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(RESEARCH ARTICLE)

Design waterwheel of hydropower on outfall condenser sebalang power plant

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Abstract

The utilization of residual energy in the electricity sector within conventional power plant environments such as Coal-Fired Power Plant remains suboptimal. Sebalang powerplant located in Sebalang hamlet, Tarahan village, Katibung district, South Lampung, with a power capacity of 2 x 100 MW employs coal as fuel and seawater as a media to generate steam and as a coolant in the powerplant cycle. The condenser cooling system at Sebalang powerplant operates on an open cycle, where seawater taken from the intake enters the condenser to cool and condense steam, then exits through the outfall and returns to the sea. The discharge flow of residual condenser cooling water through the outfall is 1.18 m3/s and currently remains unutilized. With a head of 1.5 meters, this potential can be converted into electrical energy, generating a power potential of 10.4 kW. The power output from this Micro Hydro Power Plant Waterwheel design can be utilized to supply the internal electricity needs of the power plant unit, thereby reducing operational unit self-consumption

Keywords: Renewable Energy; Micro Hydro Power Plant; Condenser; Outfall; Waterwheel

1. Introduction

Most areas in Indonesia use electricity sources from coal-fired power plants [1]. Seawater power plants are used as a medium to produce steam and cool the condenser in the cooling system [2]. There are two types of condenser cooling systems in power plants, namely closed cycle and open cycle. Closed cycle power plants use a cooling tower system to lower the temperature of the water from the intake after entering the condenser [3]. While open cycle power plants drain water out through the outfall and return to the sea. Sebalang power plant uses an open cycle so that the potential energy of the flow has the potential to become hydro power by converting kinetic energy with micro hydro turbine equipment. The outfall flow at Sebalang power plant is as shown in the image below.

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Figure 1 Outfall Condenser of Sebalang Power Plant

2. Material and Methods

This study uses a quantitative approach, especially on the outfall flow of the Sebalang power plant condenser. With research observations located in Sebalang hamlet, Tarahan village, Katibung sub-district, South Lampung. The Sebalang power plant has a capacity of 2 x 100 MW with an open cycle flow, making the condenser cooling flow in the power plant not yet utilized its exhaust flow. Microhydro plant planning on the outfall flow begins with measuring flow data, calculating power potential, planning the type and design of the appropriate generator, as well as prototypes and simulations [4].

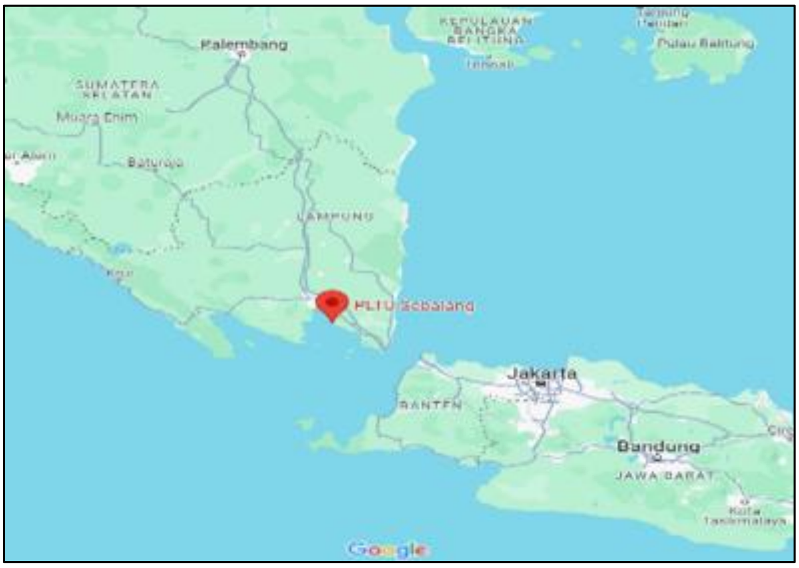

Figure 2 Maps Location of Sebalang Power Plant

The first step in data collection is collecting speed data using the floating method by measuring the speed (V) of the flow in an open channel using an object from one point to another within a distance (L) determined in several data collections. The results of the time data (t) are calculated by measuring the width (w) and depth (h) of the cross-sectional area so that the flow rate value (Q) can be known [5] [6] [7][13].

