Application of savonius turbine behind the propeller as energy source of fishing vessel in Indonesia

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Abstract. The energy wasted by the propeller of vessel can be gained as benefit by converting it using turbine as the source of electrical energy. The electrical energy can be used as the main energy source of fisherman vessel. The method in this research is redesigning the fisherman vessel combined with savonius turbine to obtain the correct dimension. Vessel dimension is built within \( L_{oa} = 30.71 \) m; \( B = 7.67 \) m; \( H = 3.5 \) m; \( T = 2.2 \) m. From those dimensions can be obtained the coefficient between the propeller into the pitch 0.8 m, with the turbine diameter 0.5 m and the position of the turbine 0.1 m from the propeller. Savonius turbine captures electrical energy that produced by the low fluid flow that comes out from the propeller rotation, and will be converted by the generator inside the turbine to become energy. The power produced by the rotation of 1.31 rpm of the turbine is 25.689 kilowatt. It is enough to supply the engine generator with the power of 20.1 kilowatt from the power that produced by the turbine as big as 25.689 kilowatt to lighting the fisherman vessel. This technology can be applied massively to the fishermen vessel as renewable energy.

1. Introduction
Indonesia is a maritime country which still need to be developed especially in infrastructure aspect. Sea area of Indonesia reaches 5.8 million \( \text{km}^2 \) and the length of the longest beaches in the world after Canada, approximately 81,000 kilometers in length [1]. In addition, Indonesia has abundant natural resources in the sea and a high esthetic value. Ironically, Indonesian coastal communities are still in poverty. One contributing factor is the price of fuel oil which are expensive. The price of fuel without subsidies lead to sea for fishing capital increase, thus reducing expenditures fishing effort, especially in the season when conditions are hostile and famine.

In recent years, oil fields in Indonesia are gradually becoming scarce. With the system of regional autonomy that is running now, it is difficult for foreign oil companies to operate for dealing with small kings in the area. Meanwhile, domestic demand has exceeded production capacity. As a result, scarcity of fossil energy could lead in an energy crisis. Based on data from the Directorate General of Oil and Gas at the Ministry of Energy and Mineral Resources of Republic Indonesia of proven reserves reached 3.741 billion barrels, or 0.3% of world reserves, while potential reserves of 3.666 billion barrels. In other word,
the fuel consumption rate of the national average reached 40 million kiloliters per year, Indonesia's oil reserves will be exhausted within 10-12 years. Not surprisingly, the title of the country's largest net importer of oil in Southeast Asia had girded Indonesia. Indeed, today is a bleak future, knowing the country is used to provide a large income from oil exports for the community. Based on that data, the government uses a strategic move to raise fuel prices in overcoming the threat of imbalance budget as a result of energy subsidies is too great. However, these measures will make the fishing communities complain due to higher capital to look for fish in the sea. Rising fuel just before the fishing community have spent money amounting to Rp 200,000 for capital ship fuel, especially when fuel prices increased, the issued capital by fishermen will be higher. In fact, revenues generated by the uncertain benefit. As for the impact of the increasing high fuel prices in Indonesia, the coastal communities who are mostly fishermen are getting poorer. This is evident from the condition of the vessel used by fishermen to catch fish at night in conditions of total darkness, without the illumination of the power source. It thus makes the fishermen trouble to find fish in the sea, so the fish gets a little search results and impact on the economic needs of coastal fishing communities.

In addition, based on the facts of a conventional propeller used on fishing vessels until now is still the primary means of ship propulsion. In the workings of the system, the propeller will accelerate the flow from the front to the back part of the ship, so that it will produce two streams are axial and rotational. The flow velocity will determine the size of the loss of energy for ship propulsion systems. Classifies energy that occurs in the system ship propulsion of propeller to 60% of energy used, 20% of energy is lost in the form of axial jet flow, 13% is lost in the form of friction and 7% is lost in the form of stream rotation [2]. Energy lost 40% of the lap behind the propeller in a fishing vessel. Minimizing of axial energy loss by using vane turbine in the propeller slipstream [3]. Based on the above problems, it is expected that the use of renewable energy more efficient, innovative, inexpensive and environmentally friendly, with a touch of technology that is used by the fishermen. Therefore, they invented fishing vessel with the latest designs utilizing renewable energy as a source of energy, with application of savonius turbin behind the propoller. Savonius turbine chosen because have the twisted rotor has very good starting characteristics [4].

