Hybrid Aerator based on Savonius Wind Turbine and *Solar Photovoltaic* Technology for Shrimp Pond

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Abstract

Indonesia has great maritime potential, one of the maritime potentials is shrimp farming. In Kulon Progo Regency, the area of shrimp ponds along the southern coast exceeds 150Ha. However, the operation of oxygen bubble maker (aerator) in shrimp ponds requires the large costs, due to the Aerator that uses a motor or generator requires the large energy. The operating cost of the tools are Rp.100.000 for a generator aerator and Rp.50.000 for an electric motor in a shrimp pond with a size of 100 m^2. Aerators on the market also still use fossil fuels that cause pollution, and require special maintenance. Renewable energy aerator innovation that purpose to save electrical energy and create an aerator without pollution. The research method to create the Hybrid Aerator used Research and Development (R&D). The result is the creation of a Hybrid Aerator with hybrid technology using wind and solar energy based on Savonious Wind Turbine and Solar Photovoltaic. When the tool is implemented, the amount of dissolved oxygen produced by Hybrid Aerator is in the range of 5.3 mg/L – 7 mg/L and only costs Rp. 6,500/day, so it is very effective and can help the shrimp farmer to minimize operational costs.

Abstrak

Indonesia memiliki potensi maritim yang besar, salah satunya adalah potensi budidaya udang. Di Kabupaten Kulon Progo, luas tambak udang sepanjang pesisir selatannya melebihi 150Ha. Namun, pengoperasian alat pembuat gelembung oksigen *(aerator)* pada tambak udang membutuhkan biaya yang besar, karena *aerator* yang menggunakan motor listrik atau genset memerlukan energi yang besar. Biaya pengoperasian alat tersebut yaitu Rp.100.000,00 untuk genset dan Rp.50.000,00 untuk motor listrik pada tambak ukuran 100 m^2. Aerator yang ada di pasaran juga masih menggunakan energi fosil yang menimbulkan polusi, serta memerlukan perawatan khusus. Inovasi *aerator* berbasis energi terbarukan yang bertujuan untuk penghematan energi listrik dan menciptakan aerator tanpa polusi. Metode penelitian yang digunakan untuk dalam pembuatan aerator *hybrid* ini adalah *Research and Development (R&D)*. Hasil yang dicapai adalah terciptanya alat *Aerator Hybrid* yang berteknologi *hybrid* menggunakan energi angin dan surya berbasis *Savonious Wind Turbine* dan *Solar Photovoltaic*. Saat alat diimplementasikan, jumlah oksigen yang dihasilkan *Aerator Hybrid* adalah kisaran angka 5,3 mg/L – 7 mg/L dan hanya menghabiskan biaya Rp.6.500/hari, sehingga sangat efektif dan dapat membantu petani dalam meminimalisir biaya operasional.

Keywords: *Aerator, Hybrid Energy, Shrimp Pond, Solar Energy, Wind Energy.*

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INTRODUCTION

Indonesia is a country that has large coastal area. The Indonesian Ministry of Maritime Affairs and Fisheries in 2019 stated that the total length of Indonesia's coastline was 95,181 kilometers [1]. This fact shows that the marine potential in Indonesia is very high and has good prospects. The regulation on the utilization of fishery resources has been regulated in the Law of the Republic of Indonesia number 5 of 1985 which states that in an effort to achieve the goals of National Development based on the insight of the archipelago, the fishery sector must be able to participate in realizing economic strength as an effort to increase national resilience.

The use of sandy land in coastal areas for shrimp and fish farming in Indonesia is in great demand by the Indonesian people. This condition is seen in several areas. The southern coastal area in Kulon Progo Regency is a new center of economic growth for shrimp farming in the Special Region of Yogyakarta. In the 2015-2019 Medium-Term Development Plan, the national shrimp production target is set at 750 thousand tons. So far, the Ministry of Maritime Affairs and Fisheries is optimistic that it will reach this figure. Slamet gave an example of southern coastal areas such as Kulon Progo and Bantul as potential ponds in the future [2].

