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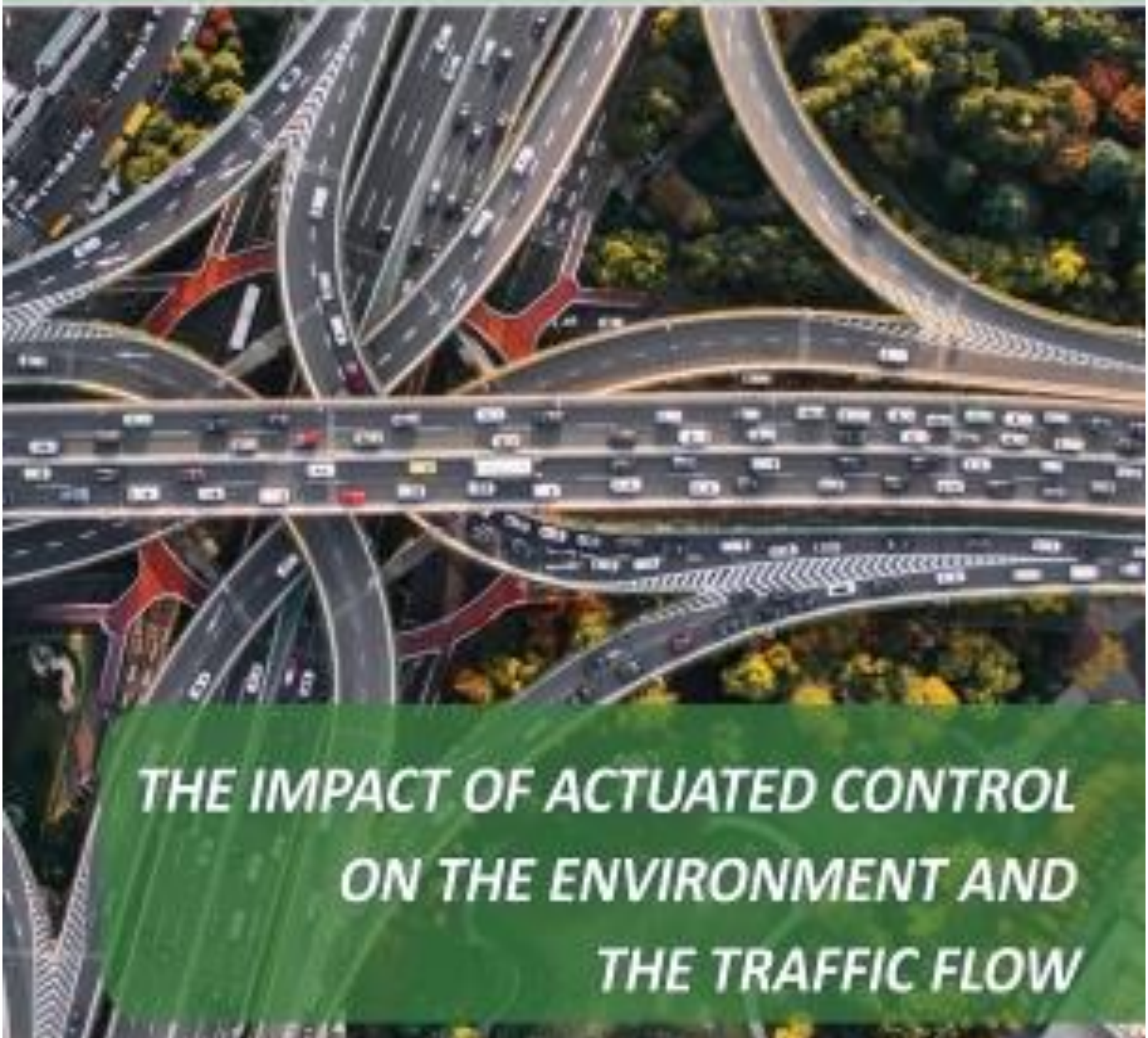

THE IMPACT OF ACTUATED CONTROL ON THE ENVIRONMENT AND THE TRAFFIC FLOW

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Key words: *Resistance, Thrust, Torque, Engine Propeller Matching, CFD*
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ENGINE PROPELLER MATCHING ANALYSIS ON FISHING VESSEL USING INBOARD ENGINE