2. Problem Formulation and Objectives

Issues to be resolved in this study are:
1. How to get a source of electrical energy is more economical, efficient, effective, and environmentally friendly, for fishing vessels illumination sources?
2. How to design a fishing vessel as an innovative power generation technologies to harness the energy lost in the rear propeller for lighting a fishing vessel?

The objectives of this study are:
1. Obtain a source of electric energy more economical, efficient, effective, and environmentally friendly, for the lighting source of fishing vessels.
2. Designing a fishing vessel as an innovative power generation technologies to harness the energy lost in the rear propeller for lighting a fishing vessel.

3. Research Method

In this research, the following steps is:
1. Literature Review and Collecting Data. The study of literature contains a series of search activities and assessment of the sources of relevant and reliable in gathering the material and become a reference in this study.
2. Identification and modelling system. Identifying the existing case, then be re-examined, and produce an assessment conclusions for the initial design process. For the modeling of this fishing vessel, the rear propeller mounted savonius turbine to capture the energy is wasted as shown figure 1:
3. Identification and modelling system. Identifying the existing case, then be re-examined, and produce an assessment conclusions for the initial design process. For the modeling of this fishing vessel, the rear propeller mounted savonius turbine to capture the energy is wasted as shown figure 2:

![Figure 1. Design of fishing vessel](image)

![Figure 2. Prototype making process, (a) framework, (b) engine, (c) engine installation, (d) prototype](images)

4. Initial Test. Once the model is finished initial testing needs to be done in the form of an initial operational testing of the prototype, then determined a deficiency or lack of perfection of the prototype. The test is done in Laboratory of Hydrodynamic, Faculty of Marine Technology ITS, is wasted as shown figure 3:
5. Evaluation and model improvement. Prototype will be refined shape and the system works. Data evaluation results on the initial tests are used as a reference for improvement. The execution-execution minor form of painting and installation of trinkets models will also be done at this stage.

6. Further Testing. In this section, collect data on the effectiveness of the prototype after experiencing improvement. In addition, we tested the feasibility of the system overall work created on the model. Once the model is completed perfected in the previous stage has now arrived for the actual test.

7. Analysis and Discussions. Data from the advanced testing above were used for analysis and discussion on the prototype system as well as the feasibility of using the system. Analysis and discussion carried out to assess the results of design and suitability of the problems encountered.

8. Conclusions and Recommendations. The last process is, the convergence of ideas with the data collection process analysis and calculation, so it can be taken conclusion that aimed to answer the purposes mentioned earlier based on the analysis results. As well as recommendation for various parties in developing a fishing vessel and applications in Indonesia.

4. Literature Review

In this research, the following steps is:

1. Fishing Vessels. Fishing vessels is a ship specially designed to catch fish, which the operation for his arrest is a bit far from the berths and in its operation may take days, so it is equipped with a refrigerated fish boxes that catch is not perishable. Even on vessels equipped with a modern fish canned fish factory. All vessels must have made based on their respective functions as well as the fishing vessel that has a function to catch fish that comes by fishing gear.

2. Propeller. Propeller is a tool for generating thrust is now the most widely used. Propeller rotated by a shaft-driven prime mover in the engine room. There are at least three types of propeller, fixed pitch propeller, propeller with leaves fixed to the casing (nozzle), controllable pitch propeller is wasted as shown figure 4:

![Figure 4](image-url)
The principle is using a hydraulic system that is, by flowing fluid oil towards a housing located on the propeller shaft, the said housing there is a rotor which is connected to the leaf blades (blade), so if the drained fluid in the forward direction then the oil will push fin dividing the rotor and pushed so that the feather with a certain angle, if the flow direction is reversed, the leaf blades will spin the opposite direction. Operation can be done with two systems, namely, pull-push rod piston system and hub system. In the push-pull rod systems use long rods connected to the hub of the shaft ship propeller. While on the hub system piston, the piston rod is placed in the propeller hub.

