



The Design and Fabrication of Waterwheels with System Floating Pontoon

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To cite this article:

Arifin, F. ., Sutanto, H. ., Iskandar, I. ., & Sukwadi, R. . The Design and Fabrication of Waterwheels with System Floating Pontoon. International Journal of Research in Vocational Studies (IJRVOCAS), 2(3), 01–06. <https://doi.org/10.53893/ijrvocas.v2i3.143>

Received: November 29, 2022; **Accepted:** December 12, 2022; **Published:** December 15, 2022

Abstract: The use of fossil energy is currently starting to be slightly reduced by the government, and at this time the government is also starting to look at renewable energy as alternative energy, just as energy, solar, wind, biomass, and water. One of the utilization of water energy for the use of electrical energy is with a waterwheel. In this study, a pontoon-type water wheel was designed, where the ratio of rotation of the wheel to the rotation of the generator rotor was 1: 4. The dimensions of the water wheel designed and made were with a pontoon width of 1080 mm x 2000 mm x 15 mm, and the diameter of the water wheel is 1200 mm, which can be generated by a generator of 1 kW.

Keywords: fossil energy, renewable energy, water wheel, generator

1. Introduction

The use of fossil energy is currently starting to be slightly reduced by the government, and at this time the government is also starting to look at renewable energy as an alternative energy, such as energy, solar, wind, biomass, and water [1] [2] [3]. Electrical energy is one of the main needs of society at this time. This makes a rapid increase in the demand for electricity in Indonesia. The increasing demand for electricity in Indonesia means that there must be a large production of electrical energy in Indonesia, electricity is produced by many types of power plants with various power sources, starting from conventional power in the form of coal and natural gas, to renewable energy in the form of wind, water, solar and mass bio.

Moreover, all this energy can be developed. One of the most developed sources of energy to produce electrical energy is water energy [3]. The waterwheel is driven by the

power of flowing water which can cause the blades of the wheel to be pushed so that the wheel rotates on its axis, which is then attached to the spindle shaft. Where the rotation from the pulley will be forwarded to the generator using a belt. This rotation will rotate the coil of the generator which will push the magnetic field lines. This movement creates an electromotive force (EMF) [4] [5]. Thousands of years ago, humans used hydropower for several purposes, for example to raise water for irrigation purposes, grind rice and so on. In the area, for example, from bamboo or wood with a large diameter you can still see it in the Hoang Ho River (China), the Nile (Egypt) and the Euphrates River (Iraq) [6]. The efficiency of the water wheel which is run by the flow of water without using all the potential of the water contained in the river, is certain to be very small. Improvements to this method were carried

out in the 15th century [7]. To run the wheels, separate channels are made with three kinds of water wheels, so that they hit the wheels at the top, middle or bottom. Hydroelectric Power Plant (PLTA) is a power plant that utilizes the flow of water that descends from a height to drive the generator, which in this case utilizes the potential energy created by the flow of water and then converts it into mechanical energy and then this mechanical energy is used to drive the blades. or turbine blades or waterwheels to produce electricity [8]. A conventional hydroelectric power plant is a model that regulates the flow of water from rivers or dams to the water wheel, after which the water flow is directed back to the disposal [9]. Meanwhile, the working principle of hydroelectric power with this water wheel is to try or convert the energy contained in the water flowing in rivers or seas into mechanical energy, which then this mechanical energy can be converted into a form of electrical energy [10]. The main tools that are always needed in making a waterwheel are turbines and generators. These two waterwheels and generators should not be forgotten in making a waterwheel. Flowing water is used to drive the water wheel blades so that the wheel rotates very hard or fast. The waterwheel shaft is directly connected to the generator, so that when the wheel rotates, the generator will automatically rotate too. As long as the wheel rotates, this generator will generate electricity. In this study, a water turbine will be designed that can be utilized in underdeveloped areas where there is no electricity by utilizing the river flow in that area [11]. For this reason, the calculations needed in the design of the waterwheel are carried out, such as the shape of the blade and the type of waterwheel that is right for the river flow.