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Fishing vessels which are used for one day operations usually use outboard engines as their driving motor. However, to improve the performance of propulsion systems, and consequently the performance of ships, inboard engines are now being used. In this study, the propulsion system of a ship was modified by upgrading from an outboard to an inboard motor. Meanwhile, the study aims to obtain an optimal interaction between the propulsion system and the hull shape of the ship. It was conducted by calculating the ship's resistance using the van Oortmerssen method, and validating the result using the CFD method. Furthermore, thrust and torque calculations were performed to obtain the characteristics of the ship's propellers, and the results were validated using the CFD method. The result obtained from the calculation of the ship's resistance was a New Fishing Vessel engine power of 11 HP. 4 types of B-Series propellers characterized based on the size of their pitch, including 14.00 inch, 14.25 inch, 14.50 inch, and 14.75 inch were, analyzed using the engine propeller matching analysis. The results show that the propeller with the pitch size of 14.75 inches was the best, as it had a power of 100%, speed of 25.35%, and efficiency of 19%. Therefore, it was chosen as the new propeller for New Fishing Vessels.

Key words: Resistance, Thrust, Torque, Engine Propeller Matching, CFD

INTRODUCTION

A Fishing vessel is one of the common means of transportation used by fishermen to find fish in the sea. Fishing is one of the main sources of income, especially on the north coast. This shows that fishing boats must have maximum performance in line with the fish catch and operational costs of the fishermen [1]. In theory, the ship gets a restraining force called resistance. This resistance must be countered by the thrust generated by the ship's propulsion system. The ship must have a propulsion system following the shape of the hull of the ship can result in optimal interaction between them, so that the performance of the ship's propulsion system is optimal [2].

Based on the results of field studies, the majority of the propulsion systems on fishing vessels use an outboard engine. In its development, some of the propulsion systems for fishing vessels with one-day fishing operations have used an inboard vessel because it is considered more efficient than using an outboard engine. In this case, fishing vessels usually only use a single propeller, but the size of the propeller varies so that each fishing vessel has a different performance [3]. This can be influenced by the size of the propeller pitch.

In the research of the MT.NUSANTARA's ship due to changes in the propulsion system, engine propeller matching was carried out to find the match between power and speed of the main engine and propeller. From the research, it was found that the main engine and propeller had the best match point [4]. Besides, in engine propeller matching research by changing the shape of the hull of the ship, a new main engine and propeller - considered to be able to optimize the performance of the drive system – was found [5].

From some of the studies described above, the author wants to do further research on engine propeller matching by changing the shape of the hull, which initially uses an outboard engine to be converted into an inboard engine. This study aims to obtain the optimal propulsion system on the New Fishing Vessel using an inboard engine. The benefit of the research carried out is as a reference in providing information related to the effect of changing the fishing boat drive system with an outboard engine to an inboard engine for those in need.

In this paper, the design of the new fishing vessel was discussed along with the determination of the main engine and new propeller calculation that is suitable for the new fishing vessels. This research also has a purpose to calculate the performance of new main engines and propellers, and analyze engine propeller matching for new fishing vessels

METHOD

In this research, to obtain data, direct measurements were made of the two fishing vessels that were examined. The two ships were named the old fishing vessel and new fishing vessel. The dimensions of the two fishing vessels are:

a. Old fishing vessel
- *Length Over All (LOA)* : 9 m
- *Length Between Perpindicular (LPP)* : 7.38 m
- *Bredth (B)* : 1.15 m
- *Draft (T)* : 0,25 m
- *Height (H)* : 0,75 m
- *Service Speed (Vs)* : 12 knots

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Besides, the data lines plan from the old fishing vessel is also obtained in Figure 1:

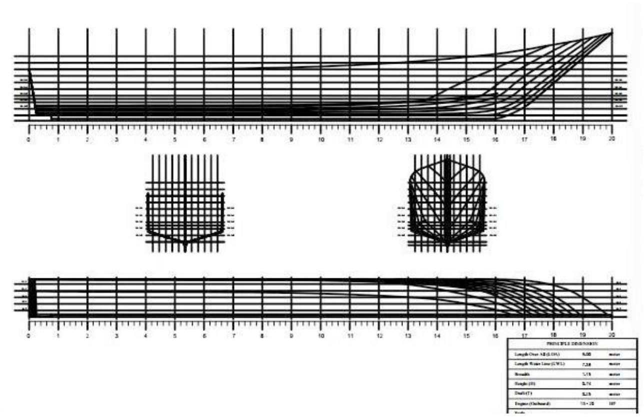

Figure 1. Old Fishing Vessel Lines Plan

This old fishing vessel uses a main engine type Yamaha, while the propeller used the B-Series type with the main engine and propeller specifications used as follows:

- Main Engine Type : Yamaha E15DMHL
- Power : 11 Kw
- RPM : 5500 RPM
- Propeller Type : B-Series
- Number of Leaves : 3
- Diameter : 254 mm
- *Direction of Rotation* : *Right-Handed*

b. New fishing vessel

- *Length Over All (LOA)* : 9 m
- *Length Between Perpindicular (LPP)* : 7.61 m
- *Bredth (B)* : 1.15 m
- *Draft (D)* : 0.5 m
- *Height (H)* : 1.20 m
- *Service Speed (Vs)* : 6 knots

Besides, the data lines plan from the new fishing vessel is also obtained in Figure 2:

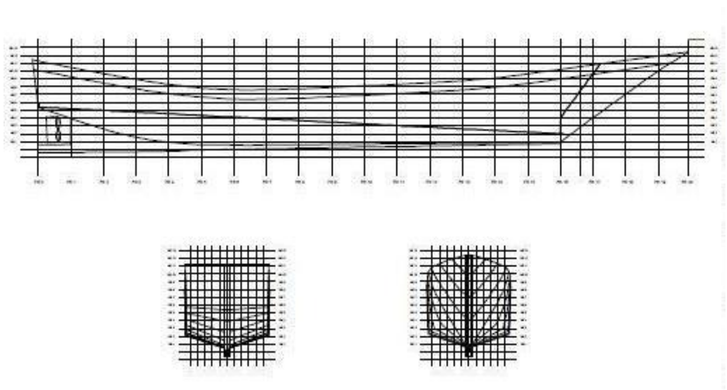

Figure 2. New Fishing Vessel Lines Plan

New fishing vessels used the main engine type Diamond, while the propeller uses the B-Series type with the main engine and propeller specifications used as follows:

- Main Engine Type : Diamond DI 1100 HM
- Power : 8,09 Kw
- RPM : 2400 RPM
- Propeller Type : B-Series
- Number of Leaves : 3
- Diameter : 381 mm
- *Direction of Rotation* : *Right-Handed*

The author researched to obtain resistance, thrust, and torque values using the Computational Fluid Dynamics (CFD) method in the fisheries laboratory and small ships located in Building B, Joint Lecture Building, Department of Naval Architecture, Diponegoro University.

The data obtained from data processing is then analyzed to obtain the desired results. The methods used in this research include:

Modeling and Analysis

In determining the amount of ship resistance the ship is modeled from the data lines plan using Computational Fluid Dynamics (CFD) software which is then validated using the van Oortmersen method calculation.

The calculation of resistance in this study was carried out using the Maxsurf Resistance software which was then validated with the resistance value obtained from the calculation of the CFD software Ansys Workbench 18.1.

For the manufacture of a shipping pool in the CFD software can be seen in Figure 3.

The size of the computational domain was 1L from the ship's bow, 3L from the ship's stern, 2L from the starboard, 2L from the portside, and 1L from the bottom, with the boundary conditions used in the simulation: Inlet, Outlet, Outflow, Sidewall, and Wall as shown in Figure 2 [7].

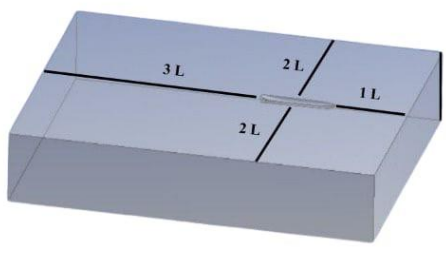

Figure 3. Size of the Ship Pool

Meanwhile, to determine the thrust and torque values, propeller modeling was carried out using Computational Fluid Dynamics (CFD) software which was then validated by manual calculations.

Then to make a propeller pool in CFD software can be seen in Figure 4.

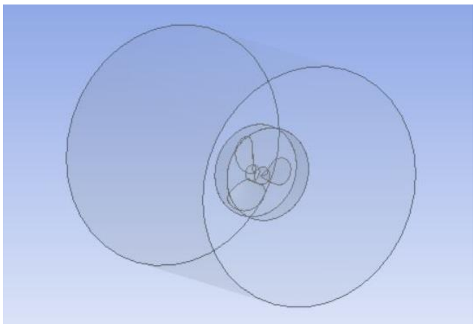

Figure 4. Size of the Propeller Pool

The sizes of the propeller domain in the CFD software were 2 diameters (D) for the rear of the propeller, 5D for the front of the propeller, and 3D for the radius of the propeller pool, with the boundary conditions used in the simulation, namely inlet, wall (opening), and outlet.

Matching Points are defined

A matching point is a point where the value of the main engine rotation (engine speed) is exactly the same (match) with the propeller character, which is the operating point of the motor rotation where the power absorbed by the propeller is the same as the power produced by the main engine, so that it can produce service speed the ship is exactly the same (approaching) at the planned speed [6].

