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Design of Turbine Screw Model for Pico-Hydro

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ABSTRACT: *The total availability of small-scale of potential water resources is enormous and have different characteristics. The rivers in the lowlands are mostly low altitudes but large flow and very long so the total high is very large, maybe dry or flooded, and maybe clear or contains garbage. Vice versa for mountain areas. To increase the added value, water energy needs to be converted into electrical energy using turbines and generators. Commonly used turbines are waterwheels, open flume propeller turbines, and others. These turbines when applied will have disadvantages, namely: certain waterfall elevations, not flood resistance, expensive, and lower efficiency. One alternative solution is the use of turbine screw models. In this turbine a flat flow of water is collected and drained in a rapid pipe in which there is a screw-shaped rotor. The purpose of this research is to design a screw turbine for pico-hydro which are resistant to flood, dirty water, can work at low waterfall elevation and have high efficiency, The method used is theoretical design and test on stream flow. The design results are tested on the river to obtain the real characteristics of the turbine. The results of the data analysis show that the screw turbine design results have an efficiency of up to 80%.*

Keywords: *design, river, turbine screw, pico-hydro*

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I. INTRODUCTION

In time, the renewable energy will replace the energy of the fossil. Consideration in the selection of renewable energy that is availability, environmentally friendly, easy, cheap, and reliable. One of the most renewable energy sources that is currently concerned is the potential energy of water, because of its availability and environmentally friendly. The use of small-scale water potential energy began to be developed. Although small scale but the number of so much that the total energy available exceeds large-scale water potential. Potential water energy sources have a variety of characteristics, including varying heights and discharges, water conditions, and excessive water discharges for a moment

Rivers with an altitude of upstream to downstream can reach hundreds of thousands of meters with discharge up to tens of cubic meters per second, representing an enormous potential energy accumulation. But this potential energy of water is scattered along the rive. This condition provides inspiration for designing compatible turbines for stream flow characteristics. The commonly used turbine is a waterwheel. Discharge and excessive water levels can damage the waterwheel. The other type is a floating turbine, although it can cope with water level fluctuations and is suitable for low waterfall elevations, but this turbine is less than optimal in energy conversion.

The turbine selected in this design work is a screw turbine, a turbine with a screw-shaped rotor / blade inserted on the stator of a rapid pipe fitted with flow guide on the inlet side and nozzle on the outlet side so that the turbine can be mounted at an elevation close to 0o and drowned. This model is resistant to diversified waterfall levels and can be used in low flow velocity of large debit, flood resistance, dirty water (except sand deposits), and no loss of waterfall height. With careful design, we can suppress the loss of energy caused by turbulent flow, friction losses, and air bubbles. Infrastructure support for the installation of screw turbines is very simple and cheap. Provision of weirs can provide feedback to improve stability of rotation. Screw model turbine development including new model turbines developed by existing bolt turbine development models. In [6] a threshold turbine elevation study was conducted as a variable to the flow of water. Also examine the comparison of pitch distance to rotation. In [7] research is done with the emphasis of various outer sectional forms (channels) on threaded turbines. Here it is concluded that the maximum velocity occurs at the surface of the stream as big as the minimum velocity occurs on the basis of the channel. In [4] the research variables are discharge, water flow velocity, turbine rotation, the resulting torque, the magnitude of the efficiency of the available potential and the power generated.Of the several studies shown above all use a threaded turbine with a monotonic shape or a perfect thread. No other innovations..

II. MATERIAL AND METHODS

2.1 Various Kinds of Turbines

Based on the fluid momentum change, the turbine is divided into: 1) impulse turbine by principle generating impulse spin through decreasing kinetic energy of fluid flow, and 2) reaction turbine with potential water energy principle converted to kinetic energy. Types of turbines: 1) The propeller turbine has a blade that resembles a ship's propeller, mounted on the end of a fast pipe. Turbine propellers with adjustable blades are called kaplan turbines. 2) The Turgo turbine is an impulse turbine, the working principle is the jet from the nozzle hit the blade at an angle of 20o with high rotation speed, 3) Francis turbine with the working principle, when water enters the rotor, some high energy drops water converted into water velocity, the remaining high energy fall water is utilized using suction pipe to enable high energy to fall to work in the blade of the road with the maximum. All the blades are immersed in water. Incoming water is flowed through a screw-shaped house. The turbine generated power is adjusted by changing the opening position of the guide blade.) Turbine type pelton is a impulse turbine, energy coming into the blade is a kinetic energy. Usually large, high pressure and momentum changes at the blades are very large. Nozzles are used to regulate the incoming water capacity of the turbine and at the same time convert the pressure energy into kinetic. Pelton turbine have low power, discharge can be adjusted by shifting the position of the blade needle. The shape is a rim with a number of ellipsoidal elbow blades in the seamelline. 5) Other, the wheel is a wheel rotated by the water flow. This is considered to be the most effective type. The advantages are cheap, simple, easy to build and have little impact on the environment. But the efficiency is low, only good used at the speed rate and the water debit is quite heavy. Thread turbineis a turbine type with threaded blades inserted in the pipe (figure 1) [1].