Flow Speed (V)

$$V=L/t \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Cross-sectional Area (A)

$$A = w \times h \quad \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Flow Rate (Q)

$$Q = A \times V \quad \ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Next, calculate the potential power of the turbine using the equation (P)

$$P = \eta\ \rho w\ Q\ g\ H \quad \ldots\ldots\ldots\ldots(4)$$

The selection of the type of turbine for low head is based on the waterwheel turbine, with comparing undershoot and breastshoot design and potential. Waterwheels is a traditional yet currently practical method of electricity generation, utilizes the stream flow of water directly onto the turbine with the water flowing along the stream without having to block its flow [8] [9]. Because in its selection, the future installation process must be taken into consideration, which of course does not interfere with power plant operations, and a portable design is needed so that future maintenance can be mobileThe equipment needed in taking flow data is a meter, stopwatch, floating object and solidwork flow simulation software. While in making a prototype turbine/simulation, namely: using aluminum paddle blades, portable pump, pump frame with iron plate, PVC pipe for flow, and mini generator.

3. Results and discussion

3.1. Flow Data Measurement

The outfall flow has 2 sources from unit 1 and unit 2 of Sebalang PLTU. Where one unit has 2 cooling pumps. When taking the flow, the condition of both units is operating with 1 cooling pump each. The results of taking flow rate data in the table below

Table 1 Measurement Flow

V	Length (m)	Time (s)	Velocity (m/s)
1	2	2,22	0.900
	2	2,21	0.904
	2	2,32	0.862
	2	2,22	0.900
	2	2,87	0.696
	V1 Average		0,8524
2	3	4,11	0.729
	3	3,33	0.900
	3	3,06	0.980
	3	3,01	0.996
	3	3,20	0.937
	V2 Average		0,8524

Keynote: m = meters

Velocity (V_total)

$$= \frac{V1+V2}{2} = \frac{0{,}8524}{0{,}9084}$$

$$= 0{,}8804\ m/s \quad \ldots\ldots\ldots\ldots (5)$$

Sectional Area(A)

$$= width(w) x height(h) \quad .... (6)$$

$$= 2{,}70 \; m \; x \; 0{,}50 \; m$$

$$= 1{,}35 \; m^2$$

Flow Rate (Q)

$$= V_{total} \; x \; A .... (7)$$

$$= 0{,}8804 \; m/s \; x \; 1{,}35 \; m2$$

$$= 1{,}18854 \; m3/s$$

3.2. Calculation of Potentional Power (P)

$$P \quad = \eta \; \rho w \; Q \; g \; H \; .... (8)$$

η = 0,65 (total system efficiency)
ρw = 1000 kg/m3 (water density)
Q = 1,18854 m3/s (flow rate)
g = 9,8 m/s2 (gravitational acceleration)
H1 = 1,5 m (head for breastshoot waterwheel)
H2 =P / ρ .g .Q (head for undershoot waterwheel)

3.3. Result of Solidwork Simulated Flow

The results of data collection are simulated using the Solidworks application to determine the output of velocity, and total pressure, with the results below on fig 3 and 4:

