Comparison of propeller thrust based on the purse seiner body shape

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Abstract. The engine on a fishing vessel is the main equipment that is assembled in a vessel's machining system. The vessel's engine, as the main driving force, is coupled with a propeller, which functions to provide thrust to the vessel. The efficiency and effectiveness of the propeller used on fishing vessels depend on the dimensions of the propeller and the type of fishing gear used, as well as the shape and size of the hull. The correlation between vessels, engines, and propellers in vessel planning determines the successful fishing operation. The objective of this study was to examine the geometrical relationship of the purse seine hull to the effectiveness and efficiency of the propeller. The analysis was conducted on nine samples of purse seiner operating in the Flores Sea through numerical simulations. The sample vessel designs were drawn from the vessel offset data using the maxsurf software to obtain the shape of the hull. Furthermore, the vessel shape specifications were simulated with the propeller technical specifications to obtain propeller efficiency values based on the shape of the hull. The results showed that the pressure value on the propeller used on purse seiners with round bottom was lower than the pressure experienced by the propeller on a U-bottom. Propeller efficiency values were higher on round bottom purse seiners than U-bottom forms. This value illustrates that the propeller thrust was greater in round-bottom vessels. This is probably indicated that the value of resistance on the U-bottom hull form was greater than the round bottom hull shape.

1. Introduction
The main consideration in planning shipbuilding in addition to designing the shape of the vessel according to the purpose of capture, also planning in the machining system. The machining system on the vessel consists of propulsion engines and devices that function to move the vessel as well as on purse seiner.

In purse seine fisheries, the function of the machining system has a very important role in the success of fishing operations. The operation of purse seiner requires a driving force by the method of purse seine fishing gear operation. A purse seine is usually referred to as a net bag because when operated like a bag. The principle of catching fish with purse seine is by encircling the horde of fish with a net, after which the net at the bottom is tucked in. Thus the horde of fish will be confined and unable to escape, which will eventually be caught [1].

Propulsion equipment on the boat in the form of a propeller has an important role in ensuring the smooth operation of fishing. The thrust generated by the propeller produces energy used by the vessel
to carry out capture operations by the fishing gear used. The shape of the propeller is similar to a fan consisting of several blades attached to the hub/boss mounted on the last axis of the shaft originating from the vessel engine [2,3].

The efficiency and effectiveness of the propeller used depends on the dimensions of the propeller and is adjusted according to the type of fishing gear used, as well as the shape and size of the hull [3,4]. Generally, fishing vessels in Indonesia use propellers based on the availability and price of propellers on the market. This can affect the success of the capture operation process because the need for propulsion for the motion of the vessel is not based on the compatibility of propeller specifications with the shape of the vessel and the fishing gear.

The purpose of this study is to determine the effectiveness and efficiency of propellers used on fishing vessels using purse seine fishing gear based on the geometry of the shape of the hull so that they can be recommended recommendations for the use of propellers for capture fisheries.

2. Materials and methods

This research is a case study of nine samples of purse seine vessels operating in the waters of the Makassar Strait and the Flores Sea. The sample vessel is measured to obtain vessel offset data, which is used to make the design of the body plan. Vessel design drawings are made by drawing general arrangements and lines plan, then calculate the hydrostatic parameters of the vessel based on the design consisting of waterplan area, volume displacement, ton displacement, block coefficient, midship coefficient, prismatic coefficient, water plan coefficient, ton per centimeter immersion and stability [2,5,6].

Data on the type, specifications, and performance of propeller used on sample vessels were obtained by observation and interviews using a questionnaire with the owner and crew of the vessel. Data were analyzed to obtain the value of technical parameters from propeller: propeller power that works on the vessel, Disc Area Ratio, propeller pressure, thrust developed propeller, blade area and propeller efficiency [2,3], then a numerical simulation is performed to determine the suitability of the propeller specifications used with the vessel specifications.

3. Results

3.1. Vessel specifications

Table 1 explained the principle dimensions of the vessels, were: Length overall (LOA) and Breadth (B) measured at the design waterline; hull Depth (D); and draft at the design waterline (d) and Gross Tonnage (GT).

| Vessels Sample | LOA  | BOA  | D   | D   | GT   |
|---------------|------|------|-----|-----|------|
| PS 1          | 21.00| 4.40 | 1.40| 1.00| 24.34|
| PS 2          | 21.00| 4.40 | 2.00| 1.20| 27.61|
| PS 3          | 20.00| 4.00 | 1.80| 0.95| 27.77|
| PS 4          | 21.00| 4.50 | 1.20| 0.90| 25.60|
| PS 5          | 20.00| 3.70 | 1.24| 1.10| 20.16|
| PS 6          | 21.00| 4.65 | 1.75| 1.15| 21.00|
| PS 7          | 21.10| 4.16 | 1.53| 1.23| 21.00|
| PS 8          | 20.20| 3.33 | 1.04| 0.92| 21.00|
| PS 9          | 21.20| 4.38 | 1.54| 1.15| 20.00|