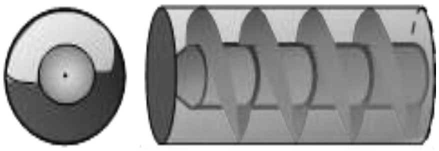


Figure 1. Thread Turbine

2.2 Turbine Analysis Theory

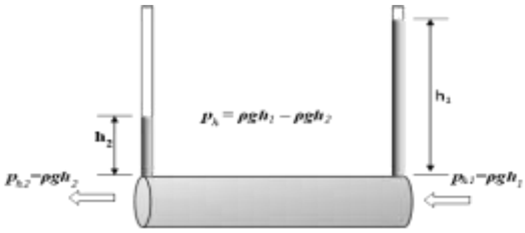


Figure 2. Difference Pressure of Inlet and Outlet in Vessel

Water produces gravity. Heavy force produces hydrostatic pressure (figure 2). The pressure at the bottom of the vessel due to the fluid as high as h becomes ph = ρgh. Potential power [2][3] generated by the flow rate and water flow height can be formulated (1):

$$P = \rho . Q . g . h \quad (1)$$

Where:

P : water power (Watt)
ρ : water density (kg/m³)
Q : water flow discharge (m³/s)
g : gravity (m/s2)
h : waterfall height (m)

While the pressure difference on the pipe relates the pipe cross section at both ends that flows with velocity v on a pipe expressed by. Bernoulli's Law [4] according to the equation:

$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2 \quad (2)$$

Figure 3. Flow of Fluid Using Pressure

The flow properties in pipes can be determined by calculating the Reynolds number:

$$R_e = \frac{DV\rho}{\mu} \quad (3)$$

Where:

R_e = *Reynolds number* μ = *fluid viscosity*
D = *pipe diameter* $v\rho$ = *mass flow rate*

2.3 Power Analysis on Turbine

Input power is the sum of losses with output power. The total losses incurred in the turbine can be measured in the manner shown in figure. 4.

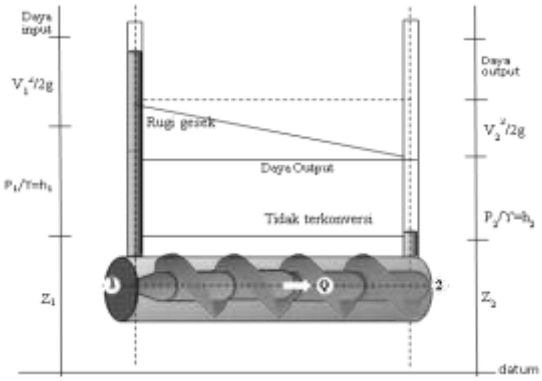


Figure 4. Energy Equations

2.4 Analyze Rotary Speed Turbine Threads

Designed with various threaded densities to obtain turbine rotation speed. Figure 6 shows: 1) 4 threads/meter, 2) 3 threads/meter, and 3) 2 threads/meters. The closer the number of threads will be obtained the faster the turbine rotation but with the lower torque. If it is considered that water flows straight then turbine rotary speed is maximum. Turbine Rotation Speed is formulated in equation 4:

$$n_{max} = 60.\ G_{threads}\ .\ V \quad (4)$$

Wheres:

n_{max} : *maximum rotation (rpm)*
$g_{threads}$: *the number of threads per mete*
V : *speed of water flow (m/s)*

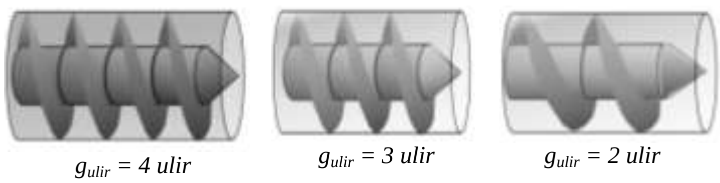


Figure 5. Definition of Number of Threads Per Meter

While the resulting torque depends on the diameter of the turbine. Particular construction to consider is the rotor diameter and the pipe diameter of the turbine with the same cross-sectional area. Here is an example illustration. Figure 6.a) has a large diameter, but with the same marking area as the figure 6.b) small diameter. To obtain optimal work required a value of comparison between the number of threads and the diameter of the turbine rotor. Figure 7 shows the prediction of turbine design values with a certain dimensional ratio to obtain optimum output power with mechanical energy values.