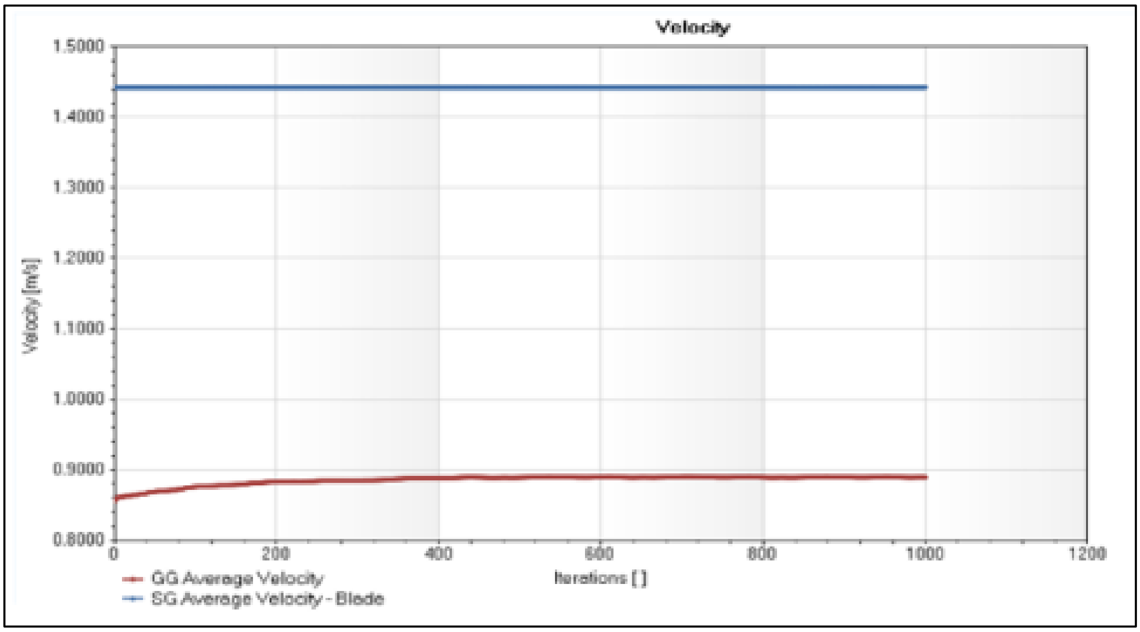

Figure 3 Velocity Value

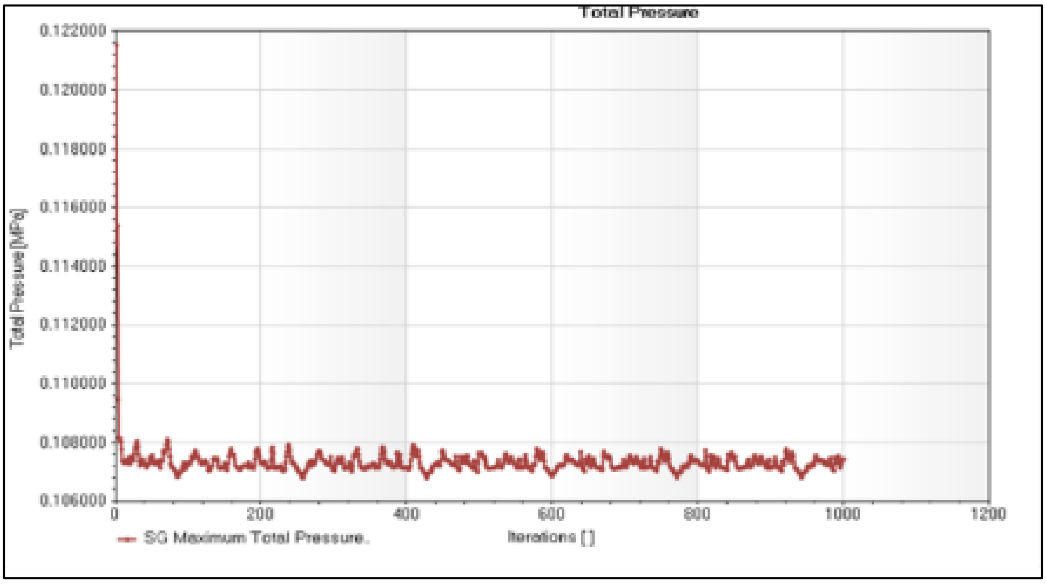

Figure 4 Total Pressure Value

3.4. Design of Breastshoot Type Waterwheel Turbine

In making the design breastshot water wheels are gravity hydraulic machines employed in low head sites [10], the design is determined with the condition that it does not interfere with the operation of the unit, and civil works in the manufacture, so this type of portable waterwheel is expected to facilitate the process of manufacture, installation, and also the maintenance process of the micro hydro power generation system on the outfall flow of the Sebalang power plant .

