INOVASIA (2) (2023) P-ISSN 2964-9420; E-ISSN 2963-2617
Check for updates
INOVASIA
https://jurnal.institutsunandoe.ac.id/index.php/inovasia

DESIGN OF KAPLAN-TYPE MICRO HYDROPOWER PLANT IN THE BRANTAS RIVER FLOW, BATU CITY - MALANG

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Accepted: 12nd April 2023. Approved: 30st April 2023. Published: 30th April 2023.

ABSTRACT

Micro hydro power plants are small power plants that use water as energy, and the initiative is a turbine. This generator system is very suitable for use in rural areas because this system is easy to manufacture, generates sufficient electricity, and production costs are relatively low. Based on the above, it is necessary to design turbines that support this process system, including Kaplan-type turbines. This study aims to determine how much power the turbine can generate. The methods used in this research are the planning method, the design method, the testing method, and the analysis method for the Kaplan turbine design results referring to the results of initial observations, which show the height of the waterfall. The primary data collection is carried out through direct observation of the research object to determine the geographic location conditions and the ideal micro hydro power plant path. A designed Kaplan-type water turbine is in such a way that there are no errors in the design (for example, the manufacturing costs), and a design is carried out. 1) with an output of 1.2 m3/s and head efficiency (Heff) = 18.9 m, specific rotation (Ns) = 153.3 rpm. Control swing height (B) = 0.069 m, and the Kaplan turbine were chosen for planning the Brantas river flow micro-hydro power plant, Batu City – Malang. The potential that can be generated based on manual calculations is 124 KW, 1500 rpm turbine rotation with an efficiency of 0.85% - 0.90%.

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Keywords: Efficiency, Microhydro, Specific Speed, Turbine Power.

INTRODUCTION

A micro-hydro power plant is a small-scale power plant that uses hydropower as its driving force, such as irrigation canals, rivers, or waterfalls (head) and the amount of water discharge, especially on the amount of electricity generated. The micro hydro power plant under 200 KW in size Hydropower under 200 KW in size is classified as micro-hydro. Thus, the micro-hydro generation system is suitable for accessing electrical energy networks in remote and rural areas (Misbachudin et al., 2016).

Micro-hydro power plants are also known as white resources with the free translation of "white energy" Because power plant installations like this use natural resources and are environmentally friendly (Martiningsih, Herudin, and Rifa'i, 2019; Prabowo et al., 2018).

On research (FAJRI 2011) explained in the design research and testing of the Kaplan turbine at the height of (H) 4 m discharge (Q) 0.025 m^3/s with a variation of the rotor blade angle of 20° and stator blade angle of 25°, 30°, 45° resulted in the conclusion that the highest rotation produced by this Kaplan turbine there is a rotation of 602.2 rpm, namely at the stator blade 25° of the three variations of the stator angle 25°, 30°, 45° with a discharge of 24.1 dm^3/s. The lowest speed produced by this Kaplan turbine is at 104 rpm, namely at 25° stator blade of the three stator angle variations of 25°, 30°, and 45° with a discharge of 20.1 dm^3/s.

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According to Herlambang & Suwoto, (2010) explained in the research on the performance of crossflow micro water turbines on variations in the runner angle at constant discharge for a micro hydro power plant to produce conclusions at a blade angle of 250, resulting in a turbine rotation of 865 rpm, blade angle of 30^o 824 rpm, blade angle of 35^o 871 rpm, blade angle 40^o 858 rpm, with a water discharge (Q) of 0.00423 m3/s, and an altitude (H) of 19.612 m.

This study aims to determine how much power the turbine can generate. The methods used in this study are planning methods, design methods, testing methods, and results analysis methods. The design of the Kaplan turbine refers to the results of preliminary observations, which show the eight of the waterfall.

Based on the results of the above studies, using the right blade or runner can increase the tangential force, improving the performance of Kaplan-type turbines. Meanwhile, the performance of the Kaplan-type turbine itself can be increased by increasing the mass of the water flow hitting the turbine blades or runners. The width of the blade is closely related to the area of the blade, where this will affect the amount of mass that hits the blade and ultimately determines the amount of efficiency and power produced by the Kaplan-type turbine.

LITERATURE REVIEW

The micro hydro power plant was chosen because of its simple construction, ease of operation, ease of maintenance and providing spare parts. Economically, the operating and maintenance costs are relatively inexpensive, while the investment costs are quite competitive with other power plants (Nurdin et al., 2020). Micro hydropower plants are usually made on a small scale for rural areas in remote areas that have not yet received electricity from the National Electric Company. Hydropower can flow water in irrigation systems, dammed rivers, or waterfalls (Apriansyah et al., 2016).

In his research Mulyono & Suwarti, (2015), the characteristics of the Kaplan turbine of the Kedungombo hydropower sub-unit based on their efficiency tend to increase according to the increase in generator power. The greater the generator power (10 MW to 22.5 MW), the greater the efficiency of the turbine (66.80% to 91.25%). There was an increase in efficiency after the annual inspection due to improvements to the turbine increasing turbine efficiency.