The propeller characteristics are used to equalize the two trendlines into the same plotting means, so that first the prices of the two trendlines are expressed in percent (%) as shown in Figure 5. [6]:

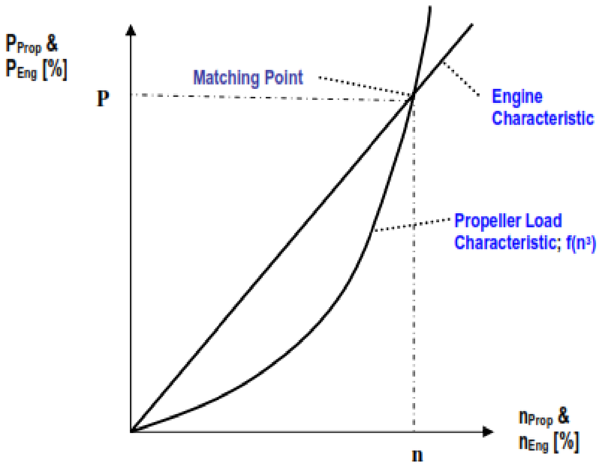

Figure 5. Matching Point Engine and Propeller

At the main engine rotation, **n**, which is following the propeller load conditions, because the power generated by the main engine is the same as the power absorbed by the propeller, P. So this will have an optimal impact on the fuel requirements of the ship's main engine on speed. service of the ship that has been planned [6].

RESULTS AND DISCUSSION

Ship 3D Modeling

To be able to analyze ship resistance, it was required a 3D model of the ship. The initial fishing vessel modeling was made based on the lines plan in Figure 1 and the new fishing vessel was made based on the lines plan in figure 2. Thus, it resulted in a 3D model of old fishing vessel as in figure 6 and new fishing vessel as in Figure 7.

Figure 6. Model of Old Fishing Vessel

Figure 7. Model of New Fishing Vessel

Then in the manufacture of old fishing vessel, it did not vary the propeller, just like shown in Figure 8, while the new fishing vessel did the propeller variation, namely the difference in pitch of the propller as in Figure 9.

Figure 8. Model B-Series Propeller Type B3-50 on Old Fishing Vessel

Figure 9. Propeller Model B-Series Type B3-50 on New Fishing Vessel

In this study, various propeller shapes were carried out in the form of propeller pitch size, namely :

- *Propeller pitch* 14.00 inch
- *Propeller pitch* 14.25 inch
- *Propeller pitch* 14.50 inch
- *Propeller pitch* 14.75 inch

Calculation of Ship Resistance

In calculating the value of ship resistance, the author used the Van Oortmerssen method and then validated the accuracy of the resistance value using the Computational Fluid Dynamics (CFD) method.

The old fishing vessel had a service speed of 12 knots and the new fishing vessel had a service speed of 6 knots, the calculation of resistance using the Van Oortmerssen method was done with software. The results of the resistance calculation are shown in table 1.

Table 1. Resistances and Speed of Old Fishing Vessels & New Fishing Vessels

Old Speed (Knots)	*New Speed (Knots)*	*Old Resistance (kN)*	*New Resistance (kN)*
0	*0*	0	0
2	*1*	0	0
4	*2*	0.2	0
6	*3*	0.7	0.1
8	*4*	1.7	0.2
10	*5*	2,3	0.5
12	*6*	2.7	0.8

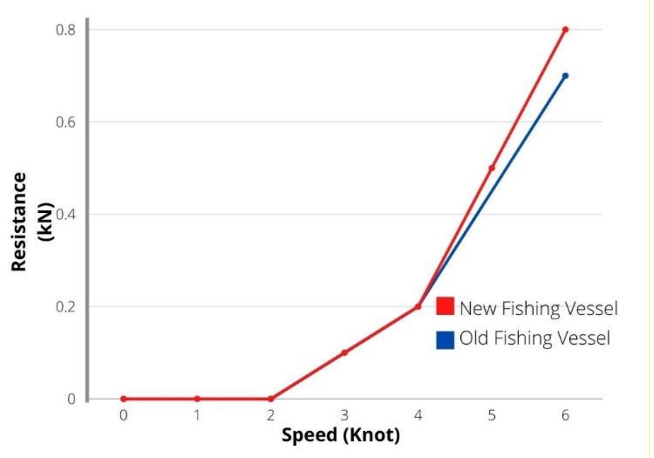

Figure 10. Speed– Resistance

From fig 10 and table 1 we know,old fishing vessel with a speed of 12 knots, the ship resistance is 2.7 kN, while new fishing vessel with a speed of 6 knots has a ship resistance of 0.8 kN.

Resistance Validation

Validation is carried out to determine the accuracy of a method used, by comparing the results between the two.

