The Volume of the Product of Backward Water Splash Based on Submerged Blade Depth of Paddlewheel Aerator

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Abstract. The paddlewheel is a common used aeration equipment. In term of aeration mechanism and driving force, it is very good to be used. However, the paddlewheel has a slow aeration rate resulting in low aeration efficiency. One of the causes is the splash of the backward water of the paddlewheel that is already aerated, but it is splashed again so it wastes the power. The aim of this study was to determine the volume of the backward water splash production. The paddlewheel used a 1 phase motor, 1 hp power, 1400 rpm motor speed, and 2 pieces of wheels. The treatment was carried out by varying the blade of 65, 85, and 105mm submerged. The test was done by collecting the backward water splash and calculating its volume. The results showed that the volume per hour of backward water splash at the blade submerged in the 65, 85, and 105mm were 10.68, 13.74, and 15.27 m$^3$, respectively. The average of forward splash volume of water was 58.04%, while the backward was 41.96%. The results of this study indicated that the volume of backward water splash is very significant to be utilized.

1. Introduction

Aeration is a mechanism of adding some amount of oxygen into water to provide sufficient amount of oxygen. Aeration is carried out by increasing water and air contact using aerator device. One type of aerator device which widely used in pond farming is paddle wheel aerator [1]. Paddlewheel aerator is considered as the most appropriate aerator device due to aeration mechanism and wide usable driven power [2]. Aerator based on Taiwan design is widely used by consumers due to affordable price, light in weight and corrosion-resistant but has low efficiency as shown Figure 1 [1][3].

![Figure 1. Paddle wheel aerator widely used in pond of aquaculture](image-url)
Standardized aeration efficiency is directly proportional to the standard oxygen transfer rate and inversely proportional to the power consumption. Aerator that was designed and fabricated by Taiwan has SAE (standard aeration efficiency) value of 1.063 kg O$_2$ kW h$^{-1}$ [4]. Bhuyar et al. designed aerator with SAE value 2.269 kg O$_2$ kWh$^{-1}$ [5]. The most appropriate paddle wheel aerator was designed by Moore and Boyd with SAE value 2.54 kg O$_2$ kWh$^{-1}$. Some of fabrications use aerator design with specification 2.25-7.5 kW and SOTR 17.4-23.2 kg O$_2$ h$^{-1}$ and average value of SAE was 2.2 kg O$_2$ kW h$^{-1}$ [6].

Aeration rate is influenced by water and air surface contact, differential oxygen concentration, film surface coefficient and turbulence [7]. In the paddlewheel aerator, the contact of surface between water and air occurred by the splash of water that produced by the wheel rotation. The splash is aerated water that is spread forward, also behind the wheel. Bahri et al. calculated these splashes in the coverage volume of the splash itself, it was not distinguished them into forward and backward splash but only of total splash of water [8]. However, only forward splash was useful, while backward splash was less effective but cannot be avoided. It was caused by the power consumption of paddle aerator is used to reaeration of aerated water.

It was clear that this study aimed to calculate the volume of water splash that occurred behind the paddlewheel. The splash volume was measured by contain the backward and forward of water splash paddlewheel aerator.

2. Materials and Method

2.1. Materials

2.1.1. Blades
The blades are based on Taiwan design is widely used by consumers. The geometry of blade is the wheel diameter was 650 mm and the hole diameter was 20 mm. The blade consist of eight pieces with the width was 200 mm and the length 180 mm.

2.1.2. Paddlewheel test unit
Paddlewheel test is aerator based on Taiwan design. Motor used is 1 phase AC electric motor with a power of 1 HP at 1400 rpm rotational speed.

2.2. Procedure

2.2.1. Treatments variations
The tests were conducted on the freshwater pool with dimensions of length 10 m, 7 m width with a water depth of 1 m. Submerged variations blade is done by changing the height position paddlewheel support. The tests were the blade submerged 65, 85, and 105 mm, respectively.

2.2.2. Splash coverage volume measurement
Splash coverage volume was done by taking the recorded images used a digital camera from the front side and side the wheel at the time of testing. Then, the digital image was processed by using a CAD programs to create segments (grid), which the splash coverage volume was the number of multiply results of segments area at the front side water splash with the side of water splash.

