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APPLICATION PLANNING OF MICROHYDRO ELECTRICITY GENERATING TECHNOLOGY with 55 kW POWER IN THE MOUNTAINS USING THE RIVER FLOW OF COBAN RONDO WATERFALL, KRAJAAN, PANDESARI, Kec. PUJON, MALANG, EAST JAWA

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ABSTRACT

Abstract, In industry 5.0 availability of electricity plays an important role in the economic development of the community. In the villages on the slopes of the mountain there are still some villages that have not been connected to electricity so that the economic activity of the community is disrupted. Micro hydro electricity generation technology can be a solution to overcome the problem of the need for electrical energy in villages around the mountain slopes by utilizing differences in the height of the area and the flow rate of water from the river which has the potential to act as a turbine generator to be used as electricity to flow into the community to support community economic activities around the mountain slope. along with the existence of energy containers, the economy of the people on the slopes of the mountain will develop.
Keywords: *generator, electricity, and microhydro*

1. INTRODUCTION

Electrical energy is a basic need in human life, especially in economic activities in a region[1]. For this reason, various plans have been carried out to explore the use of various alternative energies, one of the natural resources which is very possible to be utilized in villages around the mountain slopes, namely the river flow from the Coban Rondo waterfall which can be used as a power source for micro-hydro electricity generation.

A microhydro turbine is a machine that utilizes fluid flow which is used to drive the turbine runer[2], [3], [4]. Turbines can be classified by paying attention to several things, including: (1) Based on Working Principles, they are classified as Action (Impulse) Turbines. turbine if the steam pressure in front of and behind the blade is the same. The steam pressure is the same in both shapes of the cross-section of the road blade, and the turbine reacts if the steam pressure in front of and behind the road blade is not the same or the steam pressure in front of the road blade is greater than behind the road blade. This also occurs due to the influence of the asymmetric cross-sectional shape of the road blade [5], [6], [7]. (2) Based on the direction of flow, they are classified into Axial Turbines, Turbines that are parallel to the direction of rotation of the turbine shaft. Axial flow turbines are used for high flow rates and with low pressure differences (1 – 40 bar)[5], [8], [9]. Axial-flow turbines are mostly used in applications involving compressible fluids, and radial-flow turbines are turbines whose flow direction is perpendicular to the direction of rotation of the turbine shaft. Turbines with radial flow are used for low working fluid flow rates and high pressure differences[10], [11], [12], [13].

2. RESEARCH SIGNIFICANCE

Utilizing the unused potential energy of the Coban Rondo waterfall using micro-hydro technology to supply electricity needs of 55 kW to support the operations of the plantation and livestock sector in Krajaan village, Pandesari, Kec. Pujon, Malang, East Java. The geographical description of the waterfall is shown in figure 1

Figure 1. Coban Rondo waterfall, Krajaan village, Pandesari, Kec. Pujon, Malang, East Java.

From the results of an environmental survey on the geography of the Coban Rondo waterfall, Krajaan village, Pandesari, Kec. Pujon, Malang, East Java. resources were found that could be developed which could be used as a reference for planning renewable energy in the form of turbines. The renewable energy potential found is shown in table 1 as follows:

Table 1. Natural Resource Potential.

Natural Resource Potential	
Waterfall height	84 m
The height of the river above the cliff	50 m
Horizontal distance of river to turbine	20 m
Rainy season river flow discharge	(Q) = 0,9 m^3 /s
Dry season river flow discharge	(Q) = 0,14 m^3 /s
Average river flow discharge.	(Q) = 0,12 m^3 /s

River flow from Coban Rondo waterfall. From the results of observations and calculations of river flow speed using the buoy method, and the cross-sectional area of the river, it is obtained that the total river discharge is Q = 0,12 m^3/s in the dry season. From the measurements it was also found that the height of the waterfall was H = 84 m. Based on the fall height and existing discharge, the main dimensions of a Pelton Micro Hydro type water turbine to drive the power generator generator are planned. Calculation results for effective head = 47.43 m, with the water discharge used to move the runner Q = 0,12 m^3/s, the power that can be generated is 56 kW.