Based on the lines plan drawing in the design of the sample vessel, the hull of vessels had two types, round bottom and U bottom (Figure 1). The vessels had V-shaped bow sections, so that vessel
has low resistance, and the vessel this is a shape which can make it easier to divide the mass of water in front of the vessel as it advances. In the midsections of the vessels, there are two forms, U bottom, and round bottom. The U bottom shape has good movement when looping the net and enough space under the deck for catches. The U-V bottom body shape vessels had low resistance so that the vessels can work properly, but the capacity under the deck is not optimal.

![Figure 1. Round bottom type.](image)

![Figure 2. U bottom type.](image)

### 3.2. Vessel engine specification

The comparison of GT and HP for a purse seiner sample ranges between 1: 0.6 – 1: 0.925 (Table 2). The data shows the use of the main engine power to drive the vessels is too small. The value is not in accordance with the standard values considered by GT and HP for fishing vessels, according to the needs of fishing operations, which range between 1: 2.5 – 1: 4.0 [3].

| Vessels Sample | GT Value | HP Value | Ratio GT and HP |
|----------------|----------|----------|-----------------|
| PS 1           | 24.34    | 30       | 1:0.81          |
| PS 2           | 27.61    | 30       | 1:0.92          |
| PS 3           | 27.77    | 30       | 1:0.93          |
| PS 4           | 25.60    | 30       | 1:0.85          |
| PS 5           | 20.16    | 30       | 1:0.67          |
| PS 6           | 21.00    | 30       | 1:0.70          |
| PS 7           | 21.00    | 30       | 1:0.70          |
The comparison between velocity value with LOA vessels (speed-length ratio/SLR) shows that the vessels have low speed (Table 3), standard values regarding speed limits with respect to the vessel's speed length ratio. The standard SLR value for low speeds is 1.448; speed 1.811, while for high speeds and when using machines with excess power and have a special shape, the SLR value is ~ 2.71.

### 4. Discussion

#### 4.1. Engine power

A vessel that moves through the water will experience resistance against its movement. To overcome this, we need a propulsion system mechanism in dealing with the force. The mechanism is in the form of engine power transmitted by the shaft to be forwarded to the propeller, which later produces thrust against the force. Therefore the magnitude of a vessel's thrust or engine power needs to be considered and adjusted to its purpose of the fishing operation and the body plan.

### Table 4. Power stage (HP) on the vessel engine sample.

| HP Stages | PS1 | PS2 | PS3 | PS4 | PS5 | PS6 | PS7 | PS8 | PS9 |
|-----------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| IHP       | 15  | 15  | 13  | 17  | 14  | 18  | 18  | 13  | 20  |
| BHP       | 12  | 12  | 10.4| 13.3| 11  | 14  | 14  | 10.1| 16  |
| SHP       | 11  | 11  | 10  | 13  | 10.3| 13  | 13  | 10  | 15  |
| DHP       | 10  | 10  | 9   | 10  | 12  | 12  | 12  | 9   | 14  |
| THP       | 8   | 8   | 7   | 7   | 9   | 9   | 9   | 7   | 11  |
| EHP       | 1.03| 1.00| 0.92| 1.18| 0.97| 1.3 | 1.2 | 0.90| 1.4 |

The amount of HP (horsepower) on a vessel's engine is not the actual driving force produced by the engine as output. When the engine is working, energy will be absorbed in several stages of the combustion process in the engine to the propeller. The value of HP (horsepower) will decrease in the percentage of power that is divided into indicated horsepower (IHP), brake horsepower (BHP), shaft horsepower (SHP), delivered horsepower (DHP), thrust horsepower (THP) and effective horsepower (EHP) [2]. Value of the power stage on the sample vessel engine (Table 4).
Table 5. Percentage (%) of the power stage (HP) the sample vessel engine.

| HP Stages | PS1 | PS2 | PS3 | PS4 | PS5 | PS6 | PS7 | PS8 | PS9 |
|-----------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| IHP       | 50.0| 50.0| 43.0| 56.0| 46.0| 60.0| 60.0| 43.0| 66.0|
| BHP       | 40.0| 40.0| 34.6| 44.3| 36.0| 46.0| 46.0| 33.6| 53.0|
| SHP       | 36.0| 36.0| 33.0| 43.0| 34.3| 43.0| 43.0| 33.0| 50.0|
| DHP       | 33.0| 33.0| 30.0| 33.0| 40.0| 40.0| 40.0| 30.0| 46.0|
| THP       | 26.6| 26.6| 23.3| 23.3| 30.0| 30.0| 30.0| 23.3| 36.0|
| EHP       | 3.43| 3.33| 3.06| 3.93| 4.30| 4.30| 4.00| 3.00| 4.67|