Calculation of resistance with the CFD method using software, ship modeling, and meshing must be done as well as possible so as to avoid errors that may occur in calculations. After calculating the resistance using the CFD method, the results of resistance are obtained as in table 2.

Table 2. Resistance Validation

***Type Fishing** Vessel*	***Resistance Van Ortmersen***	***Resistance CFD***	***Difference***
Old F.V	*2.7 kN*	*2,786*	*3.08%*
New F.V	*0.8 kN*	*0.836*	*4.3%*

The value of the resistance validation correction meets the requirements, which is below 5% [8]. This shows that the two methods used are valid. Then the calculation of the required engine power on the new fishing vessel will be carried out.

Because of the Ship new fishing vessel uses an inboard engine, then the calculation of the engine power of the ship is carried out as follows [9]:

EHP (Effective Horse Power) calculation

EHP = Rt x Vt (1)

= 0.8 x 3.0864

= 2.469 kW

EHP = 3.357 HP

The calculation of SHP (Shaft Horse Power) requires a Pc value, as follows [10]

SHP = EHP / Pc (2)

= 3,357 / 0.694

SHP = 4,837 HP

DHP (Delivery Horse Power) calculation

DHP = SHP x ηs (3)

= 4,837 x 0.98

DHP = 4,740 HP

The calculation of BHP (Brake Horse Power) is influenced by the gear transmission system (ηG)

BHPscr = SHP / ηG (4)

BHPscr = 4,837 / 0.98

= 4,936 HP

BHPmcr = BHPscr / 0, 85 (5)

BHPmcr = 4,936 / 0.85

= 5,807 HP ~ 6 HP

Propeller Calculation

The propeller used on the new fishing vessel is of the B-Series type. However, variations in the size of the pitch propeller were carried out to determine the type of propeller to be used on new fishing vessel, namely:

- *Propeller pitch* 14.00 inch
- *Propeller pitch* 14.25 inch
- *Propeller pitch* 14.50 inch
- *Propeller pitch* 14.75 inch

The propeller calculation is done to get the right propeller, the following is the propeller calculation:

a) Propeller Diameter

The propeller diameter on the New Fishing Vessel measures 15 inches / 381 mm. This size is recommended on the specified Engine Spec.

b) *Blade Area Ratio (Ae / Ao)*

To produce a large propeller thrust while sailing the value (Ae / Ao) usually ranges from 0.30-1.05, the value (Ae / Ao) is chosen 0.50 [10].

c) *Pitch Ratio* (P / D)

The Pitch Ratio value ranges from 0.50 to 1.4, the selected value (P / D) is 0.8 [10].

d) Number of Blade Propeller
The number of propeller blades 3 (three) was chosen because it is a small ship and has been recommended in the specified Engine Spec.

e) Va (Speed od Advance)
To find the Speed of Advance, the value of w is needed, as follows [10]

w = 0, 55 x Cb - 0.2 ………………..(6)

w = 0, 55 x 0.5 - 0.2

= 0.075

Va = (1-w) x Vs ……………….(7)

Va = (1-w) x Vs

= (1-0,075) x 3.0864

= 2,855 m / s

f) *Advance coefficient (J)*

$$J = \frac{Va}{n \times D} \quad \text{………………(8)}$$

$$J = \frac{2,855}{13,33 \times 0,381}$$

J = 0.61

After calculating the propeller, the type B3-50 was obtained. Then the kt and kq value were calculated using the Wageningen B-series chart, the kt and kq value were obtained as in table 3.

Table 3. Diameter Calculation of Wageningen B-Series

J	0.61		
P / D	kt	kq	eff
0.8	0.114	0.0214	0.32

From table 3 it is known that the kq value is 0.0214 which can then be used to calculate the propeller torque.

Propeller Selection

After knowing the propeller characteristics, the thrust propeller value was calculated as follows [10]:

$$T = \frac{Rt}{(1-t)} \quad (9)$$

$$= \frac{0,8}{(1-0,065)}$$

T = 855,614 N

In developing the propeller characteristic 'trend', the variables involved were propeller speed and propeller torque, which were then developed into the following equation [6]:

Qprop = Kq x ρ xx $n^2 D^5$ (10)

= 0.0214 x 1025 xx $13,33^2 0,381^5$

Qprop = 49,897

After that, calculations were carried out using the CFD method to get the thrust and torque values as follows.