3. RESEARCH METHODS

By finding the results of a survey of the geography of the waterfall, a dam can be planned with a mechanism to stem the flow of the waterfall river in a high place as the water falls and then channel it to a lower level using a pipe to get water with a high discharge. Water from the pipeline will be channeled to the calming pool. The calming pool is connected to a jet pipe, and the water with a high discharge will move the impeller turbine. The dam installation schematic can be seen in Figure 2 as follows:

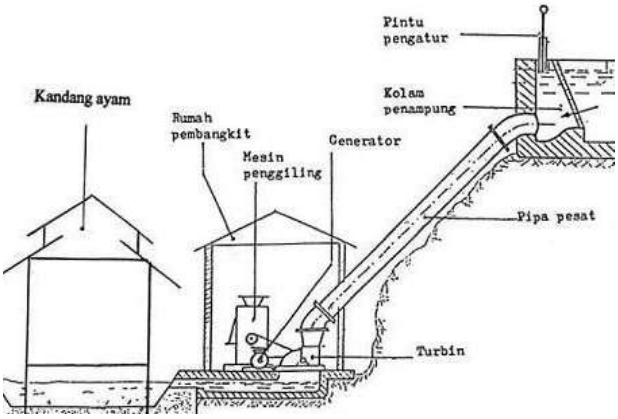


Figure 2. Water dam installation.

Determining the Specific Speed of Microhydro Turbines. To determine the type of microhydro turbine runner that will be used in planning, the specific speed of the turbine must be calculated, there are various influencing factors, namely the height of the water fall (Heed), flow speed (Q), rotational speed (Speed). The formula for calculating the turbine speed specifications is as follows:

$$N_{sp} = \frac{N \, . \, P^{0,5}}{\rho \, . \, (g.H)^{1,25}}$$

Keterangan:
N_{sp} = Specific speed (rad)
N = speed (rpm)
P = planned power (Kw)
H = height of water fall (m)
ρ = water density
g = Earth's gravitational speed

From the calculation results of the Specific Speed of the turbine, the recommended type of turbine runer can be determined referring to the standard "*Tanaka suiryoku Turbine selection chart*" which can be seen in figure 3. As follows:

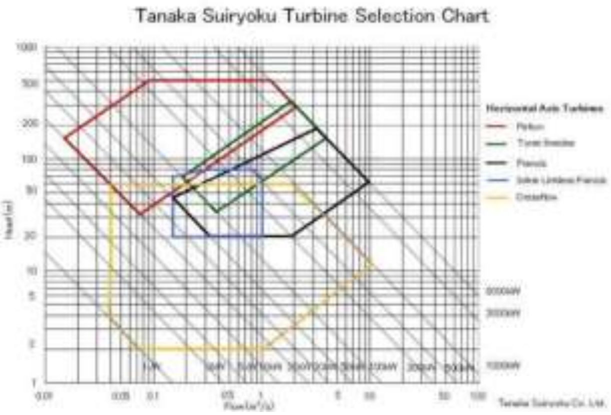


Figure 3. Tanaka suiryoku Turbine selection chart.

Based on references from the "Tanaka suiryoku Turbine selection chart" the Pelton turbine is included in the impulse turbine group[14]. The general character is the input that enters to move the runer at atmospheric pressure. Micro[15], [16], [17] Pelton turbines have an electrical output capacity ranging from 5 kW to 50 kW[18], [19], [20].

The main part of the pelton turbine is the turbine housing which functions as a turbine housing which also functions to catch and divert the splash of water flowing out of the bowl so that both the runner and the jet are not disturbed. The shape of the turbine housing can be seen in Figure 4. As follows:

Figure 4. Shape of the turbine house to be planned.