Table 5 shows the range of percentages of power loss at each stage of energy use IHP and BHP describe of the engine working limits on the propeller shafts, while the SHP, DHP, and EHP describe the power transmission system in the propulsor that will be used to overcome the total resistance of the vessel, and EHP is the effective power/actual power to overcome the resistance of the vessel.

Percentage of power loss at IHP and BHP ranges 33–66 %, with the breakdown of the energy in the driving motor that comes from fuel (fuel) is lost to the atmosphere in the form of heat ± 35 %; ± 25 % lost through cooling water and vibration, so that the loss that occurs in the engine (at the stage of IHP and BHP) is around ± 60 %. The stages of SHP and DHP are around 30-50%, about ± 38% is left behind for the propulsion force (THP) to overcome resistance on the vessels [3].

The results of the calculation of engine power vary due to the different total resistance values experienced by each sample vessel caused by differences in size from the main dimensions of the vessels. The total resistance values of the sample vessels can be seen in Table 6.

Table 6. Total resistance on the vessels sample.

| Vessels Sample | Total Resistance (kN) |
|----------------|-----------------------|
| PS1            | 16.54                 |
| PS2            | 26.30                 |
| PS3            | 22.66                 |
| PS4            | 24.66                 |
| PS5            | 20.37                 |
| PS6            | 26.27                 |
| PS7            | 25.95                 |
| PS8            | 18.80                 |
| PS9            | 30.01                 |

4.2. Propeller specifications

The dimensions of the propeller used to affect the value of the blade pressure, which can cause cavitation on the propeller blade. Cavitation can occur if the blade gets a pressure reaches 8 psi (55 kN/m²) [5]. Based on the analysis, the value of blade pressure obtained 1–9.96 (kN/m²). Blade pressure for each vessel can be seen in Table 7.
Table 7. Blade Pressure of Sample Vessels

| Sample Vessels | Thrust Developed | Blade Area | Blade Pressure (kN/m$^2$) | Blade Pressure (psi) |
|----------------|------------------|------------|--------------------------|----------------------|
| PS1            | 5.10             | 4261.36    | 1.19                     | 0.17                 |
| PS2            | 5.04             | 4261.36    | 1.18                     | 0.17                 |
| PS3            | 4.25             | 4261.36    | 1.96                     | 1.44                 |
| PS4            | 4.40             | 4261.36    | 1.03                     | 0.14                 |
| PS5            | 5.70             | 4261.36    | 1.33                     | 0.19                 |
| PS6            | 6.02             | 4261.36    | 1.41                     | 0.20                 |
| PS7            | 5.75             | 4261.36    | 1.34                     | 0.19                 |
| PS8            | 4.39             | 4261.36    | 1.03                     | 0.14                 |
| PS9            | 7.19             | 4261.36    | 1.68                     | 0.24                 |

Blade pressure is the result of a comparison between thrust developed and blade area. Table 7 shows the blade pressure values for the sample vessels in the range 1.03–9.96 kN/m$^2$ or 0.14–1.44 psi. The value of the blade pressure that triggers the cavitation release is very high on the work of the engine with a propeller increasing slip which involves air viscosity as well as one of the factors that cause the propeller pressure on the fluid/air media, thus allowing the acceleration of air to seek help produced by energy at the THP (thrust horsepower) stage. When the vessels get a big boost from the engine and propeller system, the vessel moves forward, simultaneously the vessel experiences resistance causing the propeller to get pressure as much as the vessel's load being rubbed on the fluid/water media that occur dynamically and can have an effect on decreasing engine power.

Table 7 shows that for all sample vessels, cavitation did not occur. Cavitation can occur if the blades get a pressure reaches 8 psi (55 kN/m$^2$) [4]. The factors that influence the occurrence of cavitation are propeller diameter, engine strength, propeller efficiency, and vessel's forward speed (VA) [1]. Cavitation of the propeller blade results in erosion of the propeller blade, which can cause vibrations and sounds [4,7].