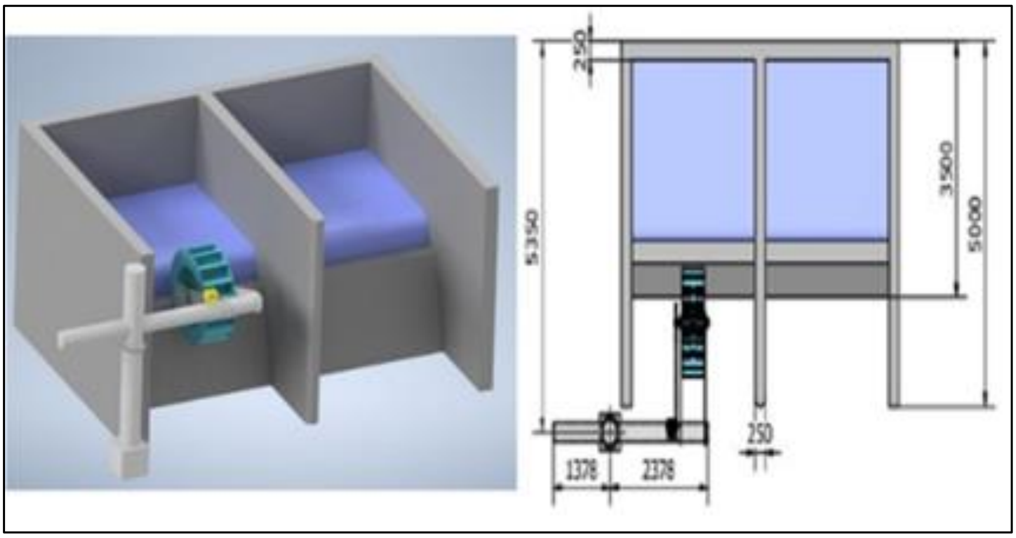

Figure 5 Design Breastshoot Waterwheel

The advantage of breastshoot waterwheel to be applied is that it can provide a greater power value because it has a head value or water fall. However, it also has disadvantages if one unit is not operating then the system breastshoot waterwheel cannot operate.

Figure 6 Prototype Breastshoot Waterwheel

3.5. Design of Undershoot Type Waterwheel Turbine

By considering when using a breastshoot turbine that can only operate on the installed unit. It is designed so that the waterwheel turbine can so that even though one unit is operating, the micro hydropower system can still operate using horizontal flow without falling water. Undershot water wheels are hydropower converters for head differences between 0.5 and 1.5 m [11]

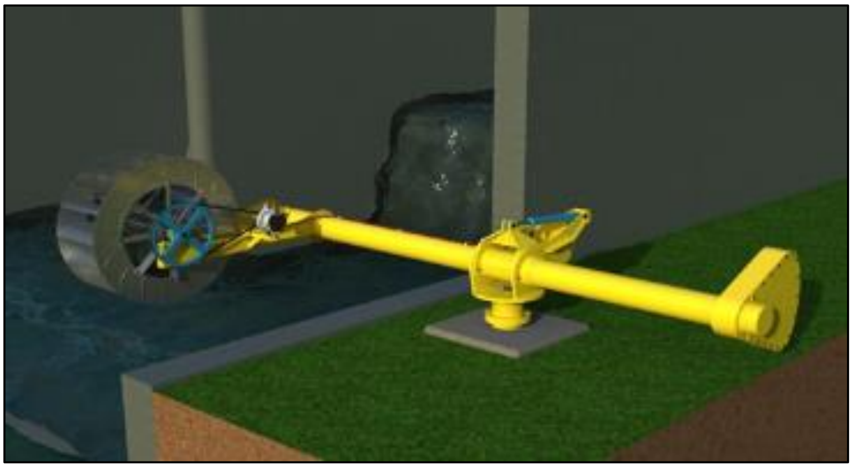

Figure 7 Design Undershoot Waterwheel

3.6. Result of Solidwork Simulated

From the velocity and total pressure values entered in the previous simulation, the design of the undershoot waterwheel simulates the flow by displaying the results of the force, blade speed, and torque, as shown in the results in table 2, fig 8 & 9.