The circular cross-sectional area is πr^2_{L0}, whereas the area of the circular penamapang between the radius of R_D to R_L is: πr^2_L - πr^2_D, thus:

$$r_L = \sqrt{r_{L0}^2 + r_D^2} \quad 5$$

Torque:

$$\tau = \pi \, P_h \int_{r_D}^{r_L} r^2 \, dr \quad 6$$

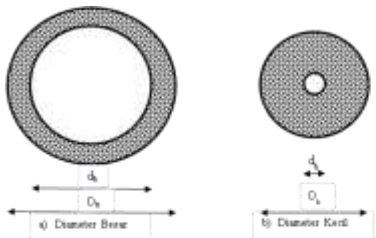


Figure 6. Comparison of Rotor Diameter On the Same Effective Cross-sectional Area

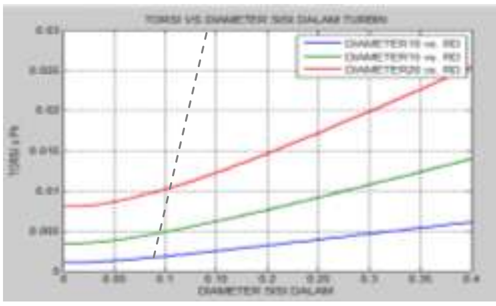


Figure 7. Torque and Turbine Rotation Speed

Figure 7 is a curve of theoretical analysis of the change of torque to the rotor diameter changes of three turbines with different discharge capacities. The dashed line shows the limits of the curve linearity.

2.5 Flow Analysis on Rapid Pipes

Rapid pipe or also called a nozzle on turbine screw has an excessive length of length compared to other types of turbines. Incorrect lengths and elevations of turbine installation can cause turbine work to be less effective ie at the turbine tail may be empty air space, as shown in Figure 8. Although turbines can still work, but the presence of empty space indicates that the turbine not working maximally or showing the lack of waterfall in either water discharge or hydrostatic pressure. To overcome this incident a turbine model with a cone shape is decoded, as shown in Figure 9. But, the speed of water in the pipe is not the same.

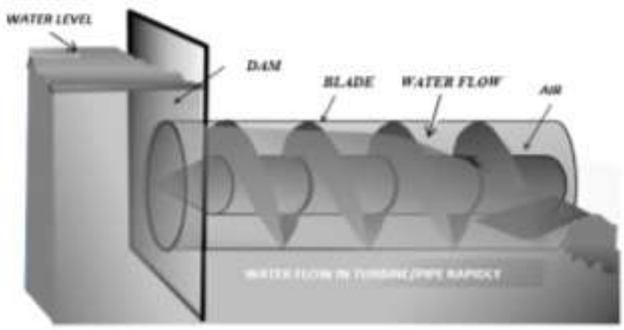


Figure 8. Empty Space on the Back of the Turbine

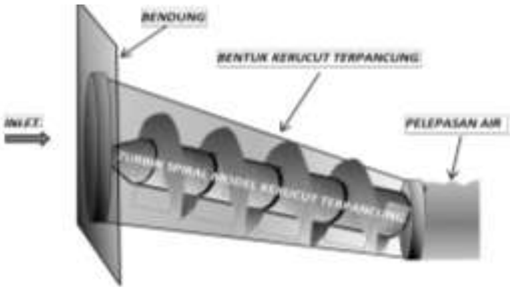


Figure 9. Thread Turbine With Pipe Conical Model

III. BASIC DESIGN

3.1 Construction and Design Variables

Threaded turbine and archimedes screws are well suited for propulsion in hydropower with low waterfall and large discharge. Variable design of threaded/screw turbine is pitch, cylinder pipe radius (R0), thread length (L), and thread slope (K), threaded shaft diameter (Ri), number of blades (N), water discharge per cycle thread. With a good design, efficiency can be achieved between 79 to 84%. Figure 10 shows the construction of a screw turbine with a unique shape. This form is designed for a variety of reasons.