3. Propeller Slipstream and Losses Energy. Conventional Propeller, until now it is still the primary means of ship propulsion. In the application, there are still large enough wasted energy in propeller is 40%. Waste stream from the propeller slipstream is referred to as flow. Slipstream propeller flow is very complex and very little has been understood. Leathard, showing the measurement point area by using the model propeller speed KCD 19. The area around the propeller flow is very complicated and is influenced by the following factors: unsteadiness, three dimensionality and high levels of turbulence. Slipstream flow axial velocity can be calculated by using the formula Maynord [6].

\[
V_{x_{\text{max}}} = 1.45V \left( \frac{X}{D} \right) 
\]

(1)

Hydrocom, a software to design the CRP (Contra Rotating Propeller) provides empirical formula to calculate the characteristics of the flow in and out.

4. Sea Currents in Stern of Ship. Sea currents involved is the difference between the speed of the ship with the speed of water flow to the propeller. By the time the ship moves, the friction of water on the surface of the hull causing water layer follows the direction of motion of the vessel. Dividing this difference by the ship’s speed or flow rate of water produced two currents join coefficient (wake fraction). This opinion was expressed by Taylor (Taylor wake fraction) and by Froude (Froude wake fraction).

5. Savonius Turbine. Savonius turbine is a tool to convert potential energy into a fluid into mechanical energy. This mechanical energy is then converted into electricity by a generator. Water turbine was developed in the 19th century and is widely used for electric power generation. In a Hydro Electric Power Plant (HEPP) water turbine is the main equipment in addition to the generator.

![Savonius turbine](figure5.png)

**Figure 5.** Savonius turbine [7]
The principle of the water turbine which converts the potential energy of water into mechanical energy. Mechanical energy is converted to electric generator into electrical power. The type of water turbine which is rarely used, namely, the vertical axis Savonius because it has the characteristics of a good starting torsi, easy in making and can work from all directions.

Figure 6. Turbine analysis by Model Actuator Disc [3]

5. Results
In this study, we will analyze based on laboratory experiments and mathematical analysis. The initial data required vessel in the calculation is as follows:

Table 1. Fishing vessel main dimensiony.

| Scale       | Quantity and Unit |
|-------------|-------------------|
| Loa         | 30.72 m           |
| Lpp         | 20.416 m          |
| B (breadth) | 7.67 m            |
| T (Draught) | 2.2 m             |
| H (high)    | 3.5 m             |
| Displacement| 84.1 m³           |
| Vs (Speed)  | 10 knot           |
| CT (coefficient of resistance) | 0.0038 |

1. Ship Resistance. Ship resistance (RT) is the amount of force that must be overcome to move the ship at a speed \( V_s \) and \( \rho \) is specific mass of sea water.

\[
R_T = C \frac{\rho}{\gamma} \frac{V_T^2 x S}{T}
\]

\[
R_T = 0.0038 \times 0.5 \times 1.025 \times 100 \times 158
\]

\[
R_T = 30.77kN
\]  

2. Calculation of Effective Power Vessels. Effective power or EHP is the power required to transform and move the ship in the water or to pull the vessel to the speed \( V_s \). Known 1 HP = 0.746 kW.
3. Ship Resistance. Ship resistance (RT) is the amount of force that must be overcome to move the ship at a speed $V_s$ and $\rho$ is specific mass of sea water.

$$EHP = \frac{R}{1000} \times V_s \times \rho$$

$$EHP \times 10^4 \text{N}$$

$$EHP = 0.308\text{HP}$$

$$EHP = 0.230\text{kW}$$

(3)

4. Thrust Horse Power Calculation. THP is a big thrust generated by the rotation of the propeller. Where the thrust is being used as a force to move the ship. Null efficiency or $\eta_H = 1.072$.

$$THP = \frac{EHP}{\eta_H}$$

$$THP = \frac{0.308}{1.072}$$

$$THP = 0.287\text{HP}$$

$$THP = 0.214\text{kW}$$

(4)

5. Speed Calculation Axial Flow Propeller Slipstream Generated. Based on the equation (1) obtained large axial velocity is generated by the propeller slipstream of 16.1 m/s.