The next part is the Pelton turbine runner which is generally shaped like a disc and has a number of bowls installed around it. The runner's circumferential speed can be calculated using the equation:

$$U_1 = k_u \,.\, (2 \,.\, g \,.\, H_n)^{0.5}$$

Information:
U_1 = Circular speed (m/s)
k_u = coefficient 0.45- 0.49
g = earth's gravitational speed (9,81 m/s)
H_n = effective fall height (m)

After calculating the circumferential speed of the runner, the diameter of the runner puncture circle can be calculated using the following equation:

$$D_o = D + 1{,}2 \,.\, h$$

$$D = \frac{60 \,.\, U_1}{\pi \,.\, n \,.\, g}$$

Keterangan:
D_o= Runner outer diameter (m)
D= Diameter of the puncture circle (m)
U_1 = Circular speed (m/s)
g = earth's gravitational speed (9,81 m/s)
n = engine speed used (rpm)

The shape of the planned Pelton turbine runner can be seen in Figure 5. As follows:

Figure 5. Pelton turbine runner.

The part that emits high pressure water is the Turbine Nozzle which consists of a casing part similar to a nose which is mounted on a pipe, and a nozzle needle which is usually moved in a curved needle cone pipe and a casing which wears out quickly. The absolute speed can be calculated using the equation:

$$C_1 = k_c \,(2 \,.\, g \,.\, H)^{0.5}$$

Keterangan:
C_1= Nozzle jet speed (m/s)
k_c= nozzle coefficient (0,96-0,98)
H = effective fall height (m)
g= Earth's gravitational speed (9,81 m/s)

The shape of the planned Pelton turbine nozzle can be seen in Figure 6. As follows:

Figure 6. Pelton turbine nozzle.

After calculating the planned nozzle jet speed, the maximum jet diameter can be determined using the equation:

$$d1 = \sqrt{\frac{4 \,.\, A}{\pi}}$$

The part that receives high pressure water is the Pelton Turbine Bowl. The Pelton turbine bowl is attached to the rotor with a positive connection. This is done by giving a dovetail shape to the stem of the bowl. The optimal number of bowls is calculated by the equation:

$$Z = \frac{\pi \,.\, D}{2 \,.\, d} \times 15$$

And the dimensions of the turbine bowl can be calculated using the equation presented in table 2. As follows:

Table 2. Equation of bowl dimensions.

Turbine bowl dimensions	
Bowl width	b1 = (2,5 ~ 3,2) d)
Bowl height	h1 = (2,1~ 2,7) d
Bowl opening width	a1 = 1,2 . d
Bowl depth	t1 = 0,9 . d
Bowl mold allowance	k1 = (0,1 ~ 0,7) D

The shape of the planned Pelton turbine bowl can be seen in Figure 7. As follows:

Figure 7. Pelton turbine bowl.

3. RESULT AND DISCUSION.

From the survey results of the geographical location of the waterfall, natural resource data was found that can be developed to design turbine installations as follows: (1) Height of the waterfall = 84 m, (2) Height of the river above the H_{gross}= 50 m, (3) Distance horizontal river to turf L_{hor}=20 m, (4)River flow discharge in the rainy season Q = 0,14 m^3 /s, (5)River flow discharge in the dry season kemarau Q= 0,09 m^3 /s, (6)Average river flow discharge Q = 0,12 m^3 /s

The flow rate of water flowing in a pipe installation causes head loss which is caused by friction between the water flow rate and the cross-section of the pipe. To calculate the head loss in the planned microhydro turbine installation as follows:

$$hf_{total} = hf_{mayor} + hf_{minor}$$

$$hf_{total} = 2{,}53 + 0{,}04$$

$$hf_{total} = 2{,}57\ m$$

From the calculations it was found that the head loss value for the planned turbine installation was $hf_{total} = 2{,}57\ m$. After finding the head loss value, the effective height value can be calculated as follows:

$$H_n = h_{gross} - hf_{total}$$

$$H_n = 50 - 2{,}57$$

$$H_n = 47{,}43\ m$$

From the calculation results of the microhydro turbine installation planning, the effective height value is $H_n = 47{,}43\ m$. An overview of the microhydro turbine installation can be seen in Figure 8 as follows:

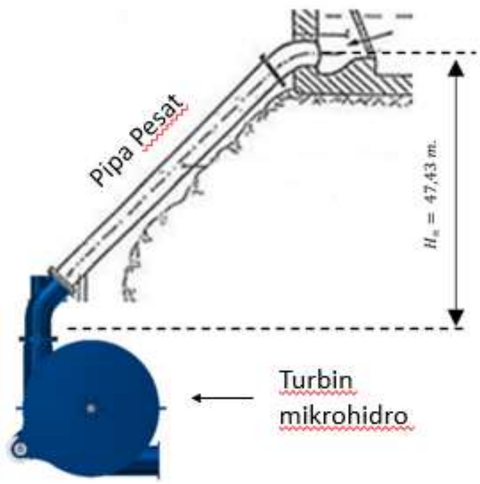


figure 8 . Microhydro turbine installation scheme

After the planned turbine installation scheme has been created, the actual power produced can be calculated using the following calculations:

$$P = \rho \,.\, g \,.\, Q \,.\, H$$

$$P = 1000 \,.\, 9{,}81 \,.\, 0{,}12 \,.\, 47{,}43$$

$$P = 55834\ Watt$$

From the calculation results, the actual power that can be generated by the microhydro turbine is $P = 55834\ Watt$ With the power that has been calculated, you can find the specific speed value of the turbine using the following calculation plan:

$$N_{sp} = \frac{N \,.\, P^{0,5}}{\rho \,.\, (g.H)^{1,25}}$$

$$N_{sp} = \frac{750 \,.\, 55834^{0,5}}{1000 \,.\, (9{,}81 \,.\, 47{,}43\,)^{1,25}}$$

$$= 0{,}0820\ rev\ \times 2\,\pi\ rad$$

$$= 0{,}5\ rad$$

It was found from the planning results that the specific speed of the turbine was $N_{sp} = 0{,}5\ rad$. The results of calculating the Specific Speed of this turbine are the reference for researchers using Pelton type turbines to design microhydro turbines.

To plan a Pelton turbine, the first thing that must be planned is the Pelton turbine runner by calculating various indicators including: (1) Absolute speed of the jet. (2) Optimum circumferential speed. And (3) Diameter of the stitch circle.

Absolute speed of the jet(C_1).

$$C_1 = k_c\ (2 \,.\, g.H)^{0.5}$$

$$C_1 = 0{,}98\ (2 \,.\, 9{,}81.\, 47{,}43)^{0.5}$$

$$C_1 = 29{,}89\ m/s$$

Optimum circumferential speed(u_1).

$$U_1 = k_u \,.\, (2 \,.\, g.H_n)^{0.5}$$
$$U_1 = 0{,}46 \,.\, (2 \,.\, 9{,}81 \,.\, 47{,}43)^{0.5}$$

$$U_1 = 14{,}03\ m/s$$

Diameter of the stitch circle. *(D).*

$$D = \frac{60 \,.\, U_1}{\pi \,.\, n}$$
$$D = \frac{60 \,.\, 14{,}03}{\pi \,.\, 750}$$

$$D = 0{,}357\ m$$

From the calculation results of the Pelton turbine runner planning, it can be presented in table 3 as follows:

Table 3. Pelton Turbine Runner Indicators.

Runer Turbin Pelton	
Indikator	**Value**
Absolute speed of the jet ($\boldsymbol{C_1}$).	$29{,}89\ m/s$
Optimum circumferential speed ($\boldsymbol{u_1}$).	$14{,}03\ m/s$
Diameter of the stitch circle *(D).*	$0{,}357\ m$

The dimensions of the Pelton turbine runner can be seen in Figure 9 as follows:

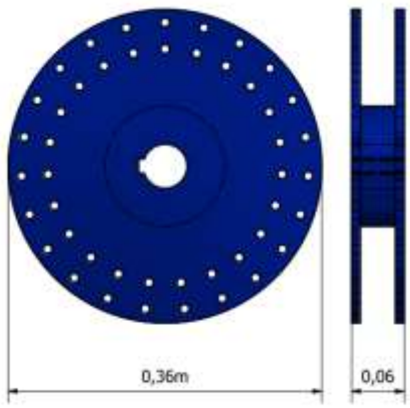


Figure 9. Pelton turbine runner dimensions

When the Pelton turbine runner calculation has been completed, nozzle jet planning can be carried out. This nozzle jet functions for parts that emit high pressure water by calculating various indicators including: (1) Jet Area and (2) Jet Diameter. The following is the planning calculation for the Pelton turbine jet nozzle as follows:

Jet Area

$$A = \frac{Q}{C_1}$$

$$A = \frac{0{,}12}{29{,}89\ m/s}$$

$$A = 0{,}00401\ m^2$$

Jet Dia.

$$d = \sqrt{\frac{4\ .\ A}{\pi}}$$

$$d = \sqrt{\frac{4\ .\ 0{,}00401}{\pi}}$$

$$d = 0{,}0714\ m$$

$$d = 7{,}14\ cm$$

The results of the calculation of the Pelton turbine nozzle jet can be presented in table 4 as follows:

Table 4. Pelton Turbine nozzle jet indicators.

Jet Nosel Pelton	
Indikator	**Value**
Jet Area	$0{,}00401\ m^2$
Jet Dia. (d1)	$7{,}14\ cm$

The dimensions of the jet nozzle diameter can be seen in Figure 10 as follows:

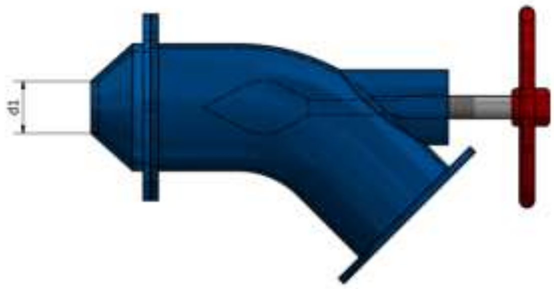


Figure 10. Jet nozzle diameter dimensions.

Once the runner and jet nozzle calculations have been found, the number of pelton turbine bowls needed can be planned. With the following calculations:

$$Z = \frac{\pi\ .\ D}{2\ .\ d} \times 15$$

$$Z = \frac{\pi\ .\ 357}{2\ .\ 71{,}4} \times 15$$

$$Z = 22{,}85$$

Based on the calculation results, it was found that the number of bowls installed on the Pelton turbine runner was 23 bowls. The formation of the bowl placement on the runer can be seen in Figure 11 as follows:

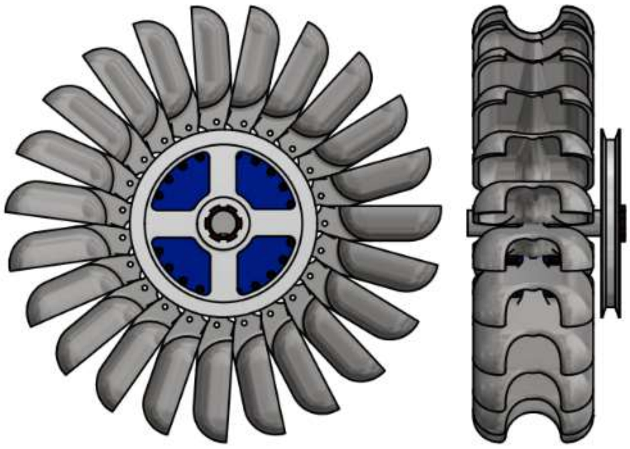


Figure 11. Bowl placement formation.

With the calculated turbine bowl dimensions specifications can be seen in table 5. As follows:

Table 5. Turbine bowl dimension specifications.

Runner bowl dimensions specifications	
Bowl width	$b1 = 228{,}48\ mm$
Bowl height	$h1 = 192{,}78\ mm$
Bowl opening width	$a1 = 85{,}64mm$
Bowl depth	$t1 = 64{,}26\ mm$
Bowl mold allowance	$k1 = 35{,}7\ mm$

A detailed image of the dimensions of the turbine bowl can be seen in Figure 12. As follows:

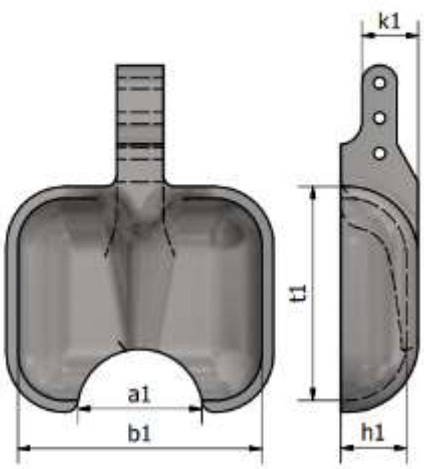


Figure 12. Detailed dimensions of the Turbine bowl

After all the main components of the planned microhydro Pelton turbine have been formed, the final step is to plan the turbine housing by calculating the outer diameter of the entire runer and turbine bowl. Calculation of outer diameter as follows:

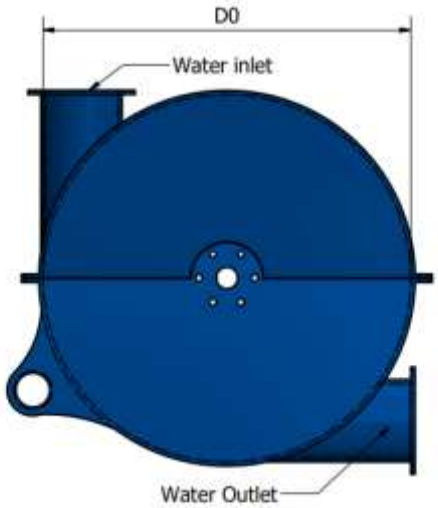
$$D_o = D + 1{,}2\ .\ h$$

$$D_o = 357mm + (1{,}2\ \times 192{,}78\ mm)$$

$$D_o = 588{,}33\ mm$$

Keterangan:
D_o= Runner outer diameter (mm)
D= Diameter of stitch circle (mm)
h = bowl height (mm)

From the results of the calculations, the design of the microhydro Pelton turbine house can be planned which consists of two parts, namely the bottom part called the basic casing where the runer shaft rests and there is a water outlet and the top part is called the deck casing where the jet nozzle rests as the water inlet. The detailed dimensions of the turbine house can be seen in Figure 13:as follows:



Gambar 13. Dimensi rumah turbin.

In this plan, a Pelton type microhydro turbine installation was produced with specifications for the actual power capacity produced by the turbine of $56\ kW$, where the total efficiency was 93% based on the application range of the micro Pelton turbine. A detailed image of the planned microhydro Pelton turbine can be seen in Figure 14 as follows:

Figure 14. 56 Kw Pelto Microhydro Turbine

From the planning results, it is known that the Pelton turbine is very suitable for use as a microhydro electricity generator driver because it can work at low pressure heights. This can be seen in the turbine installation specifications presented in table 6 as follows:

Table 6. Turbine Specifications

Spesifikasi Turbine	
Actual power	P = 56 kW
The actual speed of the jet	c1 = 29,89 m/s
Stitch circle diameter	D = 357 mm
Jet diameter	d = 71,2 mm
Number of bowls	z = 23 buah
Bowl width	b = 228,48 mm
Bowl height	h = 192,78 mm
Bowl opening width	a = 85,64 mm
Bowl depth	t = 64,26 mm
Runner outer diameter	D0= 588,33 mm

5. CONCLUSIONS

Based on the results of research and calculations, conclusions can be drawn. A Pelton type micro-hydro air turbine can be designed to be used as a power generator in the mountains by utilizing the river flow at Coban Rondo Waterfall, Krajaan, Pandesari, Kec. Pujon, Malang, East Java. With an effective head of 47.43 m and an air flow of 0.12 m^3/s a power of 56 kW can be produced, and the main dimensions of the turbine are obtained: (1) Diameter of the puncture circle = 375 mm, (2) Optimum jet diameter = 71.2 mm with 1 nozzle, (3) Outer diameter of runner = 588.3 mm, (4) Number of bowls = 23 pieces.

6. ACKNOWLEDGEMENTS

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7. AUTHOR CONTRIBUTIONS

- Conceptualization: Lazuardi Lazuardi, Maryono Maryono.
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- Visualization: Lazuardi Lazuardi, Maryono Maryono.
- Writing – original draft: Lazuardi Lazuardi , Maryono Maryono.
- Writing – review & editing: Muhammad Akhlis Rizza,

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