The design of turbo jet surface aerator to enhance dissolved oxygen level in shrimp pond

S D Nugroho¹, C Z Pratiwi¹², and S Holil¹

¹Politeknik Kelautan dan Perikanan Sidoarjo, Department of Mechanical Fisheries, Sidoarjo 61253, East Java, Indonesia
²orresponding author: citra.pratiwi@kkp.go.id

Abstract. The dissolved oxygen (DO) is crucial water quality parameters for shrimp farming. The farmers need aerator to break water into fine drops or creating bubbles that can enhance dissolved oxygen level in the pond. Turbo jet surface aerator is the one type of aerator. This aerator works by rotating propeller which is connected by a hollow shaft to the motor. The angular adjustment that is used from the engine holder is 20°. Therefore, the propeller can rotate in half submerged position which is 4.5 cm immersion depth. This turbo jet surface aerator is designed using 0.5 HP electric motor, 7 blades, and 2 floats. The measurement result shows the turbo jet surface aerator can be used to enhance DO level up to 2.8 mg/L with the average of DO level of 6.8 mg/L. Turbo jet surface aerator can be operated properly for 168 hours nonstop with the electric motor temperature of 69°C.

1. Introduction
Shrimp farming technology has developed from traditional, semi-intensive, intensive, to super intensive system. These systems have different shrimp density. The density of shrimp must be balanced with the input oxygen. Oxygen is an important aspect of success in the aquaculture [1-4]. Besides that, oxygen is used also by aerobic bacteria in the nitrification process using ammonia. The concentration of ammonia which is harmful to shrimp is reduced by nitrification process [5, 6]. The ponds used for production, may witness a drop in DO by 5-10 mg/l at night, also the concentration of DO may further drop to less than 2 mg/l at sunrise in un-aerated ponds [7]. Stress and mortality rate are high due to low DO concentration. Therefore, aerator is needed to enhance DO level in shrimp farming.

There are several methods of aeration like diffusion of compressed air, diffused air with submerged, air aspirators of venturi and sudden expansion type, U-tube aeration, turbine dispersers, mechanical surface aerators, jet aeration, etc [8]. Surface aerators are used to break up or agitate the surface of water bubbles so that oxygen transfer takes place, for example paddle wheel and spiral aerator [9].

One type of aerator is turbo jet surface aerator. This aerator works by rotating propeller which is connected by a hollow shaft to the motor. Tuwo et al. (2020) studied about turbo jet aerator was designed to be able to produce of oxygen with a small energy consumption using sustainable solar energy [10]. This turbo jet aerator has a brushless DC motor as an oxygen generator. The turbine in the aerator jet can increase dissolved oxygen in water to 6 ppm.

Therefore, the design of turbo jet aerator is developed to enhance dissolved oxygen in shrimp pond. Turbo jet surface aerator is designed using 0.5 HP electric motor (AC motor). The propeller has diameter of 9 cm with 7 blades and directly connected to bussing sleeve. Turbo jet surface aerator uses 2 floats
with diameter of 4 inch and length of 1.2 m. The angular adjustment of 20° from engine holder and the propeller depth of 4.5 cm are used to dissolved oxygen measurement and endurance test for electric motor.

2. Materials and methods
Turbo jet surface aerator is designed using some components such as electric motor, bussing sleeve, propeller, and floats.

2.1 Materials
1) Electric Motor
Electric motor is a component that converts electrical energy to mechanical energy for driving turbo jet surface aerator. The energy consumption of electric motor is 372 Watt (0.5 HP). It has the rotational speed of 1400 rpm with the voltage of 220 V/1 phase.

2) Bussing Sleeve
Bussing sleeve is a component which is formed from cast iron rods, through the welding and painting steps. It is used to continue the rotation of electric motor to propeller. The dimension of bussing sleeve is 57 cm x 10 cm x 5 cm. It is mounted with angular adjustment to produce surface aeration.

3) Propeller
The dimension of propeller is 9 cm, it has 7 blades with the gap between blades of 2 cm. The purpose of using this propeller is to reduce the water thrust and resistance of the blades when moving in the water. The gap between blades can create water droplets that are splashed from the rotation of propeller on the water surface. The propeller is directly connected to bussing sleeve without any reduction. Therefore, the propeller rotation of 910 rpm is generated from ±35% losses of engine rotation.