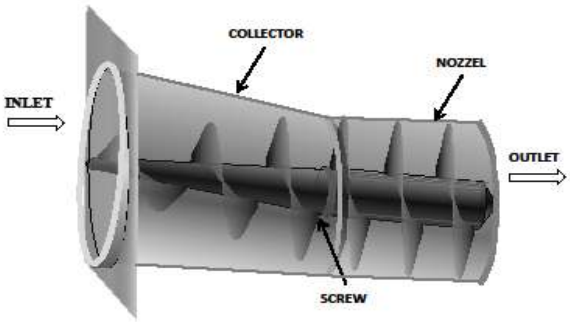


Figure 10. Turbine Screw

The installation of the turbine is horizontally submerged so that no air enters into the turbine. The tip of the rotor is made taper with a widened pipe widened in order that there is no whirlpool that can draw air into the turbine. The front-side thread has a wider pitch over the inner edge used to condition the flow of water and is designed according to the local water velocity. On the back side with a uniform pitch inside a fast pipe that resembles a nozzle to obtain steady speed and stability.

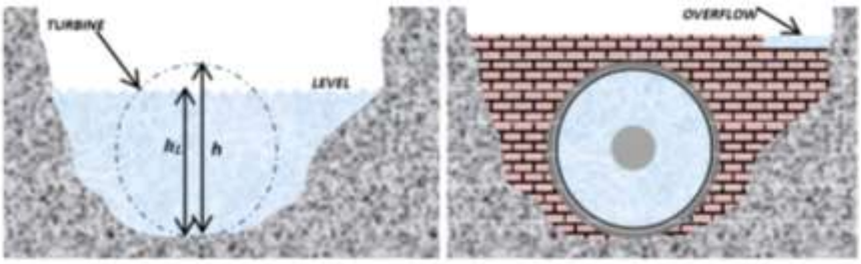


Figure 11. Level of River Water and Turbine

a) Sectional Area of The Front Side of The Turbine and Area of The River, b) Simple Weir

The design of the fast pipe diameter adjusted with the available water discharge. Calculated from the cross-sectional area of river water is equal to or greater than the area of the pipe cross section to keep the turbine always submerged in water. This can be done with the addition of a simple weir as shown in figures 11.a and 11.b.

The speed of the water flow can be used to calculate the speed of the turbine. The design of the number of blades per unit length adjusted to the need for turbine rotational speed. The calculation of effective water head (hs) is equal to the difference between the river water level in front of the weir with the water level behind the weir. If the cross-sectional area of the river flow is 0.15 m^2, then the pipe diameter of the front side is: π

$(r_{Doutside})^2$ = 0.22 meters with the front rotor diameter is considered zero. The diameter of the back side quick pipe is set at 0.38 meters with the inner side rotor diameter of 0.10 meters, so the comparison of front and rear side cross-sectional area is:

$A_{ratio} = ((r^2_{Doutside} - r^2_{Dinner})/(r^2_{Boutside} - r^2_{Binner})$.

$=((0,22^2 - 0)/(0,18^2 - 0,1^2)) = 2,16$

If the river water velocity is 0.5 m/s and is considered equal to the velocity of the water in the front side pipe, then the flow rate of water in the back pipe is 1.08 m/s. This speed has a stable tendency because if the water flow rate decreases then the water level will rise and increase the hydrostatic pressure bigger, vice versa. If the expected turbine speed is 300 rpm or 5 rps, then the number of blades per meter is:

$N_{blade} = N_{rotation}/V_{water} = 5/1 = 5$ *blade/meter*

This is the minimum blade amount, due to slip, friction, and load causing the rotation to drop by 50%, maybe, so the amount of blade required is 10 blade/meter or with a 10 cm pitch. In the same way the blade distance of the front side of the pitch is 22 cm. Figure 12 shows the number of blades and pitches required

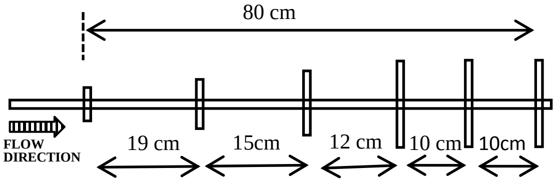


Figure 12. Blade Structure Based on Pitch

Figure 13 shows the results of the screw turbine production according to the design results. The connecting gear to the generator is mounted on the depat side due to the low water flow rate. On another occasion, the generator will be installed inside the rotor shaft.

Figure 13. Screw Turbine Production Results

3.2 Calculation of Power Availability

For calculation of power availability, it is necessary to define the waterfall height (h). In accordance with image 2 then the so-called waterfall height is the difference in the height of the water level of the front and rear of the turbine.

