moves through the water, the disturbed water creates additional resistance that must be overcome by the engine. The greater the wake value make the reverse speed (Va) becomes smaller so it can reduce the ship's effective speed and require more power to maintain a certain speed [8]. therefore Calculating Effective Power Margin (EPM) is critical to accurately assessing the impact of wake on a vessel's reverse speed.

This Ro-Ro Passenger ship previously had a main engine with 12640 kW at 127 rpm which has a 2-stroke configuration that drives the C5-75 propeller. From the data obtained to achieve a speed of 21 knots in clean hull conditions, the engine is 114 rpm with propeller performance J: 0.832, KT: 0.272, 10KQ: 0.563, η: 0.624, and in rough hull conditions, the engine 112 rpm with propeller performance J: 0.807, KT: 0.295, 10KQ: 0.588, η: 0.621. Then adding 2 new engine units with 1040 kW at 1650 rpm with a 4-stroke configuration drive the MAU4-65 propeller in the portside and starboard at third deck engine room so that it becomes a triple screw ship. Triple screw ships have superior propeller performance compared to single-shaft and double-shaft ships [12]. The research also investigated the performance of one C5-75 propeller driven by the main engine and two MAU4-65 propellers driven by the auxiliary engine under 3-engine and 3-propeller operational conditions with speed power prediciton resulting in performance at 21 knots.

2. Methods

2.1. Holtrop Resistance

Ship resistance (Rt) is the fluid force acting against the ship's motion. It consists of components such as viscosity resistance (RV), wave resistance (RW), air resistance (RA), friction resistance (RF), appendages resistance (RAPP), and others. However, air resistance is often ignored due to its small value, only about 4% of the total resistance [10]. Ships operate on liquid fluid with a greater mass density of liquid fluid than air. As a result, the greater speed and dimensions of the ship will result in more wave energy being dissipated. Opposing forces will arise because the waves will rub against the hull and move in the direction opposite to the direction of motion of the ship.

This method is an extension of the previous method. This additional method is focused on improving power prediction results on high-block ships with low L/B ratios of direct ships with additional components outside the hull, such as the submerged stern transom [6]. By using the formula of total resistance based on the following equation:

$$R_T = R_F 91 + k 1 ¿ + R_{APP} + R_W + R_B + R_{TR} + R_A \quad (1)$$

Note:

R_T	=	Total resistance
(1 + k)	=	*The factor of the hull*
R_{APP}	=	*Appendage resistance*
R_W	=	*Wave resistance*
R_B	=	*Additional pressure resistance of bulbous bow near the water surface*
R_{TR}	=	*Additional pressure resistance due to transom immersion*
R_A	=	*Model-ship correlation resistance*

2.2. Propeller Performance

Propellers are used on ships as actuator blades that can change the pressure or drive in the fluid flow to produce thrust on the propeller blades [2]. The propeller is one of the key components in a ship's propulsion system. Propeller performance affects the ship's overall efficiency, fuel consumption, and speed. In determining the performance of the propeller, constants α and β are required to obtain KTtrial and KTservice to obtain the intersection point obtained from the open water test propeller graph KT - J - KQ - η. The model for the following open water test characteristics:

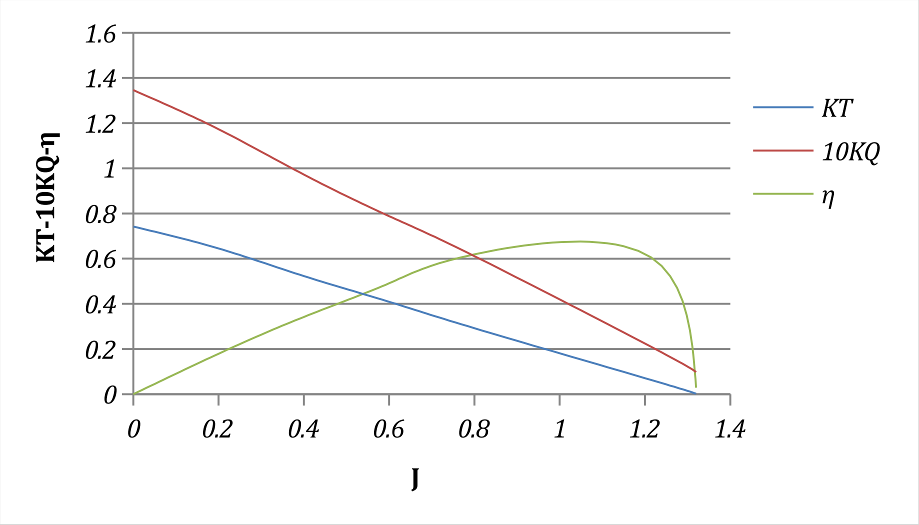

Fig. 1. Open Water Test Propeller C5 – 75

2.3. Engine Propeller Matching (EPM)

Ensuring the selected propeller can be considered using EPM (Engine Propeller Matching). Matching point is the operating point of the ship's propulsion motor rotation by the characteristics of the propeller load where the power absorbed by the propeller is the same as the power generated by the main engine and produces a ship speed close to the planned service speed [5].

After obtaining the propeller rotation condition, it is necessary to calculate the torque (Q) to be used in the calculation of DHP, SHP, BHPscr, and BHPmcr of the engine. From these calculations, the operating point of the engine and propeller relationship is found in clean hull and rough hull conditions to get BH-Pmcr power that can be transmitted to the propeller. Engine Propeller Matching (EPM) also includes speed power prediction to predict engine power value so that the ship will have the expected power and speed.

3. Result and Analyze

3.1. Ship Data

The Ro-Ro Passenger ship has Lpp dimensions of 137 m with a displacement of 10747.8 tons which is designed with a service speed of 21 knots. This ship has a 2-stroke main engine with 12640 kW power which has a rotation of 127 rpm which is used to drive the C5-75 propeller with a diameter of 5.3 m and 2 additional auxiliary main engine 4-stroke with 1040 kW and an engine speed of 1650 rpm equipped with a gearbox with a ratio of 4.08 to drive the MAU4-65 propeller with a diameter of 2 m. To investigate the propeller performance, the C5-75 propeller open water test simulation was conducted [4]. The open water test of the MAU4-65 propeller graph is obtained according to Figure 2.

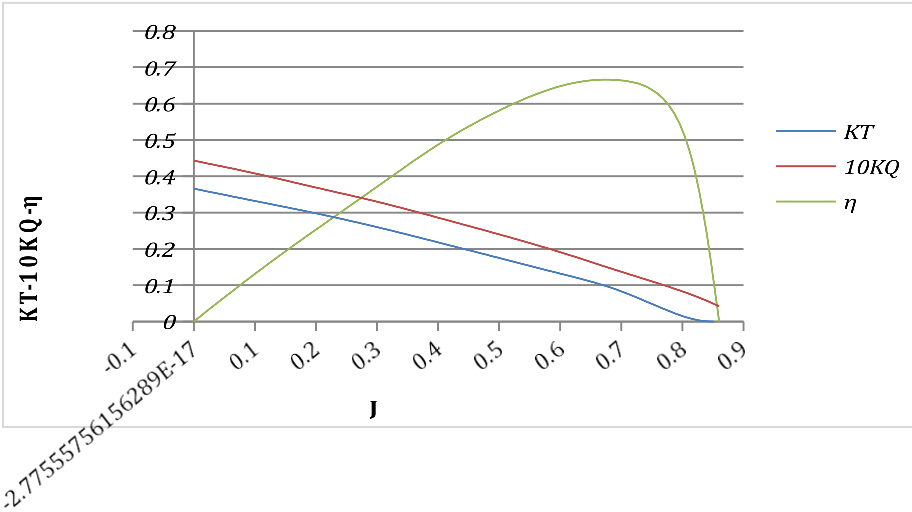

Fig. 2. Open Water Test Propeller MAU4 - 65

The wake and thrust values for EPM calculation are obtained from the self-propulsion test [1]. with the following values:

Table 1. Wake and Thrust

Paramete r	*Value*
t	-0.038
w	0.127

The thrust measured during the self-propulsion test resulting a negative value due to the insufficient thrust generated by the triple screw configuration, which is inadequate to overcome the existing resistance encountered by the ship.