Table 2 Results of Simulation

Name	Unit	Value
GG Average Velocity	m/s	0.8897
SG Maximum Total Pressure - Blade	MPa	0.107440
SG Force - Blade	N	203.99
SG Average Velocity - Blade	m/s	14.430

Keynote: m = meters, m/s = meters/sec, kW = kilo Watts

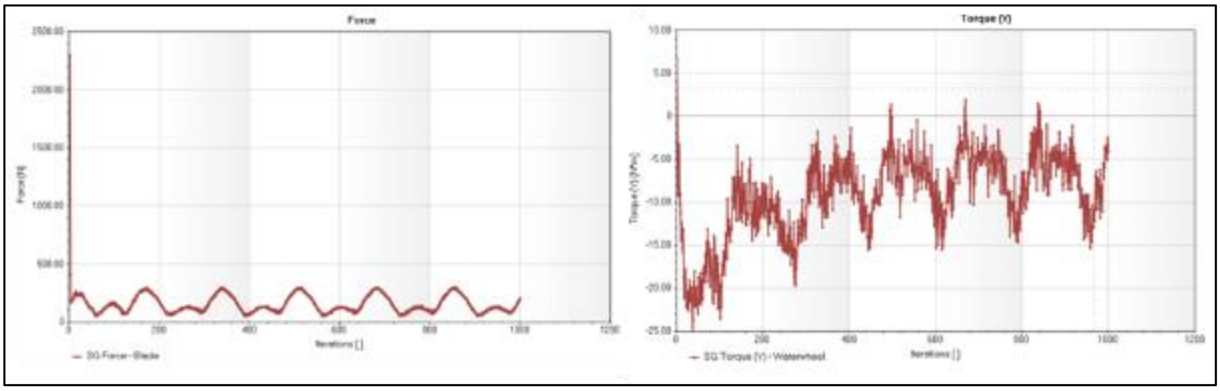

Figure 8 Force and Torque Value

3.7. Detail Design of Undershoot Waterwheel

The following is the front view in Fig. 10 and the part dimensions in Table 3. Figure 11. Mobile Design of Undershoot Waterwheel.

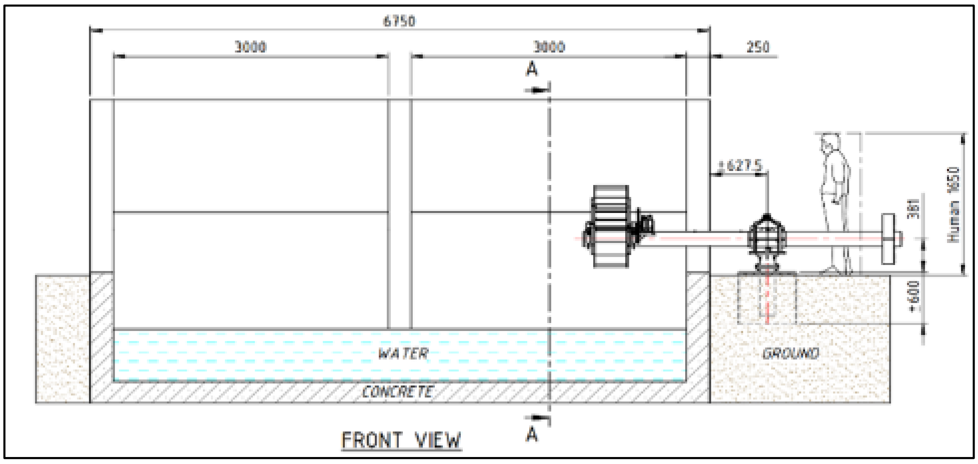

Figure 9 Front Undershoot Waterwheel

Table 3 Part Dimension

Parameter	Value	Unit
Outer Diameter Waterwheel	950	mm
Diameter Shaft	30	mm
Blade Length	350	mm
Blade Widht	186	mm
Blade Angel	22.5	°
Blade Distance	182	mm
Blade Thickness	2	mm
Number of Blades	16	PCs
Shaft Length	581	mm