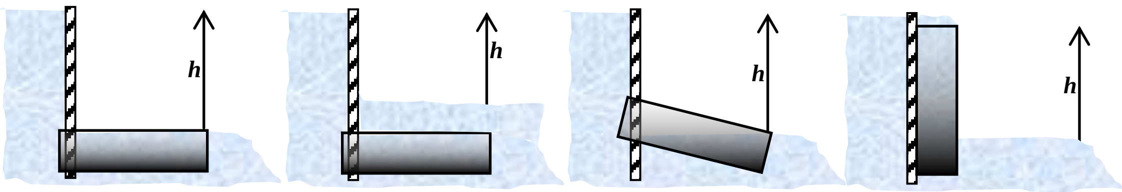


Figure 14. Determination of Altitude and Zero Point

While water velocity is calculated without friction, is V (t) = √2gh and the result is shown in figure 15.

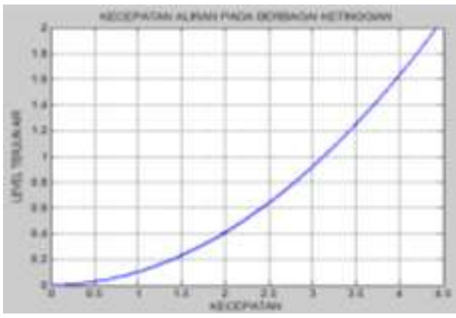


Figure 15. Waterfall Speed Various Altitude

The turbine's turning speed is very high by the airfall. While turbine rotational speed can be calculated using the equation nmax = 60. η. Gblade. V, and the results in figure. 16

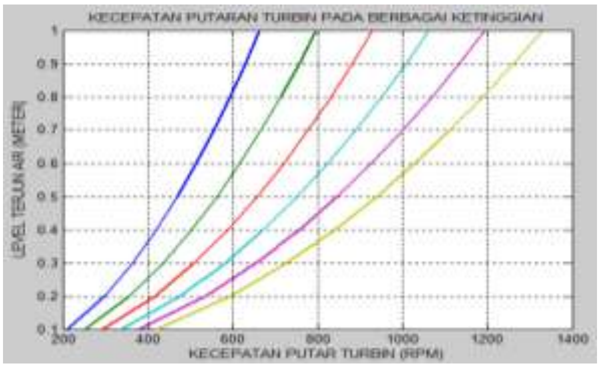


Figure 16. Turbine Rotation Rate at Waterfall Height

Minimum hydrostatic pressure occurs when the height of hs = r2Doutside r2Boutside = 0.44-0.36 = 0.08 meters. In this condition the entire turbine is submerged in water and no air enters the turbine. If the water level is less than 0.48 meters above the base of the turbine then there are some turbine blades that are not subjected to pressure so that the turbine is not working optimally. The stresses are: Ph = ρgh = 0.784 N/m2. The flow of water flow along the pipe is the same. If the velocity of the uniform flow in one of the cross-sectional areas, then the water discharge Q is the multiplication of the velocity of water flow with the cross-sectional area of water, ie $Q = AV$. For D = 0.44 meters with V = 0.5 m / s, then Q = 0.076 m3 / s. The potential power generated by the discharge and flow height of water is $P = \rho.Q.g.h$ = 0.06 watts. The result of power output analysis as a function of altitude is presented in table 1

Tabel 1. Daya Output Turbin Fungsi Ketinggian

No.	KETINGGIAN h_s (meter)	ALIRAN*) $V_{D\_aliranr}$ (m/s)	DEBIT AIR Q (m^3/s)	DAYA OUTPUT P (kw)**)
1.	0,1	3.0240	0.4026	0,395
2.	0,2	4.2766	0.5694	1,116
3.	0,3	5.2377	0.6973	2,050
4.	0,4	6.0480	0.8052	3,156
5.	0,5	6.7619	0.9002	4,411
6.	0,6	7.4073	0.9862	5,799
7.	0,7	8.0008	1.0652	7,307
8.	0,8	8.5532	1.1387	8,928
9.	0,9	9.0720	1.2078	10,653
10	1,0	9.5627	1.2731	12,477