3.2. Calculation of Holtrop Resistance

The ship's resistance is calculated using the Holtrop method with a calculation range at a speed of 15 - 24 Knots. The total resistance of this method also adds 15% hull roughness to the service margin condition. From the Holtrop resistance in equation (1), the following graph is obtained:

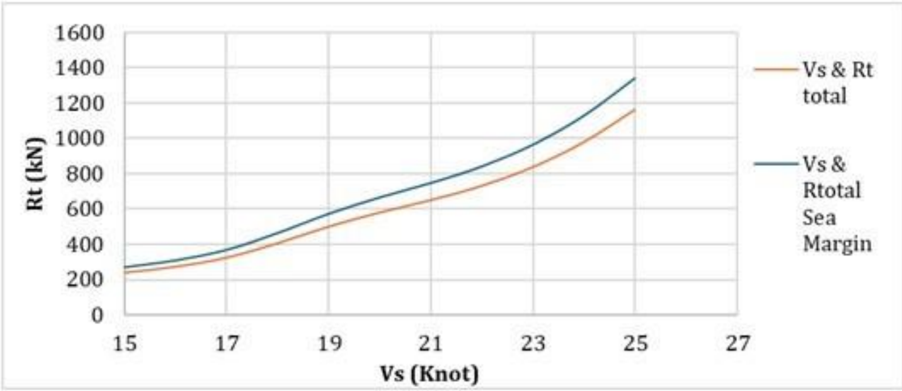

Fig. 3. Holtrop Resistance Ro–Ro Passenger Ship

At an operational speed of 17 knot this Ro-Ro Passenger ship has Rt = 308.915 kN and Rt Sea Margin = 355.253 kN. Whereas at an operational speed of 21 Knot service has Rt = 631.361 kN and Rt Sea Margin = 726.064 kN the resistance value of the Ro-Ro Passenger ship increases 104% when it is at service speed.

3.3. Distribution Resistance Triple Screw

EPM (Engine Propeller Matching) calculation for triple screw total resistance value (RT) is divided into 3 engine to represent the resistance of each propeller of the Ro-Ro Passenger ship at 21 knots. The main engine has much greater power than the two additional engines on the starboard and portside, In this configuration the engine providing 87% of the power is the primary source of thrust, driving most of the propulsion and influencing the ship's speed and maneuverability significantly. The engines with 7% each provide supplementary thrust, helping to balance the load and maintain stability.

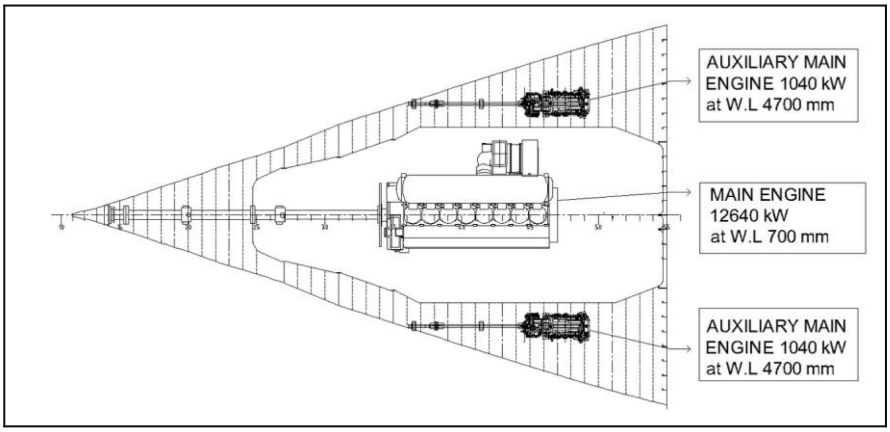

Fig. 4. Position of Engine Ro – Ro Passenger Ship

For the empirical calculation of EPM, the resistance is assumed with the main engine facing a very large resistance, which is 86% of its capacity, which is equivalent to 542.147 kN in clean hull conditions and 623.469 kN in rough hull condition. In contrast, the two auxiliary engines only experience 7% of their capacity, with the same resistance value of 44,607 kN in clean hull conditions and 51.298 kN in rough hull condition. For other speeds, the engine resistance is apportioned consistently at 87% and 7%, or the propeller's rotational ability is adjusted to align with the 'J' value and the engine's power output to the propeller.