From the results of research conducted by Mafruddin et al., (2017), it can be concluded that the guide vane opening affects turbine performance. The highest turbine efficiency of 40% is obtained with an 80% guide vane opening. The smaller the guide vane opening, the lower the turbine efficiency. Sofyan & Bancin, (2021) Research, where the turbine power generated at six moving blades is 20.911 Watts, with an efficiency of that, can be produced by a Kaplan turbine of 17.119%. The turbine power generated at the eight blades is 23.2488 watts, with an efficiency that the Kaplan turbine of 19.03% can produce.

METHODS

The research method begins by collecting secondary data, including historical data on rainfall, rainy days, humidity, air temperature, wind speed, and topography. Primary data collection is carried out through direct observation of the research object to determine the geographical location conditions to determine the ideal micro hydro power plant (Tangkudung, 2011).

The research flow is as follows: (1). Secondary data collection is taken from the Malang district rain station (2). Calculate the water balance, debit, and mainstay water discharge. 3. Determining the location and designing the micro hydro power plant, calculating penstock dimensions and effective head. 4. Calculating the potential of water power, determining the Power of the micro hydro power plant turbine, the Power of the electric generator, the dimensions of the Kaplan water turbine, and the dimensions of the generator.

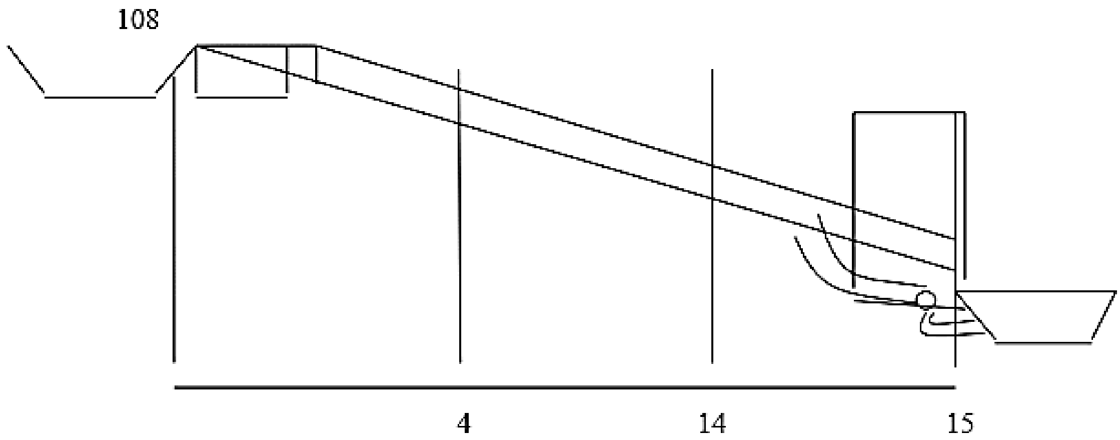

Figure 1 Power Plant Plan Concept

Water Flow Capacity (Discharge)

Discharge is one of the important parameters in planning a micro hydro power plant. The size of the water discharge will determine the amount of energy that can be produced. The discharge determines the turbine size and type (Susatyo & Subekti, 2009). Measurement of river flow discharge is usually done using a current meter counter; measurements are made along the cross-section of the river. The tool specifications are as follows; The kit is supplied with basic accessories, namely propeller type a, 3 m connecting lead, tools, oil, spare bearing, unitary reed switch of 3 x 0.6m rods, diameter 20 mm (in a canvas bag), with points and base plate, table calibration and storage.

Debit is the volume of water flowing per unit of time. In the science of fluid mechanics, the discharge water flowing from a reservoir is determined by the flow velocity and the cross-sectional area of the flow. So it can be written with the equation Frank W (1998) to calculate the flow capacity at the blade can be calculated with the equation below;

$$Q = V \cdot A \quad (1)$$

Where:

Q: Flow Rate (m^3/s)

V: Flow Velocity (m/s)

A: Cross-sectional area (m^2)

Fall Height (Head)

The head is the vertical height at which the waterfalls. Head measurements were carried out using a theodolite; measurements were carried out along the river from the upstream of the river, which is thought to be the dam's location, to the downstream, which is thought to be the location of the generator engine installation. The amount of heads is expressed in meters (m).

Turbine Power

After obtaining the amount of discharge and head, turbine power (P) can be determined. Turbine power is the amount of electrical power produced, expressed in kilowatts (kW). So the equation (Frank W 1998) can be written with the equation below to calculate the amount of turbine power.

$$P = \rho \times g \times Q \times \Delta h \quad (2)$$

Where:

P: Turbine Power (kW)

g: Gravity (9.81)

Q: Debit (m^3/s)

h: Heads (m)

PLTMH planning

In general, the layout of the micro hydro power plant system is a power plant that utilizes runoff river water. Kusnadi et al. (2018) States that the supporting components needed in designing a turbine as a driver for a micro hydro power plant are as follows:

1. Diversion Weir and Intake (Diversion Weir and Intake)

Diversion dams function to divert water through an opening on the side of the river (intake) into a settling basin.

2. Settlement Basin

Settling tanks are used to remove sand particles from the water. The function of the settling tank is very important to protect the following components from the impact of Saluran Pembawa (*Headrace*).

3. Channel Carrier (Headrace)

The conveyance channel follows the contour of the knoll side to maintain the elevation of the conveyed water.