Head of Fisheries and Cultivation Division, Marine, Fisheries and Livestock Service (DKPP) of Kulon Progo Regency, Eko Purwanto said the area of shrimp ponds along the southern coast of Kulon Progo is more than 150 hectares. With a land area of 150 hectares, and the price of shrimp at a minimum of Rp.60.000 per kg to Rp.110.000 per kg, the yield is around Rp. 25 billion per harvest. If in one year there are three harvests, it will produce more than IDR 75 billion per year [3].

In shrimp ponds, an aeration device or oxygen bubble maker is needed to make dissolved oxygen levels in ponds for optimizing shrimp cultivation [4]. Dissolved oxygen (DO) levels in water greatly affect the continuity of shrimp growth. Description of the ned for DO levels in shrimp can be seen in Table 1 [5].

Table 1. DO levels for shrimp farming

DO level mg/l	Information
0,75-2,5	Shrimp can survive for 24 hours
2,6-5,2	The speed of the shrimp to swim is reduced, the growth of the shrimp is stunted
5,3-8	Good for survival and growth

Based on direct observations on shrimp farms on the coast of Trisik, Kulon Progo which is one of the leading economies in the surrounding community. Shrimp pond farmers complain about the high cost of operating a motor that produces oxygen bubbles in the pond for shrimp rearing operations. In shrimp farming, we always encounter oxygen bubble producers using electric motors or generators, so the energy used in operating the oxygen bubble maker (aerator) is very large. The consumable cost in operating the equipment is Rp.100.000 for the generator and Rp.50.000 for the electric motor, aquaculture farmers who use a generator for a pond area of 100 m2 can spend around Rp.3.000.000/month and operational costs of Rp.1.500.000/month for electric motor operation. In addition to requiring large fossil energy, these tools also require special maintenance.

On the other hand, wind energy and solar are renewable energy sources that can be converted into electrical energy or motion energy. Both of these energies have enormous potential in Indonesia, especially in coastal areas [6]. In Indonesia, from a total of 9,290 MW of wind power plants developed, only about 2 MW have been implemented or equivalent to 0.02% of the total wind potential used [7]. The use of solar power in Indonesia is very potential to be

developed considering that Indonesia is located on the equator with available solar energy of 81,000 Terrawatts [8].

From these problems, we need a tool that can produce oxygen bubbles that are cheap and environmental friendly, and can also save on electricity costs incurred by shrimp farmers. *Hybrid Aerator* is the right choice as an alternative solution for producing oxygen bubbles based on hybrid energy to save electrical energy issued by shrimp farmers. Implementation of *Hybrid Aerator* for shrimp farming in Indonesia can increase production and reduce farmer's operational costs. The tool is an electronic device that is composed of an air vane, wind turbine and *Solar Photovoltaic* so that it is able to move a propeller that produces oxygen bubbles.

The working principle of this tool uses three energy systems. Wind energy is the main energy for tool operation. When the wind speed is 3-10 m/s, the tool will be supplied from wind power which is converted directly by the *Savonious* Wind Turbine to the shaft and gear of the tool. Meanwhile, if the wind speed is below 3m/s, the oxygen-producing device will be supplied from the battery. The battery gets solar energy through *Solar Photovoltaic*, then the energy is converted into electrical energy for the operation of the tool. In actual conditions, if there is no wind and solar, the energy of this tool will use electrical energy from PT. PLN (State Electricity Company). The system will be controlled automatically by Arduino installed on the tool.

RESEARCH METHOD

This research was conducted in a shrimp pond on the Trisik Coast, Kulon Progo Regency, Yogyakarta Special Region Province. The research and data collection will be carried out from April to July 2021. The activity starts from the preparation stage to testing the *Hybrid Aerator* in the field.

The method used in the implementation of this program is Research and Development (R&D) which is a research method to produce a new product and test the effectiveness of the product [9]. This R&D research has several stages by following the Linear Sequential Model (NGO) model which consists of 5 stages, namely the preparation, design, manufacture, testing and evaluation stage. These stages will be repeated until the purpose of research is completed. The purpose of this study is the tool can functions properly as planned.