3.4. Propeller Performances

Propeller performance using the thrust and wake values contained in Table 4 for further calculation of the coefficient in the KTtrial and KTservice conditions refers to the parameters that describe the relationship between engine and propeller characteristics at the trial condition of the ship's service speed of 21 Knot calculated by equation (8).

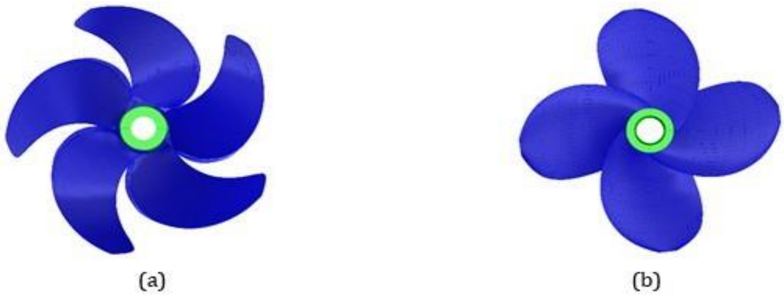

Fig. 5. (a) Propeller C5-75 and (b) Propeller MAU4-65

The main propeller driven by the main engine is a C5-75 propeller with the total resistance of the ship at a speed of 21 Knots which has been divided into 542.147 kN clean hull conditions and 623.469 kN rough hull conditions. Auxiliary main engine that drives the MAU4-65 propeller with total resistance at a speed of 21 knots which has been divided into 44,607 kN clean hull conditions and 51,298 rough hull conditions. The KTtrial and KTservice graphs used to investigate the intersection point of the open water test. The result J, KT, 10KQ, η value are showed in Figures 1 and 2.

Table 2. Propeller Performances of C5 – 75 and MAU4 - 65

Propeller Performances	Propeller C5 - 75		Propeller MAU4 - 65	
	Clean Hull	Rough	Clean Hull	Rough Hull

		Hull		
J	0.981	0.951	0.737	0.732
KT	0.195	0.212	0.062	0.064
10KQ	0.427	0.435	0.117	0.118
η	0.66	0.655	0.643	0.646

3.5. Engine Propeller Matching (EPM)

3.5.1 Engine Propeller Matching (EPM) 12640 kW Main Engine

From the intersection of open water test propeller C5-75 clean hull and rough hull conditions, KQ, KT, and η are obtained in Table 2 with thrust and wake values in table 1 which are used to determine BHPmcr power output according to RPM. From the rpm calculation, the clean hull and rough hull conditions fol - low the main engine rpm limitation which has 127 maximum rpm. So to achieve a ship speed of 21 Knots, the main engine can be operated at 109 rpm in clean hull conditions and 112 rpm in rough hull conditions. For other speeds, the engine resistance is split fixed with 87% and 7% configurations or ad - justing the propeller rotation capability to the "J" value and the power delivered by the engine to the pro - peller.

Furthermore, the EPM calculation is then plotted on the engine envelope graph to get the engine power that can be forwarded by the propeller and speed power prediction. The Figure 4 is the engine envelope graph and speed power prediction.

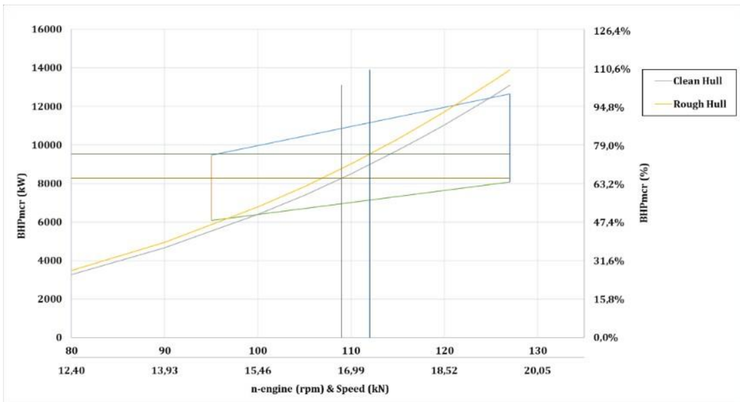

Fig. 6. Engine Envelope and Speed Power Prediction of Engine 12640 kW

The results of matching points in the engine envelope graph and speed power prediction obtained C5-75 propeller load driven by the main engine in clean hull conditions BHPmcr power 8279.2 kW at 109 rpm obtained a percentage of 65.5% while in rough hull conditions, BHPmcr power 9543.2 kW at 112 rpm obtained a percentage of 75.5%. As a result, the engine and propeller relationship are still matching based on the operating point in the engine envelope graph. The results of calculating the speed and power prediction can be seen that to achieve a ship speed of 21 Knot Ro-Ro Passenger in field conditions the main engine has to be operated at 109 rpm so that in clean hull conditions a speed of 16.48 knots is ob - tained with the power released 66.5% and at 112 rpm rough hull conditions a speed of 17.28 knots is obtained with the power released 75.5%.