4. Tranquilizer Tub (Headtank)

The Head tank regulates the difference in water output between the penstock and the conveyer as a final separation of impurities in the water, such as sand and wood.

5. Rapid Pipe (Penstock)

The penstock is connected at a lower elevation to a water wheel (turbine) Rumah Pembangkit (*Powerhouse*)

6. Powerhouse

7. Turbine and Generator

Turbines and generators function to convert potential energy into mechanical energy to produce electricity.

8. Tail Race

RESULTS AND DISCUSSION

Design of Runners and Main Shafts

Kaplan water turbine is one type of reaction turbine. The Kaplan turbine is composed of turbine wheel propellers like a ship's propeller. The Kaplan turbine wheel functions to obtain a rotary/tangential force on the turbine shaft, which can generate torque. The selection of type of turbine for a micro hydro power plant must first know the number of heads and the amount of discharge. After knowing how much head and available water discharge, the selection of the type of water turbine to be used can be determined (Layman'Guidebook, 1998). The type of turbine can also be determined using the table of criteria for selecting the type of water turbine based on the head or rotation provided in **Table 1** below.

Table 1 Types of Turbines and Nominal Speeds

Turbine Type	Nominal Speeds (N)
Semi Kaplan, Single Regulator	75-100
Kaplan, Doubleregulated	75-150
Small-Medium Kaplan	250-700
Francis (Medium & High Head)	500-1500
Francis (Low Head)	250-500
Pelton	500-1500
Crossflow	100-1000
Turgo	600-1000

The turbine is one of the main pieces of equipment in the generation system. The turbine generates mechanical energy through rotation by utilizing the driving fluid. It is this driving fluid that generates torque so that the turbine can rotate. The force exerted by the fluid (steam) with a certain enthalpy can create the large torque needed to rotate the turbine at high speed (3000 rpm). According to Kusnadi et al., (2018), the results of their research on the Kaplan turbine design produce a specific turbine rotation of 249.372 rpm with an outer diameter of the turbine wheel (runner blades) of 10.70 cm and an inner diameter of the turbine wheel of 3.56 cm and a height of the turbine guide blade (guide) vanes) 3 cm.

The indicated power produced by the water turbine (water horsepower) is 351.590 Watts with a torsional moment of 6.711 Nm. The effective power of the water turbine or Brake Horse Power (BHP) is 280.964 Watts. The turbine efficiency is 79%; this is an absolute requirement for creating electrical energy because electrical energy is created due to the angular velocity and the resulting torque, as explained earlier.

The turbine itself is one of the main pieces of equipment in the generation system; therefore, the operator needs to know the characteristics of the turbine, both from the function of components and work protection, so that the operator can ensure that the turbine operation takes place in a safe and controlled manner. Steam turbines consist of several blades or blades arranged in series, and these blades have various characteristics in their working principles. The components contained in the Kaplan turbine design are calculated using the equation Dietzel, (1999), and the following results are obtained:

$$Ns = \frac{N\sqrt{P}}{\sqrt[4]{H^5}} \quad \text{(Yassen, 2014)} \qquad (3)$$

$$Ns = 500\frac{\sqrt{146}}{18{,}9^{\frac{5}{4}}}$$

$$\text{Ns} = 500 \text{ x } \frac{12{,}0830}{39{,}4073}$$

$$\text{Ns} = 500 \text{ x } 0.3066$$

Ns = 153,3 Rpm

1. Calculate Runner Diameter

The runner is the heart of the turbine; This is where the hydropower is converted into rotary force, which drives the generator. Regardless of the type of runner, the bucket or blade captures as much energy as possible from the water. The curvature of each surface, front and back, determines how the water will push it down. Also, remember that any runner will work most efficiently at a given head and flow. **Figure 2** below is the design of the runner diameter. In the results of research conducted by Kusnadi et al., (2018), the design results of the Kaplan turbine produce a specific rotation of the turbine of 249.372 rpm with an outer diameter of the turbine wheel of 10.70 cm and an inner diameter of the turbine wheel of 3.56 cm and a guide blade height of 3 cm.

The indicated power produced by the water turbine (Water Horse Power) is 351.590 Watt with a torsional moment of 6.711 Nm, the effective power of the water turbine (BHP) is 280.96Watts, and the turbine efficiency is 79%. In the research conducted above, the design is very large with a high discharge, making it impossible to install or use in a small river flow field. In this study, a Kaplan turbine was designed, which is very simple and can be installed in a river that is not that big.

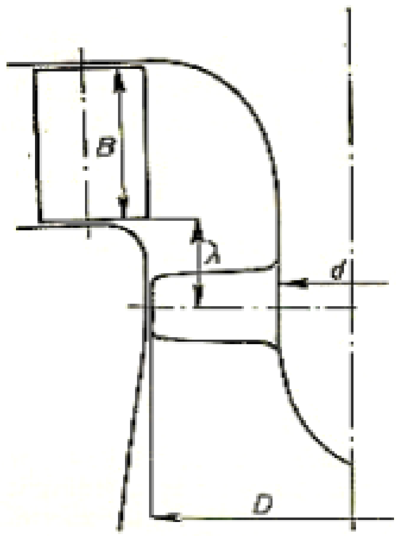

Figure 2 Runner Diameter (Didik 2020)

Information:

D: Outside Diameter Of The Runner

B: Guide Vane Height

Λ: Vertical Distance Of The Runner To The Inside Of The Guide Vane

d: Hub Diameter

2. Calculate the Outer Diameter of the Runner

The runner is the main component of the water turbine, which operates in the form of rotation. The rotation of the runner is generated due to the strong water-pushing force that hits the runner blades. After determining the specific speed, the turbine rotational speed is obtained. To calculate the diameter of the runner and guide vane can be determined by the Euler turbomachine equation below (Cengel & Cimbala, 2006).

$$D = (66{,}76 + 0{,}136\,.\,Ns)\frac{\sqrt{Heff}}{N} \qquad (4)$$

$$D = (66{,}76 + 0{,}136\,.\;153{,}3)\frac{\sqrt{18{,}9}}{750}$$

$$D = 87.6088 \text{ x } 0{,}00579$$

$$D = 0{,}50\ m$$

3. Calculating Guide Vane Height (B)

The guide vane is a component to determine the direction and amount of water discharge that will enter the turbine. To calculate the guide vane can be determined with the Euler turbomachine equation below(Cengel & Cimbala, 2006).

$$B = \left(0{,}45 * \frac{31{,}80}{Ns}\right) * Do \quad (5)$$
$$= \left(0{,}45 * \frac{31{,}80}{153{,}3}\right) * 0{,}50$$
$$= 0{,}046 \text{ m}$$

4. Calculating Hub Diameter (d)

The blade is the part that directly converts the potential energy contained in the water into torque energy on the turbine shaft. For this reason, computational fluid dynamic analysis is needed to obtain an optimal turbine blade design. This calculation is done theoretically and manually. From the calculation results, the design of the blade profile is carried out.

$$d/D = 0{,}5 \quad (6)$$
$$d = 0{,}5*Do$$
$$= 0{,}5*0{,}50$$
$$= 0{,}25 \text{ m}$$

Table 2 Connection Ns, d/D

Ns	1000	800	600	400	350	300
d/D	0.3	0.4	0.5	0.55	0.60	0.70

Table 2 shows various variations of rotational speed and specific speed.

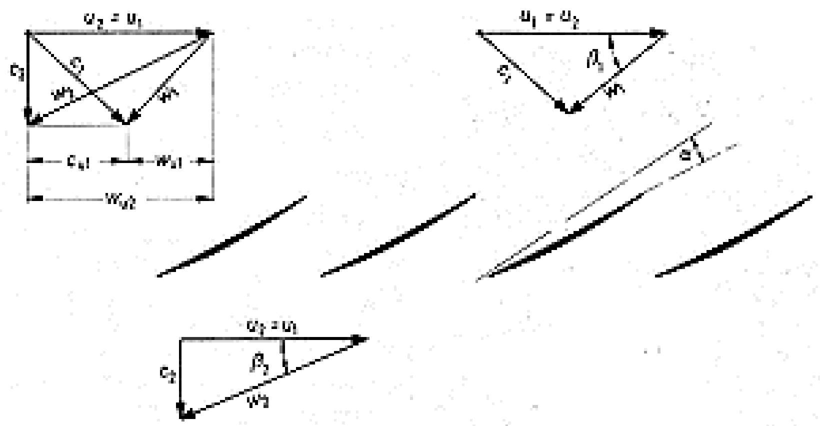

Figure 3 Speed Triangle on the Runner and Guide Vane

Figure 3 explains that the flowing water entering from the outer side of the runner to the blades of the first stage flows across inner space at the centre of the runner and then flows again to another side of the outer edge of the runner through the two bulkheads. The first stage, turn-around flow, is caused by some of the flow along the gauge vane being unable to cross because the flow along the bottom of the gauge vane pushes it. As a result, the flow at the outlet of the gauge vane is under considerable pressure and is not a free jet.

There is also measured data that the runner of a Kaplan-type turbine is accelerated from the outlet of the first stage to the inlet of the second stage in the interior so that the flow velocity triangle will not be homologous at either the outlet of the first stage or the inlet of the second stage (Yamamoto, 1983). Before designing a turbine, its components, operating principles, and performance characteristics must be studied. The main components of the turbine are runners, shafts, bearings, casings, draft tubes, and guide vane. And valves.

In this turbine, the guide vane is in the form of a long ellipse whose width matches the width of the runner. Its main function is to convert the total available head into kinetic energy and simultaneously flow water to the runner blades at the desired angle. The turbine cawell-builtbe well-built and sturdy because it regulates the power of the incoming water and the outgoing shaft power. The shape and dimensions of the casing have a significant effect on efficiency. Draft tube installed under the casing.

Take advantage of the draft effect; the end of the tube is submerged below the waterline of the tail. Its function is to recover most of the remaining energy left in the flow of water from the runner, the head between the tailwater. A shaft is a mechanical device component that transmits power from hydraulic to mechanical power. The impeller consists of blades attached to a shaft or ring. The runner allows water to enter and leave the turbine without impingement.