1. Preparation Stage
   This preparation stage has several steps, namely:
   a) Preparation of the program accompanied by a companion lecturer
      This preparation was conducted at the Department of Mechanical Engineering, Faculty of Engineering, Yogyakarta State University.
   b) Preparation of tools and materials
      Prepare plates for the manufacture of wind turbines, prepare *Solar Photovoltaic*, waterwheels, gears and other components.
   c) Preparation of cooperation with related parties
      Preparation was conducted by collaborating with the Mechanical & Electrical UNY lab, the organization in the field of research and the community that owns the shrimp ponds.
   d) Literature Study
      The preparation of this study related to the components that create the tool, such as electrical component and frame. Literature study is also directed at the usefulness of aerator on shrimp, so that the tool that will be made do not harm the shrimp in the pond.
1. Design Stage
   At this design stage, there are two important parts of the *Hybrid Aerator* manufacturing process, including:
   a) Software Design

Software is created using Code Vision AVR and C programming language. Software development is created out with logical problem solving steps (algorithms/flowcharts), then finished in program form.

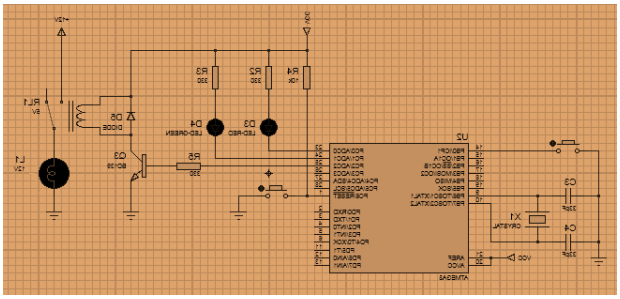

Figure 1. Electronic Design

This program functions to adjust the rotation of the water wheel that produces oxygen bubbles with the wind around the pond, if the wind is strong so that it is able to move the water wheel through the air vane, but if the wind is not able to rotate the propeller then the electric motor will automatically turn on the water wheel. In addition, the program can adjust the battery consumption for the operation of the tool.

b) Hardware Design

Electronic hardware design is created using ISIS Proteus software and uses Solidwork for the design of the tool framework. The hardware that will be made is suitable to the needs and variables, in the tool frame using L type ST-42 40x40x3mm, the Savonious Wind Turbine making frame using 1100 series Aluminum plates with a thickness of 1 mm and Solar Photovoltaic 130WP tools.

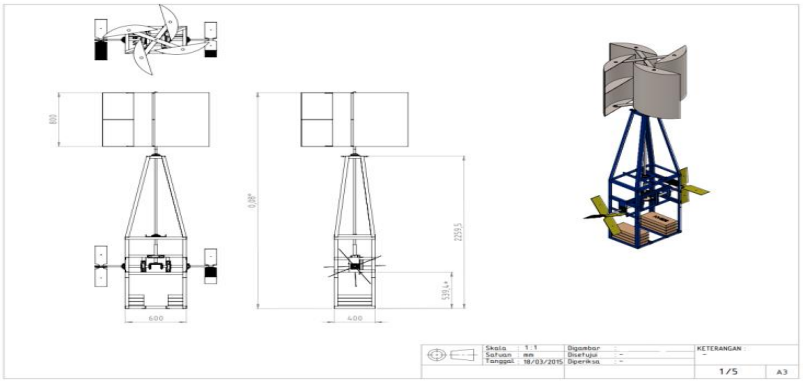

Figure 2. Tool design via Solidwork

2. Manufacture Stage

At the manufacture stage, the circuit that has been created in the PCB design is made in real form. There are two steps to making a Hybrid Aerator, there are the step of making an electronic device and the step of making a framework.

a) Step for making electronic devices

- The design is printed on glossy paper and then printed on a plain PCB.
- PCB which already contains the circuit is dissolved in FeCl.

- Circuit cleaning and drilling.
- Component installation.
- Hardware programming.