Table 4. Validation of Thrust

Pitch Size	Calculation Thrust	Thrust CFD	Validation
14 inch	855,614 N	862,733 N	0.00825

Table 5. Tourqe Validation

Pitch Size	Calculation Torque	Torque CFD	Validation
14 inch	33.0264 Nm	32,9686 Nm	0.00175

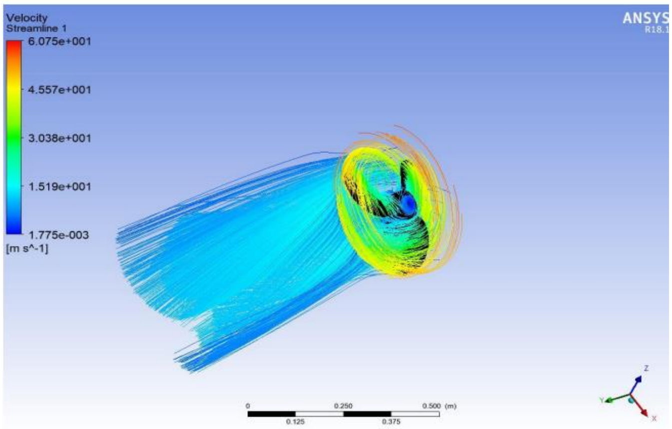

Figure 11. Thrust and Torque of 14-inch Pitch Size Propeller

The results of the calculation of thrust and torque using the B-Series diagram with a propeller pitch of 14.00 inches have been validated using the CFD method as show in Figure 11 with correction of 0.0085 for thrust calculations, and 0.00175 for torque calculations, so that the CFD setup is said to be valid and usable. to calculate the propeller with other variations in the size of the propeller pitch.

Then the results of the calculation of thrust and torque propeller are obtained as shown in Tables 4 and 5.

Table 6. Calculation Results of Thrust and Torque with the CFD Method

Pitch Size	Torque CFD	Thrust CFD
14.00 inch	32,9686 Nm	862,733 N
14.25 inch	33.1469 Nm	868,367 N
14.50 inch	33.1611 Nm	872,386 N
14.75 inch	33,3028 Nm	879,389 N

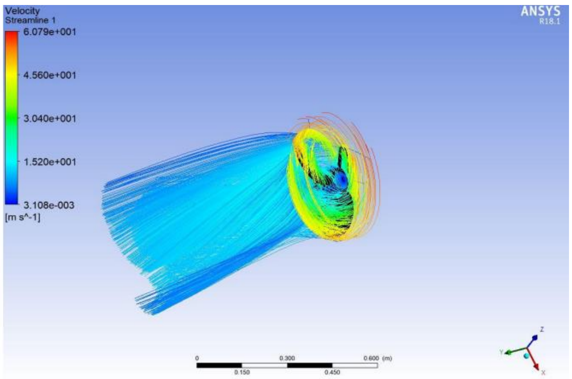

Figure 12. Thrust and Torque of 14.25-inch Pitch Size Propeller

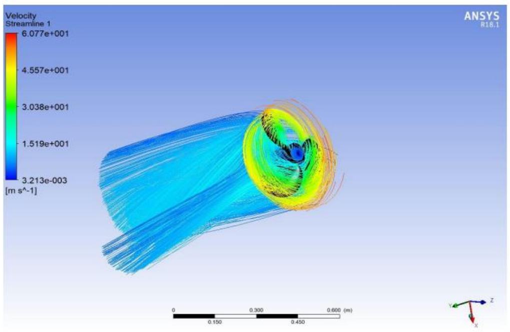

Figure 13. Thrust and Torque of 14.5-inch Pitch Size Propeller

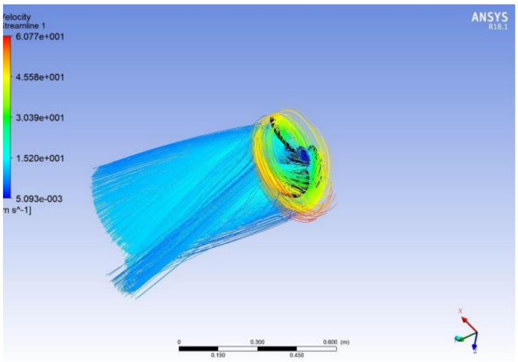

Figure 14. Thrust and Torque of 14.75-inch Pitch Size Propeller

From table 6 and Figure 11,Figure 12, Figure 13, and Figure 14, it can be seen that the largest thrust and torque values are owned by the propeller with a propeller pitch of 14.75 inches, amounting to 879.389 N for thrust values and 33.3028 Nm for torque values.

Engine Propeller Matching

Then the propeller power (P) calculation was performed so that the engine propeller matching analysis can be carried out for each propeller using the equation formula 11 [6].

Pprop = Qprop x Speed Propeller (11)

From the calculation of the power of variation in the size of the propeller pitch, the results are as in table 7.