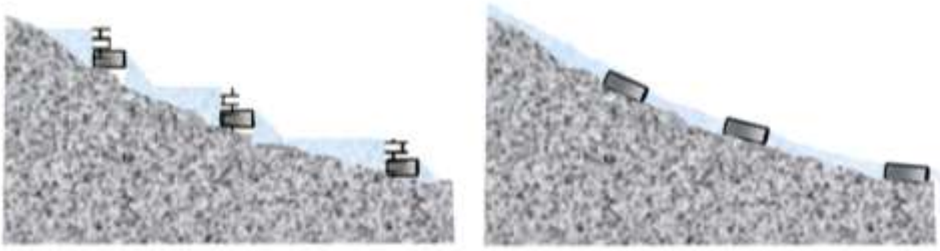
Note:

**) Using the free fall equation with Vo = 0 m / s*
***) Turbine output power with efficiency is assumed 100%*

3.3 Discussion of Design Results

There are two ways of turbine in the field, namely a) using a simple weir to obtain potential energy of water (Figure 12.a), b) direct installation (figure 12.b). To keep the effective head maximally utilized, the installation of the turbine is recommended as shown in Figure 17.a. This will also have better speed stability.

Figure 17.b shows a mounting model which prioritizes kinetic energy to be converted to mechanical energy by the turbine. This method has a tendency to have a unstable rotation, lose head because the friction also becomes larger.



(a) (b)

Figure 17. Turbine Installation(a) Models of Simple Bend Usage, (b) Direct Installation Mode

Figure 18 shows one problem: the contour of the river is widened so that it is not suitable for the implementation of the turbine type of the design result, due to the still large number of unused water discharge in the energy conversion process. Increased efficiency is done by using a lot of tubin although it is still less effective

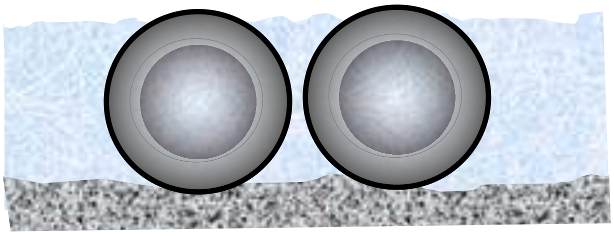
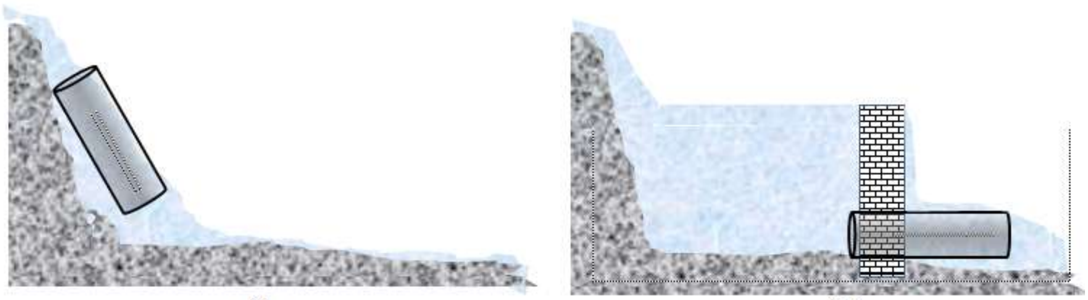


Figure 18. No Compatible River Flow



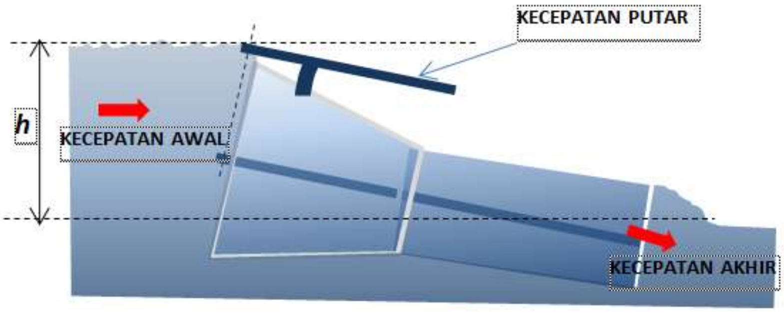
(a) (b)

Figure 19. Alternative Installation of Turbines at The Waterfall(a) Vertically, (b)Horizontally

The waterfall has a large enough potential/kinetic energy. Figure 19 shows two ways of mounting a turbine on a field that has a waterfall. The mounting method shown in Figure 19.a has many disadvantages: much water does not pass through the inside of the turbine, air can enter the turbine, the majority of which is only kinetic energy converted to mechanical energy, and unstable turbine spinning. All these losses will decrease the efficiency of energy conversion, besides that turbines are not designed for such treatment. It is therefore recommended that the mounting procedure as shown in figure 19.b be treated according to the design of the turbine in terms of rotational stability and energy conversion ie the conversion of potential energy.