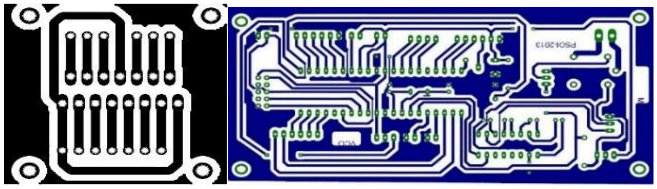

Figure 3. *Hybrid Aerator* PCB Design

b) Steps of making the framework
- Design outlines or working drawings using the Solidworks application.
- Cutting of L angle iron and aluminum plate according to the size on the working drawings.
- Assembling the frame with an electronic circuit to combine into an easy and safe oxygen bubble generator.

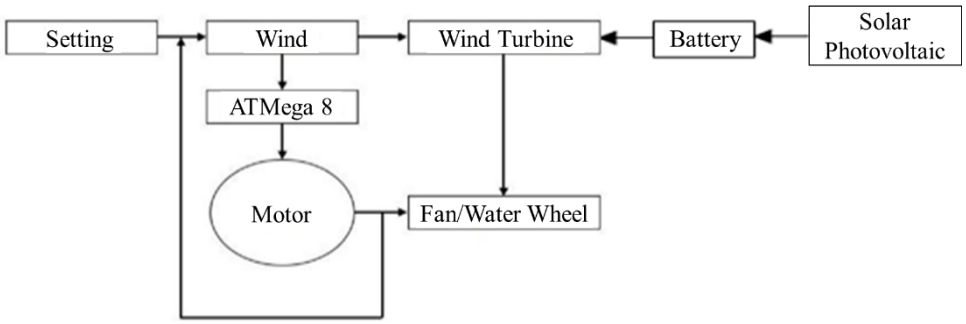

Figure 4. Workflow Diagram of a Software program

3. Testing Stage

This stage is conducted based on the hybrid function of wind power, electric power and solar power. If the wind speed ranges from 3-10m/s then the tool will be supplied from wind power. Meanwhile, if the wind is below 3m/s, the oxygen-producing equipment is supplied from solar power *(Solar Photovoltaic).* When there is no wind around the shrimp pond, the Hybrid Aerator will operate using a battery derived from solar energy produced by Solar Photovoltaic. If the environmental conditions are no wind and no sunlight, then the generator will be active using electrical energy. All these systems will be controlled automatically by Arduino.

4. Evaluation Stage

The purpose of the evaluation is to know the suitability of the plan and realization. So that if there are deficiencies, they can be corrected while the proper implementation can be maintained and developed.

At the time of evaluating the tool, the researcher found a weakness in safety sector. Researchers added a safety component, namely electric magnets for wind turbine braking. This component was added because of the experience in the field where the researcher tried the wind turbine capability by removing the shaft lock. On the coast there is a possibility of a storm that causes wind speeds above 10 m/s so it is included in the over

speed category which can damage the turbine. For this reason, the researchers created a braking component, so that the wind turbine can only rotate at a normal speed (<10 m/s) and not over speed.

Figure 5. Testing Tools

Figure 6. Additional Safety Components on *Hybrid Aerator*

RESULT AND DISCUSSION

Konsep *Hybrid Aerator*

The concept of the *Hybrid Aerator* is the use of solar energy and wind energy as an energy producer to drive the water wheels for shrimp farming operation.

Table 1. DO levels for shrimp farming

Specification	Information
Tool Dimension	3500 x 1000 x 600 mm
Electric motor	1,5 HP (1.119 Watt / 1,12 kWh)
Wind Turbine Dimension	550 x 12 x 80 mm
Number of Water wheels	4
Energy sources	Wind, Solar, and Electricity PT. PLN
Frame Type	*ST- 42 (40x40x2.mm)*
Plate Type	*Alumunium 1mm*

To utilize wind energy, the *Hybrid Aerator* uses a *Savonious* type vertical axis wind turbine which is very suitable for use in coastal areas that have abundant wind resources. If the wind speed is low or below 3m/s, the *Hybrid Aerator* energy will use energy from battery or electricity from PT. PLN. The wind turbine will not be able to activate if the wind speed is below 3m/s. However, based on research that has been conducted in the coastal area of Trisik Beach, Kulon Progo Regency, the wind speed is always above 3m/s.