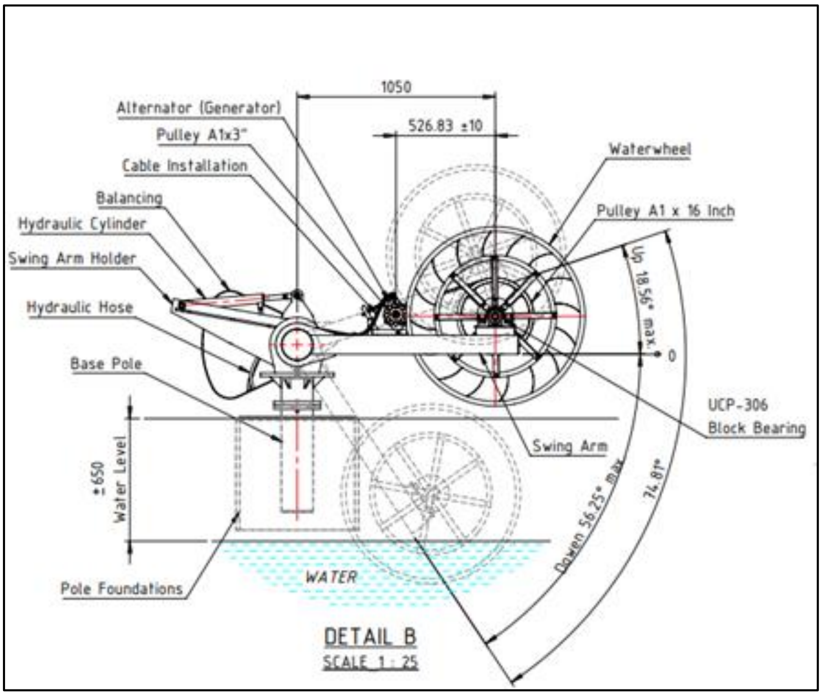

Figure 10 Mobile Design of Undershoot Waterwheel

In figure 11, the design can be lifted up to 18.56 degrees, and lowered up to 56.25 degrees. There are hydraulics to regulate it, and balancing to balance it. Creating a mobile design is useful so that routine maintenance or repairs to the waterwheel can be carried out. More clearly visible in the 3D view in figure 12 below :