The rotor is attached to the shaft. When the shaft is vertical, it is called a vertical turbine; when the shaft is horizontal, it is called a horizontal Low-runner. Low-runner head blades can be made of cast high-head runner blades and can be made of steel or aluminium. The rotor is made of a special alloy if the water is chemically contaminated. The speed of the turbine rotates in a unit of time and determines the specific speed of the turbine to determine the type of turbine suitable for use in certain conditions. In selecting the turbine's rotational speed, it is better to determine it with a high number because it affects the small torque and the diameter of the turbine wheel.

5. Calculating Runner Fingers

The inner diameter of the turbine can be calculated using the following equation (Fox & Donalds, 2011).

$$R_1 = r + \left[\frac{D-r}{X}\right] \qquad (7)$$

$$= 0{,}4 + \left[\frac{0{,}50-0{,}4}{1}\right]$$

$$= 0{,}5 \text{ m.}$$

6. Calculating Angular Speed

Angular speed is the angle travelled per unit of time. Angular speed is also known as angular speed. An object's speed when it moves in a circle in the direction tangent to its spin trajectory is called linear speed. Linear velocity will always touch a circular path with a path length equal to the circle's circumference. This factor is often expressed as angular velocity and is used in the equation (Fox & Donalds, 2011).

$$\omega = \frac{N*2*\pi}{60} \qquad (8)$$

$$= \frac{750*2*3{,}14}{60}$$

$$= 78{,}5 \text{ rad/dt}$$

7. Calculating Circumferential Speed

The tangential velocity U is the circumferential speed of the turbine at the average disc diameter. The performance of energy conversion equipment, including a water wheel, according (Kamal, 2004). Tangential velocity can be obtained from the following equation.

$$U_1 = \omega * R_1 \quad (9)$$

$$= 39{,}25 : 2$$

$$= 19{,}625 \text{ m/dt.}$$

The ratio between the circumferential speed (tangential) and the absolute speed is a very important variable in turbine design, especially in determining the relative internal efficiency of the turbine. Circumferential velocity at the tip of the blade or the inlet of the blade (U1) The circumferential velocity at the tip of the blade is the same both at the inlet and the outside (U1, tip = U2, tip = U tip)

8. Calculating Specific Roving Speed

The speed (rotation) of the turbine that will be transmitted to the generator. For example, for a direct couple transmission system between a generator and a turbine at a low head, a reaction turbine (propeller) can reach the desired speed. In contrast, the Kaplan and crossflow turbines rotate very slowly (low speed), which will cause the system not to operate. This factor is often expressed as a specific speed (Fox & Donalds, 2011).

$$u_1 = \frac{U_1}{\sqrt{2*g*H_{eff}}}$$ (Židonis and Aggidis 2015) (10)

$$= \frac{19{,}625}{\sqrt{2*9{,}81*18{,}9}}$$

$$= 1{,}032 \text{ m/dt}$$

Table 3 Components for the Depiction of the Speed Triangle

N	R_1 (m)	u_1=u_2 (m/dt)	Cm (m/dt)	ci (m/dt	ω (m/dt)
750	0,5	1,032	2,79	0,145	78,5
600	0,6	1,87	1,76	0.124	68.3
500	0.75	2,06	1.15	1.43	52,33
400	0,84	2,65	0.12	2.23	43,22

In turbomachinery or turbo engines, a speed triangle or speed diagram is a triangle representing the various components of the velocity of the working fluid in turbo engines. For steady flow, the Euler turbomachine equation below can be used (Cengel & Cimbala, 2006).

$$\sum(r \times F) = \int cs\ (r \times V)\rho V.\hat{n}dA \quad (11)$$

The left side of this equation represents the amount of external torque (moment) acting on the control volume, and the right side is the angular momentum through the control surface so that:

$$T_{shaft} = -\dot{m}1(r1V\theta1) + \dot{m}2(r2V\theta2) \quad (12)$$

Where Tshaft is the torque applied to the control volume, the sign (-) represents mass flow to the control volume and (+) is the flow leaving the control volume. $V\theta$ is the absolute velocity in the tangential direction, and U is the tangential velocity of the blade. If $V\theta$ and U are in the same direction, then $V\theta$ is positive. Tshaft is positive if it is in the direction of rotation and negative if it is not. As in the equation, the shaft torque is directly proportional to the mass flow rate $\dot{m}=\rho Q$. This equation is often called the Euler turbomachine equation. The shaft power is related to the torque on the shaft and the angular speed, so that: Euler's turbomachine equation for the turbine:

$$Wshaft = T_{shaft}\ .\ \omega \quad (13)$$

$$Wshaft = -\dot{m}1(U1V\theta1) + \dot{m}2(U2V\theta2) \quad (14)$$

Value $V\theta$ is positive when $V\theta$ and U are unidirectional and negative when it is not unidirectional. $Wshaft$is positive when the shaft torque and ω have the same direction and negative otherwise. $Wshaft$ will be positive when power is entered into the volume control (pump) and negative if the power goes out of the volume control (turbine). The mass unit works $\dot{m} = \rho.\ V.\ A$ (kg/s) (Cengel and Cimbala 2006).

$$W_{shaft} = -U1V\theta1 + U2V\theta2 \quad (15)$$

Besides the efficiency and power of the waterwheel, another interesting parameter in the water turbine topic is the velocity triangle which describes the direction and magnitude of the velocity components. These quantities are useful for designing the blades' geometry and dimensions and checking the water turbine's power. The velocity triangle is the basis of the kinematics of the fluid flow hitting the water turbine angle. Understanding the velocity triangle will help us understand the energy conversion process in a water turbine. The solid velocity triangle of the water turbine in this study is shown in **Figure 4** below.