Aerator *Hybrid Aerator* utilize solar energy by using *Solar Photovoltaic*. The use of *Solar Photovoltaic* here as an additional energy supply, especially if the surrounding environmental conditions are lacking wind energy. Electrical energy from PT. PLN is an alternative to back up energy in this tool. Storage of solar energy generated from *Solar Photovoltaic* will use an accumulator / battery.

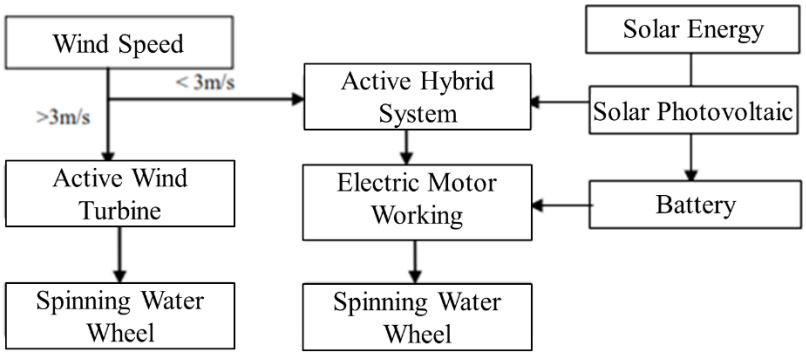

Figure 7. Schematic Diagram of the *Hybrid Aerator*

The results achieved in this research is a prototype of the *Hybrid Aerator* which is a producer of Oxygen bubbles in shrimp pond. *Hybrid Aerator* can be implemented as an effective and environmental friendly aerator. *Hybrid Aerator* is useful for increasing shrimp productivity and saving electricity usage for shrimp farming operations.

Figure 8. *Hybrid Aerator*

Comparison of *Hybrid Aerator* than Diesel Aerator and Electric Aerator

Comparison between *Hybrid Aerator*, diesel aerator, and electric aerator is conducted by trials related to aerators DO level, aerators emission and aerators operating cost.

Oxygen level testing is a study to determine the dissolved oxygen (DO) level produced, the test is conducted by measuring the DO levels produced from each aerator. The results of the DO level test conducted using the DO Meter can be seen in table 3.

Table 3. Result of DO Level measurement in Diesel, Electric, and *Hybrid Aerator* in mg/l

Date	Diesel Aerator	Electric Aerator	*Hybrid Aerator*
Day 1	6,70	6,70	6,79
Day 2	6,73	6,70	6,78
Day 3	6,70	6,73	6,79
Day 4	6,72	6,72	6,77
Day 5	6,70	6,70	6,78
Day 6	6,70	6,71	6,79
Day 7	6,73	6,70	6,79
Average	6,71	6,70	6,78

Furthermore, the diesel, electric and *Hybrid Aerator* will be tested for emission. Emission testing is to determine the level of exhaust gas in the aerator used. Test is conducted using the Exhaust Gas Analysis Machine. The emission test results can be seen in table 4.

Table 4. Emission Test on Diesel, Electric, and *Hybrid Aerator*

Gas Name	Diesel Aerator	Electric Aerator	*Hybrid Aerator*
CO	6,354 %vol	0	0
CO_2	6,81 %vol	0	0
HC	736 ppm vol	0	0

In the emission test, the Diesel Aerator has emission levels that can cause air pollution in the surrounding environment. While the Electric Motor Aerator and *Hybrid Aerator* are not tested, because the two Aerators do not use fossil-powered fuel sources in their operations so they do not cause pollution. This emission test proves that the *Hybrid Aerator* is very environmental friendly.

Figure 9. Paper of Emission Test Result from Diesel Aerator and *Hybrid Aerator*

In the current condition, the aerators that are often used by pond farmers are diesel aerators and electric aerators. Because of that, the researchers conducted a comparison related to

operational costs in the use of diesel aerator, electric aerator and *Hybrid Aerator*. Comparison of operational costs is carried out to determine the efficiency of each product.