Table 7. Calculation Results of Power (P) Propeller B-Series

Pitch Size	Power (P)
14.00 inch	11,1058 HP
14.25 inch	11,1658 HP
14.50 inch	11,1706 HP
14.75 inch	11,2184 HP

From the calculation, the propeller power was obtained with the propeller pitch of 14.75 inches, namely the power 11,2184 HP.

Then the calculation of the power and speed of the main engine and also the variation of the propeller was done by changing it in percent (%) so that the engine propeller matching analysis can be performed as shown in Figure 9.

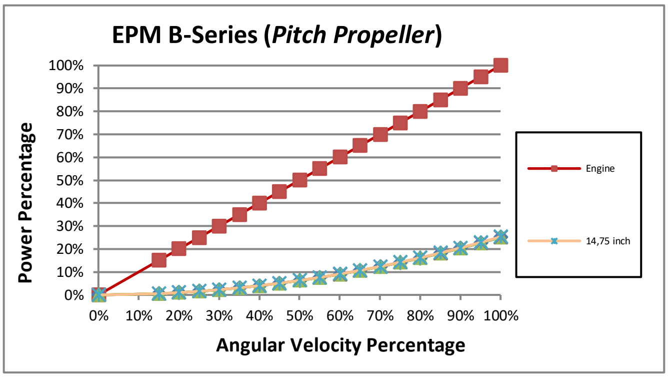

Figure 15. Comparison of Matching Propeller B-Series with Pitch Propeller 14.75 inch

Based on Figure 15, it is known that the B-Series propeller with a propeller pitch of 14.75 inches has a matching point between the engine character and the propeller character ranging from 100% rated power and 25.09% rated speed.

For the B-Series propeller with a propeller pitch of 14.25 inches, the matching point between the engine character and the propeller character ranges from 100% rated power and 25.23% rated speed.

For the B-Series propeller type with a propeller pitch of 14.5 inches, the matching point between the engine character and the propeller character ranges from 100% rated power and 25.24% rated speed.

Then the B-Series propeller with a propeller pitch of 14.75 inches has a matching point between the engine character and the propeller character ranging from 100% rated power and 25.35% rated speed.

So that a propeller with a propeller pitch of 14.75 inches was chosen as the new propeller for new fishing vessel because it has the best match point value.

Then the selected propeller must have great efficiency to optimize the propeller rotation [10]. Then the calculation of the efficiency of the B-Series propeller with a propeller pitch of 14.75 inches is as follows [7]:

$$Eff = \frac{T \, x \, V_a}{Q \, x \, Angular \, Speed} \quad (12)$$

$$Eff = \frac{0{,}879389 \, x \, 2{,}855}{33{,}3028 \, x \, 2 \, x \, 3{,}14 \, x \, 2400 \, / \, 60}$$

$$= \frac{2714{,}146}{8365{,}663}$$

$$Eff = 0{,}32$$

$$Eff = \frac{T \, x \, V_a}{Q \, x \, Angular \, Speed}$$

$$Eff = \frac{862{,}733 \, x \, 2{,}855}{32{,}9686 x \, 2 \, x \, 3{,}14 \, x \, 2400 \, / \, 60}$$

$$= \frac{2463{,}102}{8281{,}712}$$

$$Eff = 0{,}29$$

Identification Old Propeller Characteristics

In developing the propeller characteristic 'trend', the variables involved are propeller speed and propeller torque, which are then developed into an equation like the following:

It is known that the thrust value for old fishing vessel is as follows:

T $= \frac{Rt}{(1-t)}$

$= \frac{2,7}{(1-0,055)}$

T = 2.857 kN

Qprop= Kq x ρ xx $n^2 D^5$

= 0.073 x 1025 xx $44,06^2 0,254^5$

Qprop= 153,56

Eff $= \frac{T\ x\ V_a}{Q\ x\ Angular\ Speed}$

$= \frac{T\ x\ V_a}{Q\ x\ 2\pi\ rpm\ /\ 60}$

$= \frac{17,637\ \ 16930,582}{4879,753\ 88402,587}$

Eff = 0,19

Next is to perform calculations using the CFD method to find out the thrust and torque values. Then the calculation validation is carried out as shown in table 8 and table 9.

Table 8. Validation of Old Propeller Thrusts

Pitch Size	Calculation Thrust	Thrust CFD	Validation
9 inch	2857 N	2836,18 N	0.00728

Table 9. Validation of Old Torque Propeller

Pitch Size	Calculation Torque	Torque CFD	Validation
9 inch	8,4746 Nm	8,27414 Nm	0.0236

The results of the old thrust and torque propeller calculations have been validated using the CFD method with correction of 0.00728 for thrust calculations, and 0.0236 for torque calculations.