2. Research Methods

As is known, there are several types of waterwheels that can be used for making waterwheels [12], namely:

1) Overshot Waterwheel

The overshot waterwheel works when flowing water falls into the upper side of the blades, and due to the gravity of the water the wheel rotates. The overshot waterwheel is the most widely used waterwheel compared to other types of waterwheels.

Advantages:

- High efficiency rate can reach 85%.
- Does not require heavy flow.
- Simple construction.
- Easy to maintain.
- Simple technology that is easy to apply in isolated areas.

Disadvantages:

- Not applicable for high speed engines.
- Requires more space for placement.
- Power generated is relatively small.

2) Undershot Waterwheel

The undershot waterwheel works when flowing water hits, the blade wall which is located at the bottom of the waterwheel. The undershot type waterwheel does not have the additional advantage of a head. This type is suitable for installation in shallow water on level ground. This type is also called "Vitruvian". Here the water flow is opposite to the direction of the blade that rotates the wheel.

Advantages:

- Simpler construction.
- More economical.
- Easy to move.

Disadvantages:

- Little efficiency.
- Power generated is relatively small.

3) Breast shot Waterwheel

The Breast shot waterwheel is a mix of overshot and undershot types, judging from the energy it receives. The drop height distance does not exceed the diameter of the wheel, the direction of the water flow that moves the waterwheel around the axis of the waterwheel. This type of waterwheel improves the performance of the undershot type waterwheel [13].

Advantages:

- This type is more efficient than the Undershot type.
- Compared to the Overshot type, the drop height is shorter.
- Can be applied to flat water flow sources.

Disadvantages:

- The blades of this type are not as flat as the Undershot type.
- Dams are required in flat flow streams.
- Less efficiency than the overshot type.

Then designed and made a water wheel that can generate electricity cheaply with the help of a pontoon type water wheel.

There are several parameters in the calculations used for the design of the waterwheel, namely:

1. Water Energy Potential (E_k)

Water energy potential besides utilizing falling water, water energy can also be obtained from flat water flow. In this case the available energy is kinetic energy [11]

$$E_k = 0.5 m v^2 \quad (1)$$

Where:

E_k = Kinetic energy (Joule)

M = turbine mass

V = speed of water flow (m/s)

2. Pipe Cross-sectional Area A (m^2)

$$A = 0.25 \cdot \pi \cdot D_{\text{pipa}}^2 \quad (2)$$

3. Water Speed (m/s)

$$V = s/t \quad (3)$$

4. Formulation of Water Discharge (Q)

$$Q = A \times V \quad (4)$$

Where:

A = Cross-sectional area through which water pass (m²)

V = Water Velocity Measurement (m/s)

Q = Water discharge (m³/s)

5. Formulation of Water Power (P_{water})

The flow capacity resulting from the calculation parameter gets a discharge (Q) [14], so the energy generated by the flow of water in the pipe is:

$$P = 1/2 PQV^2 \quad \text{or} \quad P = 1/2 PAV^3 \quad (5)$$

Where:

P = Water Power (Watts)

A = Pipe Tube Area (m²)

Q = Water Discharge (m³/s)

V = Water Speed (m/s)

6. Distance Between Blades (D_r)

The calculation to get the distance between the blades needed to turn the wheel based on the wheel construction and its design and the average value is [15]:

$$D_r = (D_1 + D_2)/2 \quad (6)$$

Where :

D_r = Average diameter (m)

D₁ = Outer Diameter of the Wheel (m)

D₂ = Diameter of the Wheel (m)

$$t_1 = (D_1 \times \pi)/Z \quad \text{and} \quad t_2 = D_2 \times \pi/Z \quad (7)$$

Where :

t₁ = distance between the inner blades (m)

t₂ = distance between the outer blades (m)