4) Floats
Turbo jet surface aerator has 2 floats, located on the right and left side. These floats made of PVC pipe with the dimension of 4 inch. The minimum length of floats is calculated using Archimedes Principle based on equation (1) – (5).

\[ W_{\text{turbojet}} = m \times g \]
\[ = 9 \times 9.8 \]
\[ = 88.2 \text{ N} \]

\[ F_a = \rho_{\text{water}} \times g \times V \]
\[ = 1000 \times 9.8 \times 0.0011 \]
\[ = 10.78 \text{ N} \]

\[ W_{\text{turbojet}} = F_a + F_{\text{floats}} \]
\[ 88.2 = 10.78 + F_{\text{floats}} \]

\[ 88.2 - 10.78 = F_{\text{floats}} \]
\[ F_{\text{floats}} = 77.42 \text{ N} \]

\[ F_{\text{floats}} = \rho_{\text{PVC}} \times g \times V_{\text{floats}} \]
\[ 77.42 = 1300 \times 9.8 \times V_{\text{floats}} \]
\[ 77.42 = 12740 \text{ V}_{\text{floats}} \]

\[ V_{\text{floats}} = 0.006 \text{ m}^3 \]
\[ 0.006 = 3.4 \times 0.05 \times t \]
\[ 0.006 = 0.007t \]
\[ t = 0.85 \text{ m} \]

Where, m denotes mass, g represents the acceleration due to Earth’s gravity, \( F_a \) denotes the buoyant force, \( \rho \) represents the density, \( V \) is the submerged volume, \( r \) is the radius of floats, and \( t \) denotes the length of floats. The result of calculation shows the minimum length of floats is 0.85 m. Therefore, turbo jet surface aerator uses the length of 1.2 m on both floats.
2.2 Methods
Turbo jet surface aerator is created through several steps. It is started with looking for references and observe the object. After that, make the design as showed in figure 1 and figure 2. Furthermore, prepare the materials such as electric motor, bussing sleeve, propeller, and floats. The next steps create engine holder and continue with assembly process of the turbo jet surface aerator components. After that, the testing process is carried out to determine the performance of turbo jet surface aerator. It should be working properly and produce Dissolved Oxygen (DO) which is needed for shrimp farming. If turbo jet surface aerator has bad performance, it will be evaluated and repaired to meet the specified standards.

![Figure 1. Top view](image1.png)

![Figure 2. Side view](image2.png)

Figure 1 and figure 2 show the top view and side view design of turbo jet surface aerator, where (1) electric motor, (2) bussing sleeve, (3) propeller, and (4) floats. There are three measurement made on the turbo jet surface aerator including DO, electric motor endurance, and flow speed. The measurement is carried out in a pond area of 200 m². During the DO measurement, turbo jet surface aerator is operated for 20 minutes until 120 minutes by taking 10 samples using DO meter. DO level is measured at 09.00 am. Turbo jet surface aerator is also operated for 7 days or 168 hours nonstop to determine electric motor endurance, the temperature of electric motor is measured by using thermometer. The measurement of flow velocity taken by looking at the speed of the object being floated in font of the turbo jet surface aerator.

3. Results and discussion
The manufacture of a turbo jet surface aerator consists of several processes, including welding, painting, assembling, and installing the floats and propeller. Welding is carried out to unite iron rods to form a
bussing sleeve as shown in figure 3. The next step is painting process to protect the bussing sleeve from corrosion (figure 4). Furthermore, the assembly process which includes installation of the bussing sleeve on the electric motor using 3 bolts. The floats are mounted on the engine holder of turbo jet surface aerator by using 4 pipe clamps and the nuts as shown in figure 5. After that, the propeller is mounted on the end of the bussing sleeve using the blots with the ring on the outside and inside of the propeller (figure 6).

![Figure 3. Welding process](image1)

![Figure 4. Painting process](image2)

![Figure 5. The installation of the floats](image3)

![Figure 6. The installation of the propeller](image4)

Turbo jet surface aerator is used to enhance DO level and generate water current with the principle of airing water on the surface. Besides that, turbo jet surface aerator has several advantages such as easy operation, low manufacturing cost, and can be used in small to medium scale cultivation. The specification of turbo jet surface aerator can be shown in Table 1.

| Specification       | Value                      |
|---------------------|----------------------------|
| Engine power        | 372 Watt/0.5 HP            |
| Engine rotation speed| 1400 rpm                  |
| Propeller rotation speed| 910 rpm                |
| Electrical voltage  | 220 V/1 phase              |
| Floats              | 2 pieces                   |
| Propeller           | 7 blades                   |

The test is carried out with an angular adjustment of 20° from the engine holder, so that the propeller can rotate on the water surface in a semi submerged state. The immersion depth of the propeller is 4.5 cm (maximum 7 cm). Turbo jet surface aerator can be shown on Figure 7.
Figure 7. Turbo jet surface aerator

The measurements consist of 3 parameters such as DO level, electric motor endurance, and flow velocity. DO measurements were carried out on the water surface from 4 points at the corner of the pond. The measurement shows turbo jet surface aerator can be applied to enhance DO level until 2.8 mg/L where DO level of 6-7 mg/L is produced after the use of turbo jet surface aerator (Table 2). The result already meets DO level standards (4-9 mg/L) for shrimp farming [11].