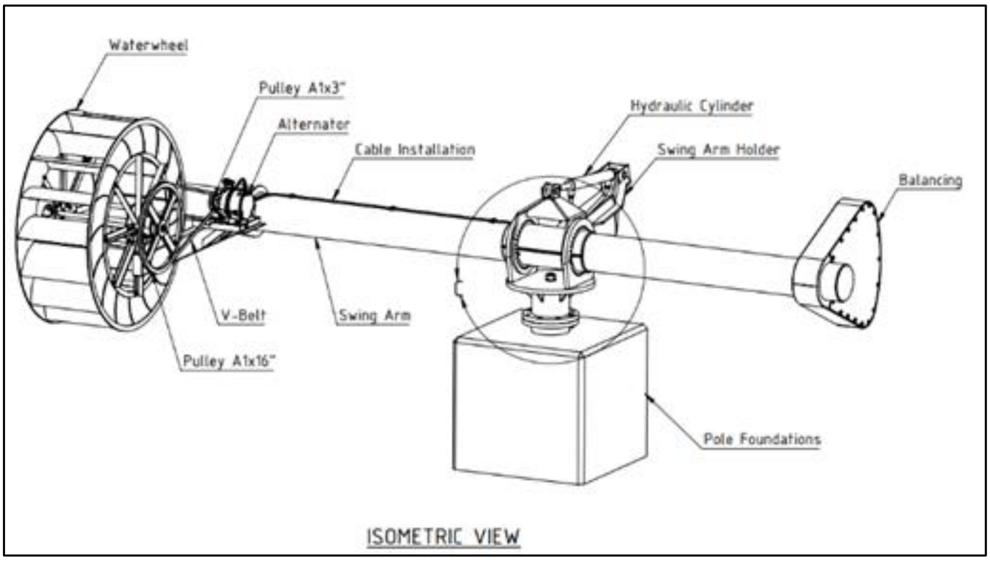

Figure 11 Isometric 3D View Design

3.8. Fluid Flow Simulation Design Undershoot Waterwheel

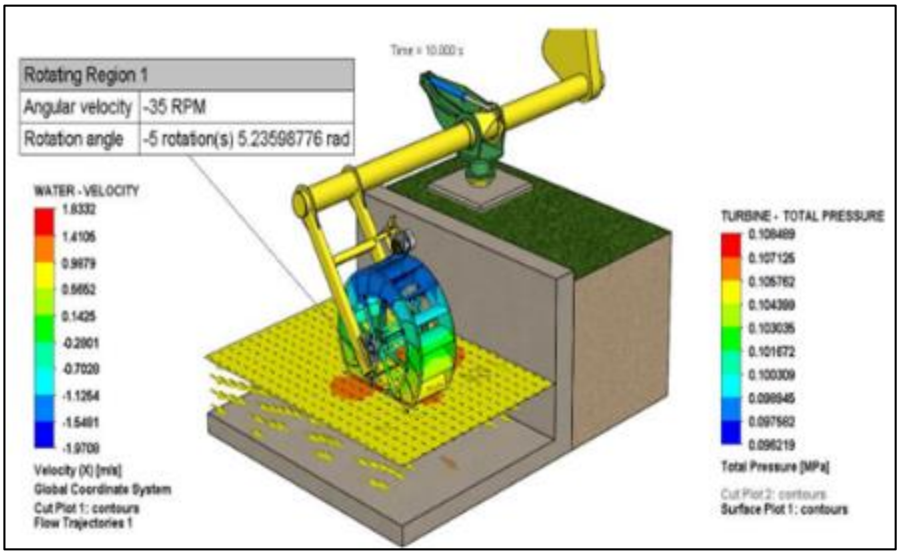

Figure 12 Flow Simulation Undershoot Waterwheel

After the flow test was carried out, the turbine rotation was able to reach 35 RPM. To increase the rotation, a pulley was added with the aim of connecting the rotation received from the electric motor and then forwarded using a belt to the waterwheel. Design and calculation of pulley, bellow Fig 14.