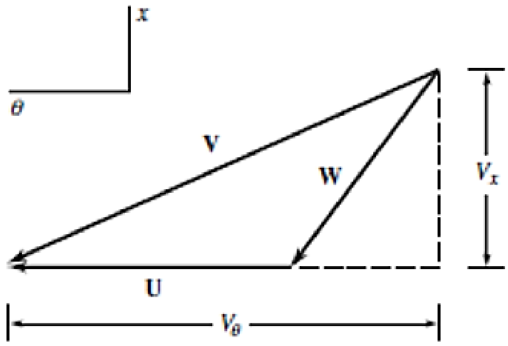

Figure 4 Velocity Triangle V: Absolute Speed, W: Relative Speed, And U: Tangential Speed

One of the key concepts in turbomachinery is understanding how flow appears from the point of view of a rotating component compared to a stationary one. Once this is understood, a form of turbomachinery becomes easier to understand, seeing the flow from the point of view of the rotating components is in a relative frame of reference, and seeing the flow from a stationary point of view is called being in an absolute frame of reference (Ingram, 2009).

Desain Guide Vane

1. Guide Vane Design

Guide Vanes are fixed grooves found on turbines that help direct water, gas, or air around bends with maximum efficiency. As the Impeller increases or decreases the flow of a substance through a system, guide vanes ensure that the substance is passed as evenly and smoothly as possible. One way to compare these propellers is to compare them to gun barrels. As firearms evolved, they were manufactured to have small, spring-loaded grooves in the barrel, and This allowed the projectile to rotate as it left the barrel, making the projectile more accurate.

Guide Vanes work this way. The decrease in surface area resistance in both samples only increases efficiency, and the guide vane affects turbine performance(Sutikno et al., 1985). Drawings of the guide vane design can be seen in **Figure 5** below.

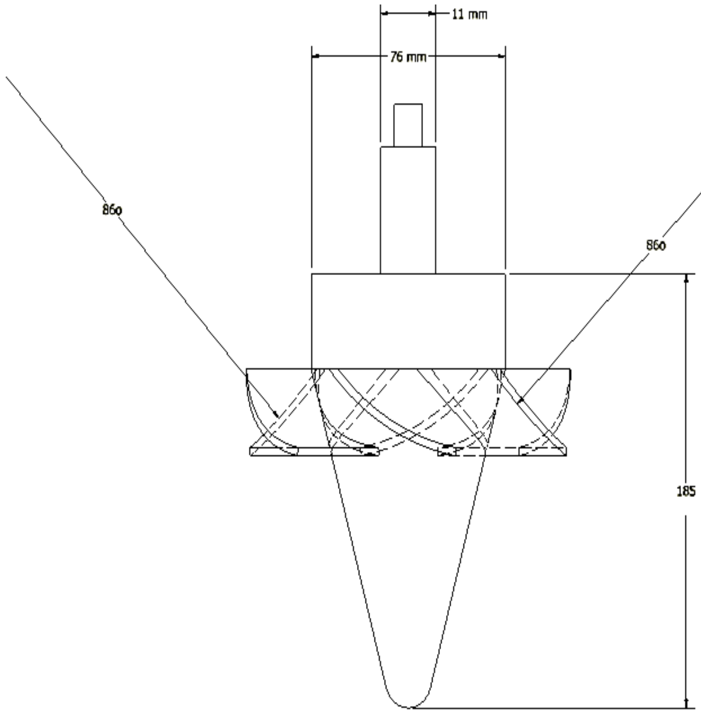

Figure 5 Guide Vane Design

To understand how to generate power, water from the penstock enters the scroll casing. After that, water passes through the scroll casing, and the guide vanes direct the water from the casing to the runner blades. The critical point is that the blades are flexible and can adjust themselves based on the required flow rate. As the water moves across the blades, it begins to rotate due to the reaction force of the water. In addition, the blades on the Kaplan turbine are also adjustable. The water passes through the draft tube, where the kinetic energy and pressure energy are reduced from the runner blades.

- Specific rotation (Ns) = 153.3 rpm
- Runner diameter (D) = 0.50 m
- Discharge (Q) = 0.79 m/s
- Head efficiency (Heff) = 18.9 m
- Guide vane height (B) = 0.069 m
- Vertical distance of guide vane and runner (λ) = 0.19 m

2. Calculate the Diameter of the Inlet Guide Vane

The inlet guide vane influences the flow pattern according to the turbine design criteria at the outlet ducting, Where the flow velocity is greater in the area approaching the ducting outlet wall. The influence of the guide vane inlet angle is not the main factor in increasing the flow velocity in the area near the wall. There is a factor of the long track and effect acceleration which also influences an increase in speed. To calculate the diameter of the Inlet Guide Vane can be determined by the Euler turbomachine equation below Cengel & Cimbala, (2006) in equations (16) and (17).