| Days | DO\(_1\) (mg/L) | DO\(_2\) (mg/L) | DO\(_2\) - DO\(_1\) (mg/L) |
|------|----------------|----------------|--------------------------|
| 1    | 4.3            | 7.6            | 3.3                      |
| 2    | 3.2            | 6.4            | 3.2                      |
| 3    | 3.6            | 6.5            | 2.9                      |
| 4    | 4.6            | 7.0            | 2.4                      |
| 5    | 4.4            | 6.6            | 2.2                      |
| 6    | 3.8            | 6.7            | 2.9                      |
| 7    | 4.2            | 6.6            | 2.4                      |
| 8    | 3.8            | 6.6            | 2.8                      |
| 9    | 3.8            | 6.8            | 3.0                      |
| 10   | 3.6            | 6.8            | 3.2                      |

Average 2.8

Flow velocity is determined by measuring the distance and time of an object that is floated in front of turbo jet surface aerator. The measured distance is 2-5 m with the time of 6-15 s. The time and distance are measured by using a tape measure and a stopwatch. The result of the flow velocity measurement is calculated using velocity formula, where velocity = distance/time as shown in Table 3.

| Days | Distance (m) | Time (s) | Flow velocity (m/s) |
|------|--------------|----------|---------------------|
| 1    | 2            | 6        | 0.33                |
| 2    | 2            | 6.5      | 0.30                |
| 3    | 2            | 6        | 0.33                |
| 4    | 3            | 10       | 0.30                |
| 5    | 3            | 10.1     | 0.29                |
| 6    | 3            | 10.5     | 0.28                |
| 7    | 4            | 12       | 0.33                |
| 8    | 4            | 12       | 0.33                |
| 9    | 5            | 15       | 0.33                |
| 10   | 5            | 14       | 0.35                |

Average 0.32

The average flow velocity of 0.32 m/s can provide a circular flow of water to push dirt (ammonia) into the central drain without mixing. The existing turbo jet aerators are generally used for Wastewater Treatment Plant (WWTP) which functions to stir up the compounds in wastewater so that they cannot be applied to aquaculture.
The next measurement is the electric motor endurance. Electric motor has a function as the drive engine of turbo jet surface aerator which will be needed in one cycle of aquaculture production. This measurement was taken during 168 hours of the operation by observing the endurance and temperature of the electric motor. The measurement of electric motor temperature uses a digital thermometer where the sensor is attached to the electric motor cover. The graphic of the measurement result is shown in figure 9.

The measurement result of electric motor endurance shows that turbo jet surface aerator can operate normally and properly for 168 hours or 7 days without stopping with a motor temperature of 69°C during the operation. The electric motor of turbo jet surface aerator is also equipped with a thermal protector so that it can keep the electric motor temperature below the maximum limit and reduce the risk of damage. Based on the endurance measurement, turbo jet surface aerator can be applied for shrimp farming in the pond.

4. Conclusion
The turbo jet surface aerator to enhance DO level in shrimp pond has been designed. It consists of electric motor, bussing sleeve, propeller, and floats. The measurement result show that turbo jet surface aerator can enhance DO level 2.8 mg/L with the average of DO level of 6.8 mg/L. Beside that, the flow velocity of 0.32 m/s was generated to push dirt (ammonia) into the central drain. The electric motor as drive engine can operate normally and properly for 168 hours or 7 days with the temperature of 69°C. Based on the measurement results, turbo jet surface aerator can be applied for aquaculture in shrimp pond.
5. References
[1] Tuwo A, Yasir I, Khan M, Aprianto R, Yanti A, Bestari A and Nakajima M 2019 Microcosm Multitrophic Aquaculture System IOP Conf. Series: Earth and Environmental Science: IOP Publishing p 012012
[2] Tuwo A and Tresnati J 2015 Echinoderm Aquaculture, ed N P Brown and S D Eddy pp 331-52
[3] Suwoyo H, Tuwo A, Haryati H and Syah R 2020 The utilizations of solid waste originatin from super intensive shrimp farm as organic fertilizers for natural feed productions IOP Conf. Series, (Makassar:IOP Publishing) p 012110
[4] Suwoyo H S, Tuwo A, Haryati and Anshary H 2020 Int. J. on Advanced Science, Engineering and Information Technology 10: 766-74
[5] Tampangallo B R, Suwoyo H S and Septiningsih E 2014 Prosiding Forum Inovasi Teknologi Akuakultur pp 353-60
[6] Makmur M, Fahrur M and Undu M C 2016 Prosiding Forum Inovasi Teknologi Akuakultur pp 277-84
[7] Yadav A, Kumar A and Sarkar S 2019 Int. J. of Innovative Technology and Exploring Engineering (IJITEE) 8: 63-70
[8] Kumar M, Ranjan S, Tiwari N K and Gupta R J. of Hydraulic Engineering 24: 61-67
[9] Tanveer M, Roy S M, Vikneswaran M, Renganathan P and Balasubramanian S Int. J. of Fisheries and Aquatic Studies 6: 342-347
[10] Tuwo A, Yasir I, Tresnati J and Aprianto R IOP Conf. Series: Earth and Environmental Science p 012035
[11] Supono 2017 Teknologi Produksi Udang (Yogyakarta: Plantaxia)

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