3.5.2 Engine Propeller Matching (EPM) 1040 kW Auxiliary Main Engine

From the intersection of the MAU4-65 propeller open water test clean hull and rough hull conditions, KQ, KT, and η are obtained in Table 2 with the thrust and wake values in Table 1 which are used to deter-mine the BHPmcr power output according to RPM. From the rpm calculation, the clean hull and rough hull conditions are in accordance with the additional engine rpm limitations which have a maximum of 1650 rpm or 404.41 rpm propeller rotation. The added engine operation makes the ro - ro passenger ship to reach a speed of 21 knots with an engine speed of 1577 rpm or propeller rotation of 386.6 rpm in clean hull conditions and in rough hull conditions the engine speed is 1597 or propeller rotation of 391.4 rough hull conditions.

Furthermore, the EPM calculation is then mapped on the engine envelope graph to determine the en - gine power that can be forwarded by the propeller and speed power prediction. The following is the en- gine envelope graph and speed power prediction.

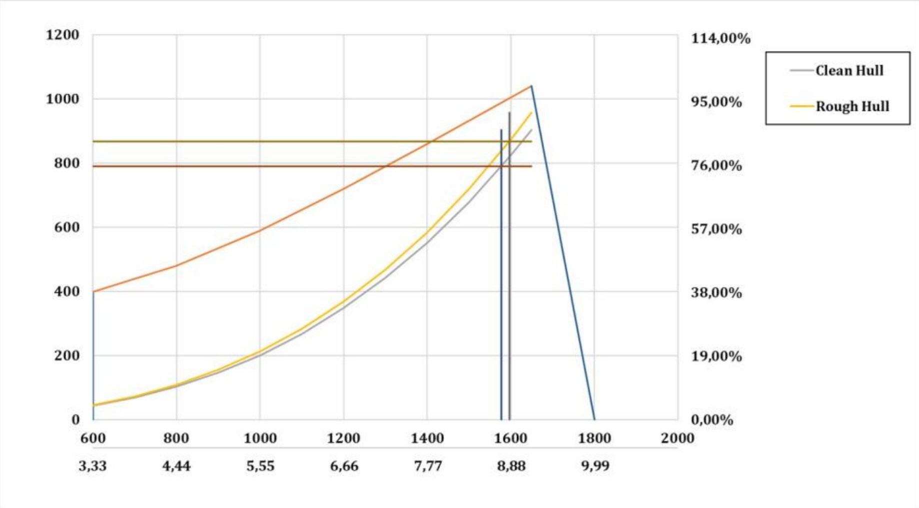

Fig. 7. Engine Envelope and Speed Power Prediction of Engine 1040 kW

The EPM results of the 1040 kW engine in clean hull conditions obtained a power of 790 kW at 1577 rpm and a propeller rotation of 386.6 rpm obtained a percentage of 75.9% while in rough hull conditions obtained a BHPmcr power of 867.58 kW at 1597 rpm and a propeller rotation of 394.2 rpm obtained a percentage of 83.5%, so that the engine and propeller relationship is still matching due to the operating point in the engine envelop graph but the propeller load has not been 100% achieved.

The Ro-Ro Passenger ships in empirical calculations reach a speed of 21 knots additional engines are operated at 1577 rpm engine speed or 386.6 rpm propeller rotation so that in clean hull conditions a speed of 8.21 knots is obtained with power released 75.9% and at 1597 rpm engine speed or 391 rpm propeller rough hull conditions a speed of 8.6 with power released 83.5%.