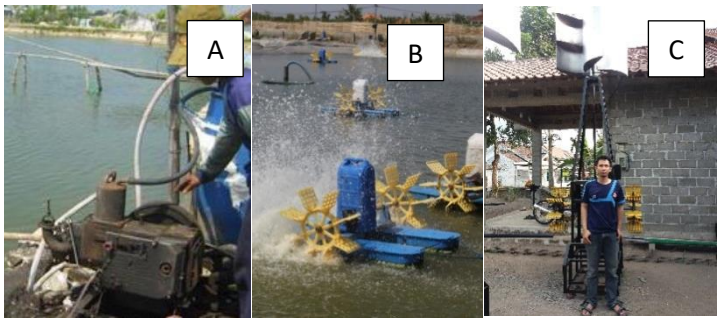

Figure 10. (a) Diesel Aerator, (B) Electric Aerator, (C) *Hybrid Aerator*

Aerators in shrimp ponds are used for 24-hour operation and cannot be turned off. Calculation of operating costs for diesel aerator, electric aerator and *Hybrid Aerator* is conducted for 7 days. Calculation of diesel aerator operating costs is conducted by calculating the consumption of diesel used every day. The calculation of the electric aerator operational cost is carried out by looking at the electricity consumption on the digital electricity meter and multiplying it with the national basic electricity tariff (Rp.1.444,70/kWh). For *Hybrid Aerator*, due to the main and secondary energy from this aerator uses wind energy and solar energy that does not cost (free), then we will only calculate the cost of electricity consumption from PT. PLN as a tertiary energy source or alternative to *Hybrid Aerator* by looking at electricity meter (the electricity meter used is different from the electricity meter on the electric aerator). Data collection is conducted every 00.01 WIB. Operational cost data can be seen in table 5.

Table 5. Operating costs of diesel aerators, electric motors and *Hybrid Aerator*

Date	**Diesel Aerator**	**Electric Aerator**	***Hybrid Aerator***
Day 1	Rp.100.000,-	Rp 52.900,-	Rp 6.100,-
Day 2	Rp.50.000,-	Rp 52.900,-	Rp 7.000,-
Day 3	Rp.80.000,-	Rp 52.900,-	Rp 7.900,-
Day 4	Rp.100.000,-	Rp 52.900,-	Rp 6.700,-
Day 5	Rp.50.000,-	Rp 52.900,-	Rp 6.100,-
Day 6	Rp.100.000,-	Rp 52.900,-	Rp 5.900,-
Day 7	Rp.50.000,-	Rp 52.900,-	Rp 5.800,-
Average	Rp.75.714,-	Rp.52.900,-	Rp.6.500,-

CONCLUSION

Based on the discussion and result that has been presented, the conclusions of this research are:

1. The *Hybrid Aerator* concept is the use of wind energy and solar energy as an energy producer to drive a water wheel for the operational of shrimp ponds. The *Hybrid Aerator* uses a Savonious vertical axis wind turbine and Solar Photovoltaic as a means of converting wind and solar energy. *Hybrid Aerator* also uses electricity from PT. PLN as tertiary energy.
2. The result of the research on the effectiveness of *Hybrid Aerator* show that the production

of oxygen levels is higher than Electric Aerator and Diesel Aerator, with DO 6,78mg/l for *Hybrid Aerator*s, DO 6,70mg/l for Electric Aerators and DO 6,71mg/l for Diesel Aerators. Based on the results of emission tests that have been conducted, *Hybrid Aerator* also environmental friendly than Diesel Aerator, due to *Hybrid Aerator* without CO, CO2 and HC, compared to Diesel Aerators which produce 6,354 % vol CO, 6,81 % vol CO2 and 736 ppm/ vol HC.

3. The operational cost of the *Hybrid Aerator* is very low, which is Rp.6.500/day is cheaper than the cost of spending an Electric Aerator which is Rp.52.900/day and the use of a Diesel Aerator with an operational cost of Rp.75.714/day.

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