4.3. Propeller efficiency

The efficiency value of the propeller is the ratio between the power produced by the propeller and the power it uses [2,4,8]. The factors that influence the efficiency of a vessel's propeller are the total resistance of the vessel, the magnitude of the speed, the thrust factor, the fraction of the current, the number of blades and the diameter of the propeller, the draft on a vessel [6]. The efficiency of vessel sample propellers ranges between 70–80 % (Table 8). This value is obtained from a comparison between the THP value and the DHP value. This difference in efficiency is influenced by the size of each total resistance of the vessel, which results in a difference in the magnitude of the decrease in engine HP (DHP and THP), differences in vessel resistance are affected by the draft height of the vessels. When the propeller absorbs power from the engine rotates simultaneously, the propeller experiences blade pressure, which comes from the total resistance of the vessel and water viscosity. The result is a large effect on the number of rounds of the propeller. So that the total resistance of the vessel causes the propeller rotation is slow due to the large load that must be pushed.

According to the propeller blade element theory, efficiency reaches a value of 1 or 100% if the propeller does not slip ($Sr = 0$) it means there is no acceleration of water caused by the propeller to produce thrust. This is not a possible cause to get the thrust. The propeller must rotate on a fluid/water medium so that the water will experience axial acceleration and cause a slip, which then produces thrust to move the hull that is experiencing resistance.
Table 8. Value of vessels propeller efficiency.

| Sample Vessels | Hull    | Draft | Total Resistance (kN) | DHP | THP | Propeller Efficiency (%) |
|---------------|---------|-------|-----------------------|-----|-----|--------------------------|
| PS1           | Round   | 1.00  | 16.54                 | 10  | 8   | 80                       |
| PS2           | Round   | 1.20  | 26.30                 | 10  | 8   | 80                       |
| PS3           | U       | 0.95  | 22.66                 | 9   | 7   | 70                       |
| PS4           | U       | 0.90  | 24.66                 | 12  | 9   | 70                       |
| PS5           | Round   | 1.10  | 20.37                 | 10  | 7   | 75                       |
| PS6           | U       | 1.15  | 26.27                 | 12  | 9   | 75                       |
| PS7           | U       | 1.23  | 25.95                 | 12  | 9   | 75                       |
| PS8           | U       | 0.92  | 18.80                 | 9   | 7   | 70                       |
| PS9           | U       | 1.15  | 30.01                 | 14  | 11  | 78                       |

In planning a vessel, the correlation between the vessel, the engine, and the propeller is a single entity that must be carefully calculated. Because if one component changes, then the other two components also change. The three components must be reviewed separately to check the interaction between the vessel, the engine, and the propeller, and then the characteristics for the vessel and propeller are matched in the working area of the main engine. Table 8 describes the shape of the hull, which has an influence on the value of the efficiency based on motion resistance and the amount of thrust (THP).

Both the shape of the hull, the round bottom shape has a higher efficiency value than the U bottom shape. This is because the resistance experienced by the U-bottom is greater than the shape of the U-bottom. The amount of total resistance causes a difference in the value of the thrust (THP) on each vessel. Vessels with a round bottom shape are a type like a slim U, so they tend to be like the V shape. This vessel with the shape of the body if the motion is good and the space under the deck can be utilized to the maximum. A vessel resistance is smaller than the U-bottom type, while the U-bottom is a nearly half-circle rounded hull. U-bottom shape will increase vessel resistance, the midship allows the vessel to work properly, but the loading capacity under the deck is not good.

5. Conclusion
The efficiency of the propeller used on the sample vessels with the round bottom shape is greater than the U bottom sample vessels, due to the total resistance received by the vessels with a U bottom is greater than the resistance received by the round bottom vessels.

References
[1] Nomura M and Yamazaki T 1975 Fishing Techniques (Tokyo)
[2] Fyson J 1985 Design of Small Fishing Vessel (Farnham. Surrey, England: Fishing News Book Ltd)
[3] Harvald S A 1992 Tahanan dan Propulsi Kapal (Airlangga University Press.)
[4] Firmansyah A D, Santoso A, and Djatmiko E 2012 Perancangan Controllable Pitch Propeller Pada Kapal Offshore Patroli Vessel 80 (OPV80) J. Tek. ITS 1 G230–5
[5] Buxton 1987 Engineering Economics and Ships Design (United Kingdom: Upon Tyne)
[6] Rawson K J and Tupper E C 1989 Basic Ship Theory. Vol 1. Longmann Scientific & Technical (England: Longmann Group UK Limited)
[7] Sambada G A 2011 Karakteristik Propeller Kapal Trammel Net Di PPI Bojomulyo,
Juana, Jawa Tengah (Institut Pertanian Bogor)

[8] Sasono E J 2009 Pemakaian Baling-baling Bebas Putar (Free Rotating Propeller) pada Kapal (Germany: Federal Minister of Research and Technology)