$$F1 = \left(1{,}45 + \frac{72{,}17}{N_s}\right) * D \qquad (16)$$

$$= \left(1{,}45 + \frac{72{,}17}{153{,}3}\right) * 0{,}50$$

$$= 0.960 \text{ m}$$

3. Calculate the Guide Vane Outlet Diameter

The inlet guide vane with ducting provides the fastest outlet speed in the configuration and shape of the inlet guide vane.

$$G1 = \left(1{,}29 + \frac{41{,}63}{N_s}\right) * D \qquad (17)$$

$$= \left(1{,}29 + \frac{41{,}63}{153{,}3}\right) * 0{,}50$$

$$= 0.780 \text{ m}$$

Turbine Shaft

As explained above, the turbine shaft functions to transfer power from the turbine rotation. The loads received by the turbine shaft include torsion and bending loads, so with this load, there will be torsional stresses and bending stresses resulting from the torsional and bending moments. If the force is on the wheel, the magnitude of the rotating moment on the wheel shaft, according to Arismunandar, (2004), is written in the hydraulic power equation. The torque generated by the wheel is affected by the force to rotate the wheel and the wheel's radius.

$$Mp = \frac{M}{w} \quad (18)$$

Where :

Mp : Torsional moment (N.mm)
P : power transmitted (Hp)
w : Angular velocity (Hp)
N : Turbine rotation speed (Hp)

W= 2*π*N (19)

= 2*π*750

= 4710 Hp

$$M_p = \frac{146}{2575} \quad (20)$$

= 0,0566 kNm/s

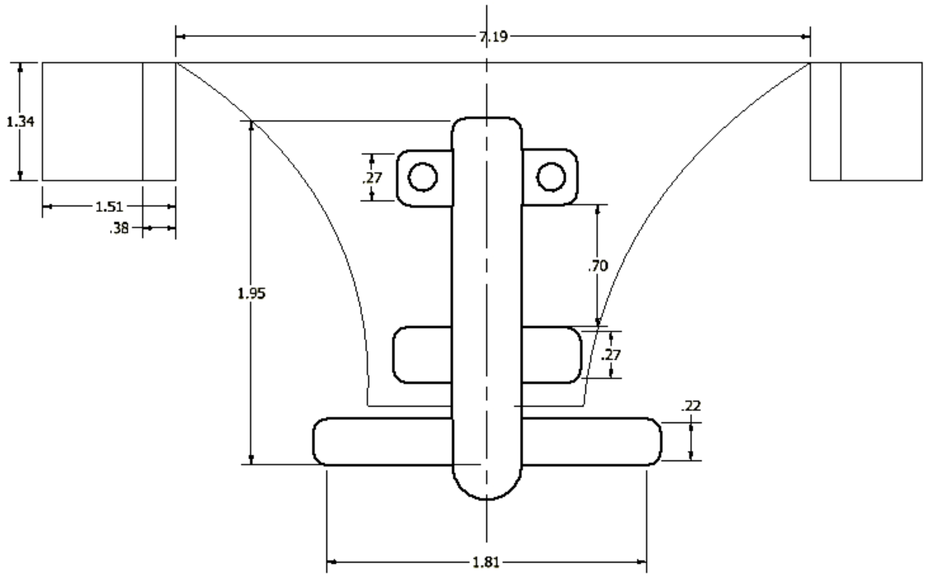

Figure 6 Turbine Shaft

In **Figure 6**, loads are applied smoothly, the value of Kt = 0.1; for loads use a little shock and impact, the value of Kt = 1.0 – 1.5, and if the load is subjected to shock or impact, the value of Kt = 1.3 – 3 because the shaft also receives a bending load from the weight turbine, a correction factor for bending load (Cb) is required, which costs between 1.2 – 2.3 (Sularso, 1994). Besides the above, the selection of shaft materials is also very important in shaft planning.

Design of Turbine Housings and Bearings.

The bearing is one part of the machine that holds the shaft with a certain load so that the shaft rotation can work smoothly and safely. In general, bearings can be classified into 2; sliding bearings are a bearing that can withstand large loads. There is friction between the shaft and the bearings in bearings because the shaft parts are in direct contact with the bearings. Examples of sliding bearings are radial, axial, and special bearings. Rolling bearings are a bearing that can withstand small loads.

These bearings are designed to carry loads while minimizing friction to maintain the separation between the moving bearings; there are rotating parts, namely balls, rollers, etc. Examples of rolling bearings are ball bearings and rolling bearings with rollers (Yassen, 2014). The design of the turbine house is in **Figure 7** as follows:

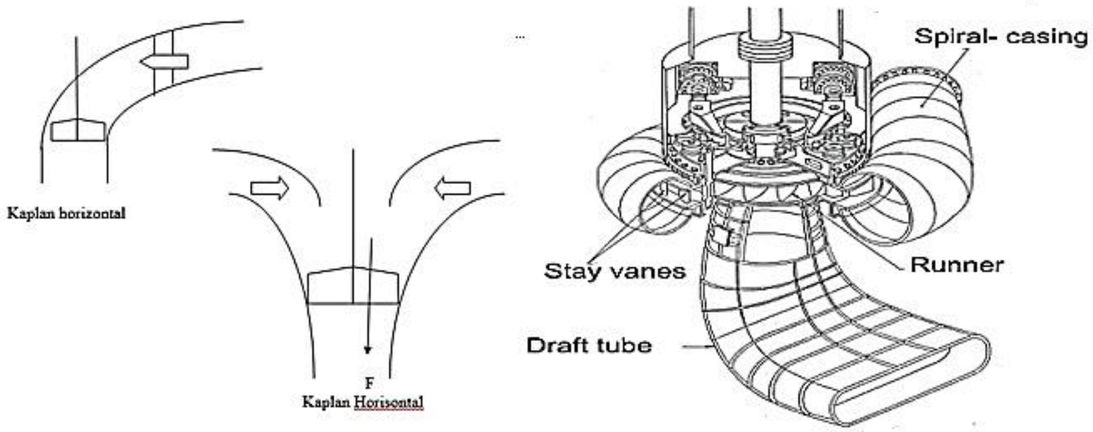

Figure 7 Turbine Housing Design and Bearings

The turbine housing is an important part of obtaining the best fluid flow. The turbine housing construction is made of welded carbon steel pipe. The selection of this material is to obtain a construction that is light but strong and easy to find in the market so that the manufacturing process does not experience material difficulties.

Generator Selection

An electric generator is a device that produces electrical energy from a mechanical energy source, usually by using electromagnetic induction. This process is known as power generation. The source of mechanical energy can be a reciprocating or turbine steam engine, water falling through a turbine or water wheel, an internal combustion engine, a wind turbine, a hand crank, solar or solar energy, compressed air, or any other source of mechanical energy. DC generator is a generator that produces a unidirectional output voltage. The generators are used in the table below.

Table 4 Generator Specifications

	Generator			
Model	ZDJP502-LJ-115	SF	ZD760	ZDT03
Rated Capacity (KW)	100KW-100MW	100KW-100MW	100KW-80MW	200KW-60MW
Rated output (KW)	100KW-100MW	100KW-100MW	100KW-80MW	200KW-60MW
Rated speed	68.2-1500rpm	68.2-750rpm	150-1500rpm	75-500rpm

One of the generators that can be selected to be applied to PLTMH is a permanent magnet DC generator. This generator is of low-speed type and without initial electrical energy. In planning this small-scale power plant, the permanent magnet DC generator is driven by a DC motor (Fauziyah, 2017). The use of permanent magnets is very useful in the application of small-scale electricity generation because permanent magnet generators have the advantage that when they only get a low rotation, they can release a large amount of electrical energy.

The expected result is a permanent magnet DC generator output voltage of at least 9.6 volts DC to supply the buck-boost converter circuit because the working voltage on the buck-boost converter is 9.6 volts DC.

1. Determination of Turbine and Generator

The turbine used is a Kaplan turbine with the following definition:

Efficiency: 0,85 - 0,9

Ns (Specific Speed): 153,3 rpm / H_{eff}: 18,9

Turbine rotation speed: 1500 rpm

Output Turbin : $P = g*Q*H_{eff} * \eta_t$ (Yassen, 2014) (21)

$P = 9{,}81*0{,}79*18{,}9*0{,}85$

$P = 124$ kW

2. Mechanical Transmission

To move the rotary blade/runner, a runner drive mechanism is used, which is made of large bevel gears as the prime mover.

The large bevel gear will drive the small bevel gear/pinion, which is mounted on the runner shaft with the help of pegs and nuts as holders. The mechanical transmission design is in Figure 8 as follows:

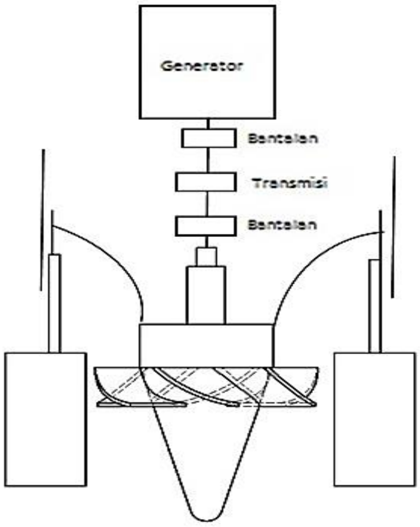

Figure 8 Mechanical Transmission

The mechanical transmission system functions to transmit the mechanical energy of the turbine shaft rotation to the generator while increasing the rotation according to the generator specifications. The micro hydro power plant mechanical transmission design uses a V-belt to increase the rotation from 1400 rpm to 1500 rpm. The transmission system on the turbine side and generator side is equipped with Plummer.

CONCLUSION

Based on head and capacity calculations in the Brantas river, Batu City - Malang, it was found that Head efficiency (Heff) = 18.9 m, Specific rotation (Ns) = 153.3 rpm, guide vane height (B) = 0.069 m and discharge of 1.2 m3 /s then the right water turbine as the driving force for the micro hydro power plant prototype in the Brantas river, Batu City - Malang is the Kaplan turbine. The potential generated based on manual calculations is 124 Kw, turbine rotation speed: 1500 rpm with efficiency: 0.85% - 0.90%.

Author's declaration

Authors' contributions and responsibilities

The authors made substantial contributions to the conception and design of the study. The authors took responsibility for data analysis, interpretation and discussion of results. The authors read and approved the final manuscript.

Funding

Write down the research funding, if any.

Availability of data and materials

All data are available from the authors.

Competing interests

The authors declare no competing interest.

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