Analysis of number propeller blades on traditional boats 3 GT capacity with engine rotation speed variation

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Abstract. Limited range of fishing areas is one form of loss experienced by fishermen in Indonesia, especially fishermen who still use traditional boats 3 GT capacity. The driving component of one of the problems, one of which is a propeller. Propeller commonly used by fishermen still uses 3 blades propeller with less than maximum thrust distribution and fluid velocity. The purpose of this study is to optimize the number of propeller blades in traditional boats 3 GT capacity with variations in the number of propeller blades 2, 3 and 4 and rotational speed of 700 RPM, 1200 RPM, 1700 RPM, and 2200 RPM. The method used to determine the amount of thrust and fluid velocity through CFD simulations. Flow simulation results show the maximum thrust obtained at 1700 RPM rotational and the maximum fluid velocity obtained at 2200 RPM with a pressure of 15.3Mpa and a fluid speed of 3340.16 m/s on a propeller of 2 blades. Whereas the minimum thrust force is obtained at 700 RPM rotational with pressure 0.21Mpa in propeller with 3 blades and the minimum fluid speed is obtained at 700 RPM rotational with a fluid speed 369.33 m/s on propeller with 4 blades.

1. Introduction
The limited range of fishing grounds is an obstacle for fishermen who use traditional boats 3 GT capacity. The lack of sea catch results, resulting in losses for the fishermen who cannot compensate for the market price with the amount of catch that is obtained. Factors that influence these problems are due to lack of power generated from the ship's propulsion system. The ship propulsion system consists of an engine and propeller. The consequences received by fishermen so as not to experience a large loss one of them by modifying the propeller drive. Propeller is one part of the engine that functions as a mechanical drive, for example on airplanes, ships, hovercraft and others [1]. Optimization of the number of blades on the propeller is very influential on the performance of the boat, especially to increase the thrust and speed of the boat and suction power. However, as the number of blades increases, the suction cavity level tends to decrease [2]. The purpose of this study is to determine the most optimal number of blades used in the traditional boat 3 GT capacity with a variation of blades totaling 2.3 and 4 at 2200 RPM, 1700 RPM, 1200 RPM, and 700 RPM rotations.

2. Material and methods
2.1. Traditional boats 3GT capacity specifications
The traditional boat 3GT capacity specifications which are carried out in this study, have parameters as a reference in the process of determining the calculation of the resistance of a boat or vessel to be used...
as a variable in the simulation process. Following are the specifications of a traditional boat 3 GT capacity [3,4]:

**Table 1. Traditional Boats 3GT Capacity Specifications.**

| Impression          | Size          |
|---------------------|---------------|
| LOA (Length Over All) | 11.12 m       |
| LWL (Length Water Line) | 10.28 m       |
| LPP (Length Between Perpendicular) | 9.06 m |
| B (breadth)         | 2.13 m        |
| H (height)          | 0.57 m        |
| T (draft)           | 0.78 m        |

**Boat Engine Specifications**

Machine Location: *Inboard and Outboard*

*Merk*: *Dongfeng*

*Model*: *Diesel Engine*

*Max Output*: 26 HP/2200 RPM

2.2. *Fix pitch propeller geometry*

![Figure 1. Fix pitch propeller dimension.](image)

Figure 1 shows the dimensions of the outer diameter of the propeller of 198 mm, with a thickness of the propeller blade of 1.67 mm, and then the magnitude of the skew angle at above geometry fix pitch propeller of 3.74 degrees and the magnitude of the rake angle on the propeller of 9.97 degrees. For determine the magnitude of the skew angle with measured at the shaft center line, in the projected plane, which can be drawn between lines passing from the shaft center line through the mid chord position of any two sections, so that it determine of the rake angle with between a calculation generator line rake ($i_G$) and skew-induced rake ($i_S$) [2].

2.3. *Material*

Fix pitch propeller material used in traditional boat 3 GT capacity uses Aluminum Alloy material with the following chemical composition [5]:
### Table 2. Chemical composition.

| Elements | Al  | Si   | Fe  | Cu  | Mn  | Cr  | Zn   |
|----------|-----|------|-----|-----|-----|-----|------|
| Composition (%) | 85.82 | 7.51 | 1.08 | 0.12 | 0.19 | 0.12 | 4.78 |

When viewed from the material composition, the dominant elements that exist are Al 85.82%, then Si 7.51%, Fe 1.08%, and Zn 4.78%. The composition when compared with the composition of Aluminum alloy ASM standard, will have similarities with the aluminum alloy series A356.0 [5].