7. Design of the wheel for measuring the weight of the wheel (Kg)

$$A_1 = \pi r^2 \quad \text{and} \quad A_2 = \pi r^2 \quad (8)$$

$$A_{\text{total}} = A_1 - A_2 \quad (9)$$

$$\text{Volume} = \text{Total} \times \text{Wheel Width} \quad (10)$$

$$B_{\text{pincir}} = \text{Volume} \times \text{Specific Gravity of Steel} \quad (11)$$

Where :

A₁ = Area of Outer Tube (cm)

A₂ = Inner tube area (cm)

A_{total} = Average Tube Area (cm²)

Volume = Total x width (cm³)

B_{wheel} = Volume x Specific gravity of steel (kg)

Specific gravity of steel = 0.0074 x 10%

8. Circular Speed of the Wheel (U₁)

The magnitude of the rotational speed of the wheel can be calculated through the equation [15].

$$U_1 = (V_1 \times \cos \alpha_1)/2 \quad (12)$$

Where :

U₁ = Circular Speed of the Wheel (m/s)

V₁ = Water speed (m/s) α₁ = Angle of Blade 20°

9. Wheel rotation: (n)

$$n = (60 \times U_1)/\pi D_1 \quad (13)$$

Where :

n = Wheel Rotation (Rpm)

U₁ = Circular speed of the wheel (m/s)

D₁ = Outer diameter of the wheel (m)

10. Number of Active Blades (i)

$$n \text{ (in rps)} = n \text{ (in rpm)}/60 \quad (14)$$

$$i = n \text{ (in rps)} \times Z \quad (15)$$

Where:

i = number of active blades

Z = Number of blades of the wheel

11. Water capacity received by each blade (q)

$$q = Q/i \quad (16)$$

Where :

q = water capacity (m³/s)

i = number of active blades

12. Thickness of Water Jet Entering the Blade Aisle (S₀)

$$S_0 = t_1 \sin \alpha_1 \quad (17)$$

Where :

S₀ = Water jet (m)

t₁ = Distance between inner blades. (m)

13. Tangential Force (F)

$$F = m \cdot V \quad (18)$$

Where :

F = Force (N)

m = mass of water (kg)

14. Water wheel radius (r_x)

The calculation to find out the radius available on the waterwheel is as follows:

$$r_x = (r_2 - r_1)/2 + r_1 \quad (19)$$

Where :

r_x = Average radius (m)

r₁ = inside radius (m)

r_2 = outer radius (m)

15. Energy on the water wheel (P_{wheel})

The calculation to find out the energy available at the waterwheel is as follows:

$$P_{\text{wheel}} = T \times \omega \quad (20)$$

Where :

T = Torque (Nm)

$\omega = (2 \times \pi \times n) / 60$

To find out the available waterwheel energy, first calculate the Torque formulation parameters, including:

$$T = F \times r \quad (21)$$

Where :

T = Torque (Nm)

F = Tangential force (N)

R = radius of the wheel (m)

16. Generator Energy ($E_{\text{generator}}$)

$$E_{\text{generator}} = 1/2 P_{\text{wheel}} \quad (22)$$

Where :

P_{wheel} = Powerwheel energy (Watts)

17. Generator Rotate ($Rpm_{\text{generator}}$)

Calculations to find out the rotation (rpm) of the generator in accordance with the specifications of the generator used by calculating the transmission ratio of the pulley used.

$$Rpm_{\text{Generator}} = n_1/n_3 = D_1/D_2 \times D_3/D_4 \quad (23)$$

$$n_{\text{generator}} = n_3 = n_1 (D_1/D_2) = n_2 (D_3/D_4) \quad (24)$$

Where :

n_1 = Wheel Speed (rpm)