2.2.3. Volume measurement
The splash volume was measured by containing the backward and forward splash water for 15 seconds. Based on the result of the test, it was measured the splash volume that produced per hour.
2.2.4. Power measurement

Paddlewheel power measurement was done by measuring the electrical power consumption of electric motors using Ammeter (DO2A) which was connected to an electrical outlet. Reading the power measurement value (Watt) was done by using a digital video camera recording on display Ammeter. Rated power was taken on the average value that often was showed from the reading video playback recording for each treatment testing.

3. Results and Discussion

The water splash produced visible from the front and side the wheel of the submerged blade 85mm as shown in Figure 2 and the splash coverage volume produced at different blade submerged shown in Table 1.

![Figure 2. Image of water splash and calculation segment of splash coverage volume.](image)

Table 1. Splash coverage volume at different blade submerged

| Blade submerged (mm) | Splash coverage volume of water (m³) | Backward | Forward | Total |
|---------------------|-------------------------------------|----------|---------|-------|
| 65                  | 0.94                                | 1.05     | 1.99    |
| 85                  | 1.32                                | 1.21     | 2.53    |
| 105                 | 1.51                                | 1.42     | 2.93    |

The results of the test shown of the dip of blade submerged increased the splash coverage volume of water, both of forward and backward water splash. The normal position of the float on the blade submerged by 85 mm was obtained that the backward splash coverage volume of water was 52.17% compared to the forward was 47.83%. The lift of blade submerged by 65 mm, it was obtained that the backward splash coverage volume of water was 47.24% compared to the forward was 52.76%. When the blade submerged dipped by 105 mm it was obtained that the backward splash coverage volume of water was 51.54% compared to the forward was 48.46%. The average of forward splash coverage volume of water was 50.32%, while the backward was 49.68%. The splash volume produced at different blade submerged for 15 second shown in Table 2.

Table 2. Splash volume produced at different blade submerged for 15 second

| Blade submerged (mm) | Splash volume of water (m³) | Power consumption (Watt) |
|---------------------|-----------------------------|--------------------------|
|                     | Backward                     | Forward                   |                     |
| 65                  | 0.0223                       | 0.0321                    | 575                 |
| 85                  | 0.0286                       | 0.0375                    | 850                 |
| 105                 | 0.0318                       | 0.0446                    | 950                 |
The results of the test shown of the dip of blade submerged increased the splash volume of water, both of forward and backward water splash. That increasing also gave influence to increase the power consumption. The normal position of the float on the blade submerged by 85 mm was obtained that the backward splash volume of water was 43.27% compared to the forward was 56.73%. The lift of blade submerged by 65 mm, it was obtained that the backward splash volume of water was 40.99% compared to the forward was 59.01%. When the blade submerged dipped by 105 mm it was obtained that the backward splash volume of water was 41.63% compared to the forward was 58.37%. The average of forward splash volume of water was 58.04%, while the backward was 41.96%. The calculation of two pieces the wheel, the volume per hour of forward water splash at the blade submerged in the 65, 85, and 105 cm were 15.42, 17.99 and 21.42 m³, respectively, while the backward were 10.68, 13.74 and 15.27 m³.

Although the backward splash volume of water was less, based on the splash coverage volume it can be concluded that the splash was rich oxygen. Based on the normal blade submerged (85 mm), if the usage of paddlewheel in a whole day for 12 hours [7], it will produce the backward splash volume of water is 164.90 m³. This means that the paddlewheel re-aerated the aerated water.

4. Conclusion
The following conclusion drawn from study were the forward and backward splash coverage volume of water of paddlewheel aerator at the normal blade submerged 85 mm was 2.64 and 2.42 m³. The average of forward splash coverage volume of water was 50.32%, while the backward was 49.68%. The volume per hour of backward water splash at the blade submerged in the 65, 85, and 105 mm were 10.68, 13.74, and 15.27 m³, respectively. The average of forward splash volume of water was 58.04%, while the backward was 41.96%. The dip of blade submerged increased the splash volume of water, both of forward and backward water splash. That increasing also gave influence to increase the power consumption.

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