2.4. Parameters

2.4.1. Hydrostatic pressure. Propeller used on traditional boats 3 GT capacity is affected by the distance of propeller height to sea level high as (h) 50 cm, with seawater density (ρ_h) of 1025 kg/m³ [6]. Then to determine the magnitude of seawater pressure, the following equation is obtained [7]:

\[ P_H = \rho_h \cdot g \cdot h \]  

From the equation above we get the seawater pressure of 5022.5 Pa (502.25Kgf/m²), the pressure will be used as a propeller domain parameter in the simulation process.

2.4.2. Wet surface area of vessels. The wet surface area of the ship is a parameter that can be used to determine the value of the ship’s pressure. Variables needed to determine these parameters include the density of seawater (ρ_h) of 1025 kg/m³ (1,025 Ton/m³), ratio between the volume of the ship to the volume of the box (Cb) coefficient block of 0.409, length of the perpendicular (Lpp) of 9.06 m, breadth (B) of 2.13 m, and height of ship laden (T) of 0.57 m. The following equation is used in determining the value of the wet surface area of the ship [8]:

\[ S = \rho_h \cdot X \cdot Lpp \cdot (Cb \cdot X \cdot B + 1,7 \cdot T) \]  

From the above equation, the result of the wet surface area of the ship is 17 m². These results will be used in the equation to determine the pressure of the ship. The coefficient of the block (Cb) value on the variable above is determined from the speed of moving the boat (V) of 7 Knots [9].

2.4.3. Volume displacement. Volume displacement is the capacity/volume of the hull below the waterline. In determining the buoyancy of a ship it is necessary to have a volume dipped in water. To determine the volume of the immersed vessel, the length of the waterline (Lwl) is 10.28 m, breadth (B) is 2.13 m, the ship's laden height (T) is 0.57 m, and the coefficient block (Cb) is 0.409. The following equation is used in determining the displacement volume of ships [8]:

\[ V_d = Lwl \cdot X \cdot B \cdot X \cdot T \cdot X \cdot Cb \]  

From the above equation, the result of ship displacement volume is 5.1 m³. The resulting volume will be used in the calculation of buoyancy.

2.4.4. Buoyancy force. The amount of buoyancy that works from a ship is influenced by the specifications of the ship used and the condition of the seawater environment. The parameter in determining the value of buoyancy is the displacement volume of the ship (V) of 5.1 m³, influenced by the density of seawater (ρ_h) of 1025 kg/m³ and gravity (g) of 9.81 m/s². The following equation is used in determining the buoyancy force value [10]:

\[ F_a = K \cdot X \cdot \rho_h \cdot X \cdot g \cdot X \cdot V_d \]  

K value is an assumption of floating force in a ship with a value of 1/3. Given the value of the ship’s buoyancy assumptions, the buoyancy results at 17076.5 N (1,70765 Ton) are obtained in the equation.
2.4.5. Ship pressure. The parameters used in the propeller domain condition are needed hydrostatic pressure and pressure from the ship. Ship pressure is influenced by the buoyancy force \((F_a)\) of 1,70765 tons and the wet surface area of the ship \((S)\) of 17 \(\text{m}^2\). The following equation is used in determining the pressure of a ship [10]:

\[
P = \frac{F_a}{A}
\]  

The results of the equation above are obtained from the traditional boat 3GT capacity pressure value of 0.10045 Ton/\(\text{m}^2\) (100.45 Kgf/\(\text{m}^2\)). For parameters used in environmental conditions obtained from the sum of the values of hydrostatic pressure with ship pressure. The results obtained were 602.7 kgf/\(\text{m}^2\).

2.4.6. Initial condition

Figure 2. Propeller load.

Figure 2 shows the environmental conditions that occur in propeller traditional boat 3 GT capacity. The environment condition is influenced by the speed of seawater currents of 4 m/s [11], with sea surface temperatures around 29 \(^\circ\)C [12]. As well as the hydrostatic pressure and vessel pressure conditions of 602.7 Kgf/\(\text{m}^2\) with a maximum propeller rotation of 2200 RPM [4], through a CFD simulation in the processing of using SolidWorks software.