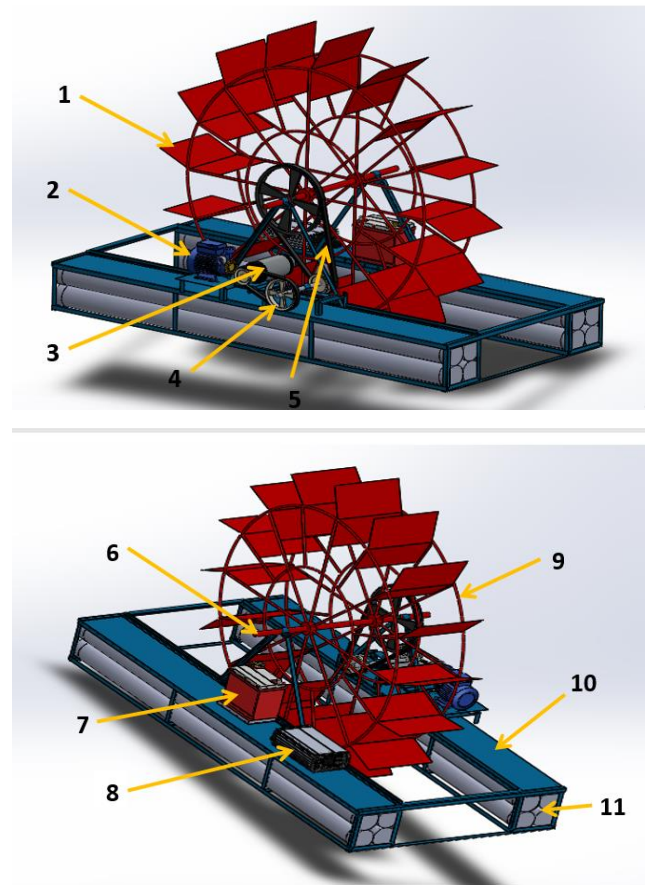
n_3 = Generator Speed (rpm)

D_1, D_2, D_3, D_4 = Diameter of the pulley (Inch)

3. Results and Discussion

3.1. Waterwheel Design

By using the formulas above, you will get the size of the desired waterwheel design with the shape as shown in Figure 1.



Note:

- 1) Blade Water Wheel
- 2) Water Pump
- 3) Electric Dynamo
- 4) Pulleys
- 5) Belts
- 6) Shaft (Shaft)
- 7) Battery
- 8) Inverters
- 9) Pinwheel Frame
- 10) Pontoon
- 11) PPC Pipe

Figure 1. The Water Wheel Type Pontoon Design

The diameter of the waterwheel was 1200 mm and the diameter of the shaft was 25.4 mm, the width of the pontoon was 1080 mm and the length was 2000 mm. Meanwhile, the power resulted was 1 kW by using a comparison of pulley ratio was 1 : 4.

3.2. Fabrication Water Wheel

This water wheel is made using welding techniques and also a machine process. For this reason, the materials needed are in accordance with the calculations obtained and the design drawings of the existing turbines. The waterwheel manufacturing process of the waterwheel can be seen in Figure 2.



a. Pontoon Fabrication of Water Wheel



b. Assembling Water Wheel

Figure 2. Water Wheel Fabrication Process

3.3. Water Wheel Performance Test

The performance test was carried out to find out the results of the waterwheel design for this power plant as well as to find out the electricity capacity produced [16]. The measurement of the flow rate of the river was installed on the waterwheel. Since, it obtained from the rotation of the waterwheel which was converted to generator rotation. The results of the test were obtained as shown in table 1.

Table 1. Test data of the windmill rotation and generator rotation.

No	rpm Water Wheel	rpm Generator
1	8,50 Rpm	85,0 Rpm
2	8,16 Rpm	81,6 Rpm
3	7,87 Rpm	78,7 Rpm
4	7,55 Rpm	75,5 Rpm

4. Conclusion

The conclusion of this design and fabrication were the pontoon type water wheel could be further developed, in which the energy generated is Pico-hydro. Since, the hope of being able to reach remote areas that do not yet have electricity from PLN and have the potential for adequate river flow for hydroelectric power plants. In accordance with government programs which use as much as possible energy that is environmentally friendly and also this can reduce pollution from the use of fossil energy, which is increasingly decreasing in number.

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