3.4 Data retrieval Method

Figure 20 shows the data retrieval method. The measurement of the waterfall height is measured by the refresh of the water level puddle on the back side of the turbine. The speed of the flow of water in the turbine at the cross-sectional position therein is considered uniform, althought the top or bottom side because the turbine has been designed so. More accurate data retrieval will be obtained if it is done with a height of more than one meter so that all ripples (less than 10 cm) that occur can be ignored. But this is not done because all the equipment is less meet the safety standards



Gambar 20. Metoda Pengambilan Data

The results of turbine design and manufacture are tested under actual conditions. Then take the data as follows:
1) The water falling height changes with zero turbine spin, then recorded the torque.
2) The height of the water fall turns and the turbine spins free to get turbine rotary speed with no load
3) Turbine is loaded (retaining) then measured retention and rotation speed

IV. DATA AND DATA ANALYSIS

4.1 Data Testing Results

The efficiency (η_s) of the turbine rotation is the difference in the velocity of water flow to turbine rotation rate. If the flow of water moves straight is not affected by the turbine spin then it is defined $\eta_s = 1$. This event can hardly occur because the behavior of water is very easy to move in all directions. Table 2 shows the turbine rotation rate values theoretically by using the free fall equation. This approach is done because it is still difficult to find a reference to analyze the case. For ease of observation then it is presented for rotation efficiency value from 0.5 to 0.9.

If the power (*P*) is in kilowatts and the rotational speed (*N*) in rpm, theoretically the torque generated by the turbine can be calculated using the equation: $\tau = (975 \times P) / N$ and the result is shown in table 2.

Table 2. Theoretical Torque and Rotate Rate

High Waterfall (cm)	Theoretical Rotation Rate (rpm)					Theoretical Torque Generated (Nm)				
	η_s =0,5	η_s =0,6	η_s =0,7	η_s =0,8	η_s =0,9	η_s =0,5	η_s =0,6	η_s =0,7	η_s =0,8	η_s =0,9
0,1	210	252	294	336	378	4.39	3.66	3.14	2.74	2.44
0,2	296	356	415	475	534	8.78	7.32	6.27	5.49	4.88
0,3	363	436	509	582	654	13.17	10.98	9.41	8.23	7.32
0,4	420	504	588	672	756	17.56	14.63	12.54	10.98	9.76
0,5	469	563	657	751	845	21.95	18.29	15.68	13.72	12.20
0,6	514	617	720	823	925	26.34	21.95	18.82	16.46	14.63
0,7	555	666	777	889	1000	30.73	25.61	21.95	19.21	17.07
0,8	593	712	831	950	1069	35.12	29.27	25.09	21.01	19.51
0,9	630	756	882	1008	1134	39.51	32.93	28.22	24.70	21.95
1,0	664	796	929	1062	1195	43.90	36.59	31.36	27.44	24.39

In table 3 shown data measurement results both conditions, without load or burden. $N = 0$ means that the data obtained is static torque, and $\tau = 0$ means that the measurement is carried out under no-load conditions and the turbine is allowed to run free. In taking this data there are some variables that are difficult to observe, namely: initial velocity of inlet, flow velocity in turbine, and final velocity of discharge stream. At larger speeds will also increase turbulence on the front and rear of the turbine, but inside the turbine does not occur the process of cavitation. The measured variables are the average flow rate in the turbine, the resulting torque, and the rotational speed, respectively in some conditions.

Table 3. Result Measurement Data of Torque , Rotation Speed Versus Head

		N = 0			***τ = 0***	
No	*h*	*τ* (N-cm)	*Q (%)*	*V(m/s)*	*V*	*N* (rpm)
1.	0,30	19	70	THE	THE	126
2.	0,40	46	90	DIFFERENCES	DIFFERENCES	208
3.	0,50	86	100	OF SPEED IS	OF SPEED IS	231
4.	0,60	132	100	HARD TO BE	HARD TO BE	272
5.	0,70	170	100	KNOWLEDGE	KNOWLEDGE	311

Wheres:
h : waterfall height (cm)
τ : torque (Nm)
N : speed of rotation (rpm)
V : flow rate (m/s)