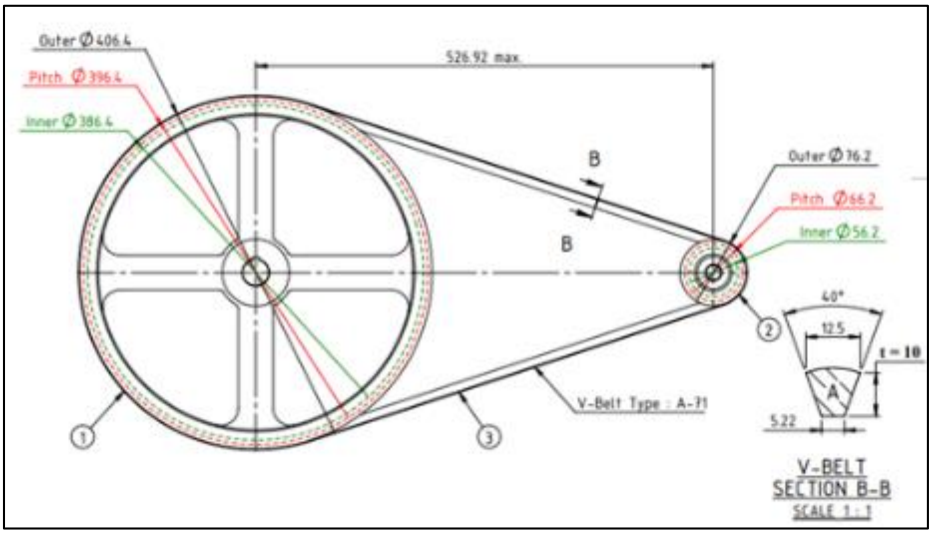

Figure 13 Pulley

3.9. Pulley Rotational Speed Calculation

Information

N_1 = Drive Pulley Rotation Speed (RPM)
d_1 = Pitch Diameter of the Driving Pulley (Pulley 1)
d_2 = Pitch Diameter of the Driven Pulley (Pulley 2)
N_2 = Pulley Rotation Driven by RPM (Pulley 2)
t = V-Belt thickness

Known

N_1 = 35 rpm (Obtained from Flow Simulation test results)

$$d_1 = 396.4 \text{ mm} = 39.64 \text{ cm}$$

$$d_2 = 66.2 \text{ mm} = 6.62 \text{ cm}$$

$$t = 10\text{mm} = 1\text{cm}$$

$$N_2 = \ldots\ldots \text{ rpm?}$$

Formula :

$$(N_2)/(N_1)=(d_1+ t)/(d_2+ t)\ldots\ldots\ldots\ldots\ldots\ldots(9)$$

$$(N_2)/35=(39.64 + 1)/(6.62 + 1)$$

$$N_2=(40.64/7,62)\ 35$$

N_2=186.66=187 rpm (Rotasi Pulley 2)

3.10. Potensional Output Power Waterwheel

Based on the calculation, it was found that the undershoot of the water figure is capable of producing an output power of around 1000 watts. This shows the potential of the undershoot turbine to utilize the available hydraulic energy efficiently. From the calculation results, it was also found that the breastshoot is capable of producing an output power of around 10417.8 watts. With efficiency value 40% 60% [12]. Further optimization and refinement of the turbine design and operational parameters have the potential to improve its performance and increase output power.

Table 4 Potential Output Power

Parameter	**Waterwheel Undershoot**	**Waterwheel Breastshoot**
Flowrate	1.18 m^3/s	1.18 m^3/s
Head	3.75 meter	1,5 meter
Velocity	0.8897 m/s	0.8804 m/s
OD Waterwheel	950 mm	950 mm
Efficiency	40%	60%
RPM	187	-
Output Power	1000 Watt	10417.8 Watt

3.11. Calculation of Generator

Information

Power Output : 1000 watt
Voltage : 24V
Current Level : 35A
COS(pi) : 0,74
Motor Type : 3 phase

Formula (Power Input) :

$$\text{Power Input} \quad = V .\sqrt{3} .I\eta . \text{Cos(pi)}\ldots\ldots\ldots\ldots(10)$$

$$\text{Power Input} \quad = 24 \times 1,73 \times 35 \times 0.74$$

$$= 1075 \text{ Watt (A. Power Input)}$$

Formula (Efficiency)

$$\eta = ((\text{Power Output})/(\text{Power Input})) \times 100\% \quad \ldots\ldots\ldots\ldots(11)$$

$$\eta = (1000/1075) \times 100\% = 93\% \text{ (B. Efficiency)}$$

The output power of this generator is 93% of the input power.

4. Conclusion

The results of the simulation value with a diameter of 950 mm, the potential flow power can be generated at 1000 watts for the undershoot turbine design, while for the breastshoot turbine it can generate power of 10417.8 watts. The breastshoot turbine has a greater power with a head value but has the disadvantage that it cannot operate if the powerplant unit is not operating, higher investment costs and materials are sturdy, less durable and can only be implemented 1 unit per 1 unit. For undershoot turbines with lower power but can be increased in size and quantity that can be installed along the outfall area.

Compliance with ethical standards

Acknowledgement

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

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