Then the propeller power (P) calculation is carried out so that the engine propeller matching analysis can be carried out for the old propeller [6].

Pprop = Qprop x Speed Propeller

= (8,4746 / 1000) 5500/60 x 2 x 3.14

Pprop = 6,54375 HP

From the results of the old propeller power calculation, the propeller power was 6.54375 HP. Then calculate the power and speed of the main engine and propeller by changing it in percent (%) so that the engine propeller matching analysis can be performed as shown in Figure 12.

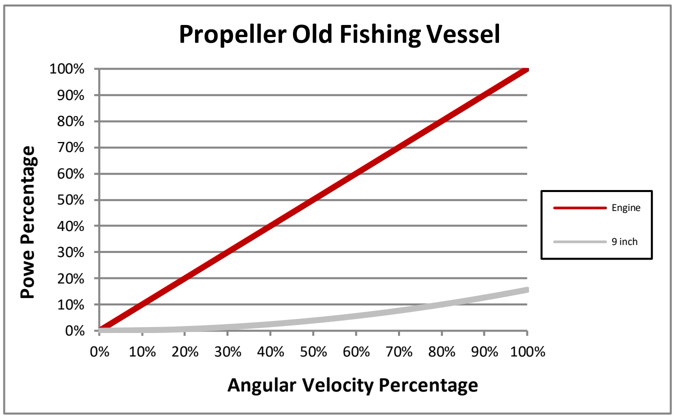

Figure 16. Comparison of Old Fishing Vessel Propeller Matching

Based on Figure 16, it can be seen that the engine and propeller characters do not have a match point because the engine power is not absorbed effectively by the propeller.

Comparison of the Engine Propeller Matching of Old Fishing Vessels and New Fishing Vessels

Engine propeller matching analysis has been carried out for old fishing vessels and new fishing vessels. The comparison of the propeller characteristics used by the two ships and the difference in match points is shown in Table 10:

Table 10. Comparison of the characteristics of the Old and New Propellers

Characteristics	Old Propeller	New Propeller
Diameter	0.254 m	0.381 m
P / D	0.60	0.80
Ae / Ao	0.50	0.50
Efficiency	0.19	0.29
RPM Va Power	5500 5,926 m / s 6,54375 HP	2400 2,855 m / s 11,1058 HP

The comparison of the engine propeller matching chart between old fishing vessel and new fishing vessels can be shown in Figure 17:

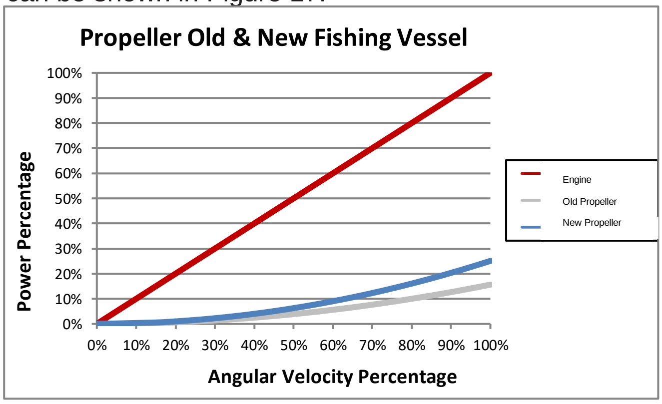

Figure 17. Graph of the Difference between Old and New Propeller Matching Points

Based on the results of the matching point comparison shown in Figure 17, new fishing vessel with inboard engine is better than old fishing vessel with outboard engine. Old fishing vessel own matching point between the character of the engine and the character of the propeller ranges from 100% rated power and 15.64% rated speed. Meanwhile, new fishing vessel has matching point between the character of the engine and the character of the propeller ranges from 100% rated power and 25.35% rated speed. So that the operating point of the motor rotation is where the power is absorbed by the propeller equal to the power produced by the engine and the resulting ship speed close to (exactly) the planned ship service speed.

CONCLUSION

Based on the comparative analysis of engine propeller matching between old fishing vessels and new fishing vessels, it can be concluded that new fishing vessel with inboard engine having a resistance of 855,614 N is the best new hull form, then calculating the main engine obtained by the main engine with a power of 11 HP to be able to overcome the drag of the ship, After that, the engine propeller matching is carried out on a B-Series propeller with a different propeller pitch size. The best match point value on the propeller with the pitch propeller size, namely 100% rated power and 25.35% rated speed with propeller efficiency of 29% was obtained, so that a propeller with a 14.75 inches pitch propeller was chosen as the propeller used for new fishing vessels

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