6. Calculation of Turbine Savonius. There are some that should be analyzed mathematically in the manufacture of turbines that will be installed in the rear propeller, that is:

a. Angular Velocity. It involves angle of rotation with $\pi = 3.14$.

$$\omega = \frac{2n\pi}{60}$$

$$\omega = 1.31\text{rpm}$$

(6)

b. Torque. It needs force and radius of turbin to calculate.

$$T = FR$$

$$T = 19.61\text{Nm}$$

(7)
c. Turbine Power. The power of Savonius turbine depends on torque and angular velocity.

\[
P = T \omega
\]

\[
P = 25.689kW
\]

\[
P = 25689W
\]

(8)

Power generated by turbine of 25.689 kW is enough to supply genset with a power of 20.1 kW

d. Hydraulic Power. Hydraulic power is the power that enters the turbine in the form of the potential power of water.

\[
P = \frac{\rho H L}{2} \left( \frac{U^3}{2} \right)
\]

\[
P = 1025 \times 1.03r0.5 \times \left( \frac{3.51}{2} \right)
\]

\[
P = 12281W
\]

(9)

e. Turbine Efficiency. Turbine efficiency obtained from the amount of power that comes out (PT) is proportional to the input power (Ph).

\[
\eta = \frac{P_h \times 100\%}{P_T}
\]

\[
\eta = \frac{12281}{25689} \times 100\%
\]

\[
\eta = 47.8\%
\]

(10)

7. Fishing Vessel Cost Comparation. Fishing vessel with savonius turbine compared to conventional fishing vessel in order to know difference in economy aspect. The price used is based on regional price standard of goods and services in Surabaya, Indonesia.

| Table 2. Production Cost |
|--------------------------|
|                       |
| Parts                  | Conventional Fishing Vessel (Rp) | Fishing Vessel with Savonius Turbine (Rp) |
| Manufacture Hull       | 1,359,457,000                     | 1,359,457,000                            |
| Vessel Equipment       | 329,825,000                       | 329,825,000                              |
| Job Engine             | 228,750,000                       | 228,750,000                              |
| Fishing Equipment      | 55,500,000                        | 55,500,000                               |
| General Cost           | 149,196,800                       | 149,196,800                              |
| Turbine (titanium)     | 0                                 | 2,460,000                                |
| Generator              | 0                                 | 23,400,000                               |
| Battery (4 units)      | 0                                 | 4,800,000                                |
| Total                  | 2,122,728,800                     | 2,153,388,800                            |
| Difference             | 30,660,000                        |                                         |
### Table 3. Operation Cost

| Parts                        | Conventional Fishing Vessel (Rp) | Fishing Vessel with Savonius Turbine (Rp) |
|------------------------------|----------------------------------|-------------------------------------------|
| Operation Cost (One Day)     | 680,700                          | 548,100                                   |
| Operation Cost (One Month)   | 20,421,000                       | 17,523,000                                |
| Operation Cost (One Year)    | 245,052,000                      | 210,276,000                               |
| Save                         |                                  | 34,776,000                                |

Based on the table above, in the construction process fishing vessels as new innovative vessels with the addition of Savonius turbines, only requires a fairly low cost. And based on that, we can be able to save operational cost of Rp 34,776,000.

6. Conclusions and Recommendations

Fishing vessel by utilizing the energy lost from round the propeller of fishing vessels were converted by the turbine into electrical energy. The electrical energy produced will be used as a power source for lighting the fishing vessels. With the implementation of fishing vessel that produces energy by 25.689 kW electrical energy source then obtained a more economical, efficient, innovative, and environmentally friendly fishing communities. Fishing vessel applied in the coastal areas of Indonesia, is expected to facilitate the fishing communities for fishing at night to fulfill their work activity. Moreover, it can help the economy of the fishing community to use a fishing vessel that can save Rp 34,776,000.

Water flows from propeller can be an environmentally friendly alternative energy solution for diesel fuel substitute on a fishing vessel. In order to produce this technology massively, it must be supported by every stakeholders which consist of government, private sector, and communities. Concept development and marketing strategy is also the key to sustainable commercialization and good management of technology. It refers to several action such as investment analysis, product development, market testing, etc.

7. Acknowledgements

This research done by assistance of several parties. Author thanks to the team in Laboratory of Hydrodynamic, Faculty of Marine Technology, Institut Teknologi Sepuluh Nopember (ITS) for support in making process of vessel design. Another appreciation is also given to all parties that cannot be cannot be mentioned.

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