3. Results and discussion

3.1. Fluid pressure and fluid velocity conditions of 700 RPM rotation

Figure 3. Fluid pressure and fluid velocity conditions of 700 RPM rotation (a) Max Pressure on 2 Blade Propeller (b) Min Pressure on 3 Blade Propeller (c) Max Velocity on 2 Blade Propeller (d) Min velocity on 4 blade propeller.

Pressure conditions and fluid velocity that occurs at 700 RPM rotation, producing a maximum pressure of 123027.62 Kgf/\(\text{m}^2\) on 2 blade propeller counts and a maximum velocity of 697.46 m/s on 2 blade propeller. While a minimum pressure occurs on 3 blade propeller count of 20625.57 Kgf/\(\text{m}^2\) and a minimum velocity of 369.33 m/s on 4 blade propeller count.
3.2. Fluid pressure and fluid velocity conditions of 1200 RPM rotation

Figure 4. Fluid Pressure and Fluid Velocity Conditions of 1200 RPM Rotation (a) Max Pressure on 4 Blade Propeller (b) Min Pressure on 3 Blade Propeller (c) Max Velocity on 2 Blade Propeller (d) Min Velocity on 3 Blade Propeller.

Pressure conditions and fluid velocity that occurs at 1200 RPM rotation, producing a maximum pressure of 159438.59 Kgf/m$^2$ on 4 blade propeller counts and a maximum velocity of 1408.21 m/s on 2 blade propeller count. While a minimum pressure occurs on 3 blade propeller count of 129216.09 Kgf/m$^2$ and a minimum velocity of 537.44 m/s on 3 blade propeller count.

3.3. Fluid pressure and fluid velocity conditions of 1700 RPM rotation

Figure 5. Fluid pressure and fluid velocity conditions of 1700 rotation (a) Max pressure on 2 blade propeller (b) Min pressure on 3 blade propeller (c) Max velocity on 2 blade propeller (d) Min velocity on 4 blade propeller.

Pressure conditions and fluid velocity that occurs at 1700 RPM rotation, producing a maximum pressure of 1530440.05 Kgf/m$^2$ on 2 blade propeller counts and a maximum velocity of 2939.88 m/s on 2 blade propeller count. While a minimum pressure occurs on 3 blade propeller count of 38881.55 Kgf/m$^2$ and a minimum velocity of 1644.54 m/s on 4 blade propeller count.
3.4. Fluid pressure and fluid velocity conditions of 2200 RPM rotation

Figure 6. Fluid Pressure and fluid velocity conditions of 2200 RPM rotation (a) Max pressure on 2 blade propeller (b) Min pressure on 3 blade propeller (c) Max velocity on 2 blade propeller (d) Min velocity on 4 blade propeller.

Pressure conditions and fluid velocity that occurs at 2200 RPM rotation, producing a maximum pressure of 471250.09 Kgf/m² on 2 blade propeller counts and a maximum velocity of 3340.16 m/s on 2 blade propeller count. While a minimum pressure occurs on 3 blade propeller count of 154562.73 Kgf/m² and a minimum velocity of 2142.04 m/s on 4 blade propeller count.

3.5. Max pressure and max velocity of propeller charts

The charts below shows the comparison between max pressure and max velocity on traditional 3 GT capacity boat propellers based on variations in rotational speed.

Figure 7. Comparison between max pressure and max velocity propellers based on variations rotational speed.
The charts on figure 7, shows that the velocity of fluid produced by the propeller from each number of blades has a significant increase in each rotation, while the pressure generated at the propeller each number of blades has a less consistent increase.

4. Conclusion

The results of research on optimizing the number of propeller blades on traditional boats using 3GT using CFD (Computational Fluid Dynamic) in Flow Simulation, show the most optimal results based on the propeller number of 2 blades with maximum pressure results of 1530440.05Kgf/m² or 15.3 MPa with required loading 1700 RPM under environmental conditions with pressure of 602.7Kgf/m² and seawater flow velocity of 4 m/s. While the most optimal fluid velocity is the propeller of 2 blades with a maximum speed of 3340.16 m/s at 2200 RPM loading with the same environmental conditions.

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