4. Conclusion

In the triple screw condition for a speed of 21 knots, discover a thrust deduction of -0.038 and 0.127 wake friction is obtained for propeller C5-75 under clean hull conditions J : 0.975, KT: 0.195, 10KQ: 0.427, η : 0.66 and rough hull condition J: 0.947, KT: 0.212, 10KQ: 0.453, η : 0.655, while the MAU4-65 propeller obtained the clean hull condition propeller performance J : 0.732, KT: 0.064, 10KQ: 0.118, η : 0.646 and rough hull conditions J: 0.718, KT: 0.073, 10KQ: 0.103, η : 0.612. From this performance, the highest efficiency and torque coefficient are obtained by propeller C5-75.

To achieve a speed of 21 knots in triple screw conditions, the main engine with a power of 12640 kW has to be operated at 109 rpm in clean hull conditions with power released 65.5% and at 112 rpm rough hull conditions with power released 75.5%, while the auxiliary main engine with a power of 1040 kW has to be operated at 1577 rpm in clean hull conditions with power released 75.9% and at 1597 rpm rough hull conditions with power released 83.5%.

During operation with three engines, the performance of the C5-75 type propeller shows high effi- ciency because the main engine does not need to work too hard. This results in a lower torque coefficient (KQ) compared to when the vessel operates with only one engine. This better efficiency results from a more even load distribution among the three engines, which in turn reduces the stress on each engine and increases the service life and reliability of the propulsion system as a whole.

References

1. Ardianto, B. (2023). Evaluasi Performa Sistem Propulsi Triple Screw Pada Kapal Ropax Dengan Metode Computational Fluid Dynamics. ITS Repository.
2. Baital, M. S., Putranto, A. B., & Waluyo, B. S. (2020). Analisa Engine Propeller Matching (Epm) Pada Kapal Rescue Boat Karena Perubahan Tahap Powering Process. Gema Teknologi, 21(1), 49–55.
3. Fitri, S. A. (2023). Optimasi Pemilihan Propeller Akibat Penggantian Mesin Unduk Kapal Charma Rucitra 3. ITS Repository.
4. Funeno, I. (2019). Cavitation Effects on Blade Spindle Torque of Controllable Pitch Propellers in Open Water. May.
5. Habibi, & Nurhadi. (2016). Analisa Pemilihan Propeller Tipe B-Series pada Kapal Feri Ro-Ro 600 GT dengan Menggunakan Aplikasi Matchpro. Jurnal Ilmiah Teknologi Maritim WAVE, 10(2), 75–81.
6. Holtrop, J., & Mennen, G. G. J. (1982). An approximate power prediction method. An Approximate Power Prediction Method.
7. ITTC, 2017. “Practical Guidelines for Ship Resistance ,” Report 7.5-03-02-04.
8. Mardi, S., Eko, J., & others. (2018). Analisa Pengaruh Variasi Bentuk Buritan Kapal Terhadap Hambatan Total Pada Kapal Twin Screw Propeller Menggunakan Metode CFD. Proceedings Conference on Marine Engineering and Its Application, 1(1), 73–78.
9. Sa’id, S. D., & Ridwan, M. (2019). Pemilihan Mesin Induk Kapal Purseiner Masyarakat Pesisir Nelayan Pekalongan. Jurnal Pengabdian Vokasi, 1(2), 99–102.
10. Sugianto, E., & Winarno, A. (2018). Computational Model Tahanan Kapal Untuk Menentukan Kebutuhan Daya Kapal Bulk Carrier 8664 Dwt. Jurnal Kelautan: Indonesian Journal of Marine Science and Technology, 10(2), 168. https://doi.org/10.21107/jk.v10i2.3411
11. Yazaki, A., & Takahashi, M. (1969). Propeller design charts of AU-type propeller series of large area ratio. Maritime Archive, July, 5–9.
12. Yokoo, K., Yazaki, A., Ito, T., et all (1973). An Investigation into the Propulsive Performance of a High Speed Container Ship with Triple Screws. Journal of the Society of Naval Architects of Japan, 1973(133), 33–47. https://doi.org/10.2534/jjasnaoe1968.1973.33
13. Yudo, H. (2012). Engine Matching Propeller Pada Kapal Untuk Mendapatkan Optimalisasi Pemakaian Mesin Penggerak Kapal Dan Baling – Baling Sebagai Alat Pendorong Kapal. Kapal, 4(1), 15–18.