Observation of the loading on the turbine, in fact, if the turbine is loaded so that the measured torque to live 9 N-cm turned out to decrease the speed to 96 rpm. The problem with this measurement is the difficulty of determining the constant load (the load always changes) so that its appointment at the torque meter is also always on the move, this change is less visible on the rotation. This occurs when the measurement is a cycle count, whereas the change in the occurrence of cycles occurs in each cycle, so that counts remain the number of cycles per minute

4.2 Analisa Data

In the design of this turbine the flow of water on the inlet side is considered calm and has no speed with unlimited volume and constant level. In fact, the flow of water has had speed before entering the turbine, this is an advantage. The speed will accelerate and accelerate when it enters the turbine caused by the hydrostatic pressure of the water itself and the suction power of the turbine blades

If it is said that the rotational speed of the turbine of the screw archimedes is not affected by the operating conditions **[7]** it must be treated by the ideal conditions approach. But in reality in lapanggan will be very different and the condition is no longer ideal as it has been done in the laboratory. Some difficulty factor factors should be considered specifically for turbines to work optimally, even increasing turbine efficiency, or optimizing available waterfall energy. In order to achieve maximum power, it should be noted that the mounting elevation, in addition to the turbine has been designed to have a certain elevation still needs to be rearranged in its installation by increasing the slope of the turbine slope to about 10 degrees. The front side of the turbine is made with a slope of 80 degrees, so it resembles an aerodynamic shape. The addition of a turbine slope that is not too large can increase the performance of the engine because the flow of water does not veer sharply. This Kimiringan has been linked in its design and manufacture. The addition of a suction pipe on the back side may also be required depending on the field conditions.

The characteristics of this turbine are very good and suitable for river rivers with low slope and waterfall. This type of turbine rotation does not have a meaningful overshot, it also has good stability at certain loading limits, but the condition will be worse if the load increases in excess because it can cause direct rotational speed will decrease drastically. In non-rotating conditions will lose considerable torque compared to spinning conditions. Precisely with the addition of flywheel with a moment of great inertia will increase overshot. Therefore, it is preferable that turbines be loaded which may cause a reduction of turbine rotary speed not more than 10% to rotation at zero load (considered maximum rotational speed). In this area will have optimal output power with good stability. Although the 10% rotation range and efficiency rates of up to 80% in this study are not perfect and less accurate, this is important information for the continuation of subsequent research. These accurate figures do not appear in the measurement data, but the numbers are close to the truth.

Other numbers that can be utilized from the results of this study is the comparison of the maximum turbine rotor rotational speed (as if the water goes straight / does not follow the turbine flow) to the reality round is between 0.5 to 0.7 and this does not mean that the value in the middle- the middle of which is 0.6 is the most correct value. The data is suitable for the design turbine with a 10 cm uniform pitch with a threaded amount of 3 pieces positioned in a fast pipe / nozzle and 4 screw pieces with a distance of a series of diameter conical with position inside the collecting pipe.

Designed turbine has the following disadvantages: 1) less precision which can lead to the formation of a wide intercept between the blade with a fast pipe resulting in wasted stream and can cause waste or other objects to be spilled within the sidelines between the blade and the wall rapid pipe, 2) incomplete ratio of front and rear side diameter ratios causing the front side turbulence and turbulence on the back, and 3) the occurrence of loss of falling water altitude caused by incorrectly installed turbine elevation. If the back side is depressed it will reduce the nozzle effect, but if not drown will lose the height of falling water as high as the pipe diameter of the back side. Such conditions can be overcome by the addition of suction pipe on the back side.

V. CONCLUSION

1) To avoid the occurrence of abnormal flow should be used rapid pipe construction in two parts, namely the nozzle and collector/conditioning side with the distance of the blade on the rotor (pitch) is not the same but the measuring row adjust the position in the pipe rapidly.
2) The speed of turbine rotation is influenced by the number of threads per unit length whose value is limited by flow velocity and form factor along with other friction on the turbine. The value of the ratio between the

maximum speed of the rotor rotation (theoretical rotation of the flow of water straightly/does not follow the turbine blade flow) of the reality cycle is 0.5 to 0.7.

3) The ratio of the area of the inlet and out side turbine sections should be greater than 2 times, and the installation of turbines with a 10 degree slope to improve turbine performance and reduce turbulence on the turbine discharge side.
4) Turbine will work optimally if the torque and speed of rotary turbine output is selected comparison between fast pipe diameter/nozzle and turbine rotor diameter (turbine shaft) whose value is limited from the availability of waterfall energy

Implications

It is necessary to design a turbine with easily modifiable construction to adjust the waterfall availability behavior and facilitate the setting of necessary parameters in order to obtain the most optimal level of efficiency.

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