Prototype Design Of Micro Hydro Using Turbine Archimedes Screw For Simulation Of Hidropower Practical Of Electro Engineering Students

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Abstract - Micro Hydro is a micro hydropower plant (MHP) on a small scale. The main problem from micro hydropower plants is a water discharge which it's flow is not continued every year because influenced by weather season. To knowing a right of micro hydro 's characteristic is not an easy thing to learn it, because a characteristic each of micro hydro's installation location is considered a specific location. One type of micro hydro is using Archimedes Screw Turbine. Udayana University of Electrical Engineering Department in this time does not have a facility for the hydropower field to use this model, so a college student less to receive a knowledge of this. Through this research, a writer wants to expand a college student's knowledge in the hydropower field with creating a prototype of micro hydro with Archimedes Screw Turbine to hydropower practical in a laboratory. In this study will discuss the influence of water pressure and slope of the altitude angle on the rotation produced by the Archimedes screw turbine so that it can be seen the voltage, current, power generated by the generator, torque and efficiency. The result of from handmade equipment for this research in angle 40^0 with biggest generator round (rpm) is 3765 (rpm) and highest power is 10.91096 watt, torque is 0.60257 Nm dan efficiency is about 14.07 %. The torque which resulted from water pressure 24 psi is 0.703 Nm and efficiency 17.594 %. The voltage, current, and output power which resulted in the generator is 83.8 Volt, 0.1932 Ampere and 1619 Watt. For generator speed round in the pressure, 24 Psi is 4579 rpm, while turbine speed round which resulted from the pressure 24 Psi is 380 rpm before coupled with the generator and 220 rpm after coupled with a generator.

Index Term : Prototype MHP, Archimedes Screw Turbine, Screw Angle, Pressure, efficiency

I. INTRODUCTION

Micro hydro or so be called Microhydro Power Plants is a small scale power plant which use water power as a power drive such as irrigation drain, river, or nature waterfall with a made use of its water level (head) and a total of water debit. One of the most important components in a micro hydropower plant is a turbine. Turbine has a function to convert energy potential and kinetic energy from water to mechanic energy. There is a lot of turbine type which used in micro hydropower plants, one of those is Screw Turbine. Screw Turbine is one of the turbines which is working to an area that had the lowest head such as irrigation drain.

The research which will discuss is Micro hydropower plants with using Screw Turbine. This turbine is operated with low round and it's still new in Indonesia. Especially in Bali already developing Micro Hydro Power Plants with Screw Turbine which developed in Jatiluwih tourism region, Tabanan District. The research very difficult to do in real conditions to do because some factor that slowing the research such as nature factor, environmental factor, economic factor, and culture customs factor. From that, the researcher interested to create a prototype of Micro Hydro Power Plants with laboratory scale Screw Turbine and practical purpose. With this prototype can learned directly characteristics micro hydro which is very useful for college student. This study will specifically study the effects of water pressure, slope angle to get maximum output power from a microhydro prototype.

II. METHOD

WATER POWER PLANTS

A. Micro Hydro Power Plants

Micro hydro or so be called Micro Hydro Power Plants, is a small scale power plant which use water power as power drives such as irrigation drain, river, or nature waterfall with a made use of its high touch (head) and a total of water debit. Technically, micro-hydro has three main components that are water (as an energy source), turbine and generator. Micro-hydro get the energy from water flow which has a certain height difference. Basically, micro-hydro make use of waterfall potential. Higher of the waterfall, then bigger water potential energy that can be changed to electric energy.

A principal of Microhydro Power Plants is using a water debit total which flowing in river flow, waterfall, or drain and use the difference of water flow heights. A water flow that impacts to turbine causing turbine will round so would produce mechanic energy. Mechanic energy which produced then will move a generator and producing electric energy. [1][2][3]

B. Screw Turbine Slope

The sharp position of the tilt of the turbine Screw to determine the high speed and water pressure in moving the turbine, the greater the pressure or speed of the water, the turbine power rotation will be faster which gives the output power effect generated from the generator, as in Figure 1. However, the slope excessive will cause reduction [2]

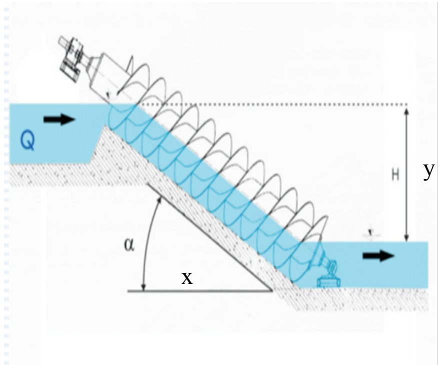

Figure 1: Screw Turbine Slope

Slope degree can be determined with a equation :

$\tan \alpha = y/x \quad \alpha = \tan^{-1}(y/x)$ ……………………..….(1)

Where :

Tan α = slope degree
y = vertical range
x = horizontal range

Power which produced in Micro Hydro Power Plants modelling with screw turbine can be calculated with a equation :[3]

$Pout = V \, . \, I$ …………………………………...(2)

Where :

Pout = Output Power (watt)
V = Voltage (*Volt)*
I = Current (A)

C. Archimedes Screw Turbine

Archimedes Screw Turbine (Archimedes Screw) is one of a special turbine because can be operated to a very low area. Archimedes screw consisting helix surface which around cylinder axis center such as Figure 2. [4] When used as a pipe, the screw usually rotated by the generator or manual power force. When the axis is rotated, the lower end rolls up water volume that called bucket. These water will launch to the spiral tube until finally burst out from the upper screw. Screw pump used especially to flowing water out from mine or another area from the lowest water. Opened trough and overall design make possible of debris track without clogging

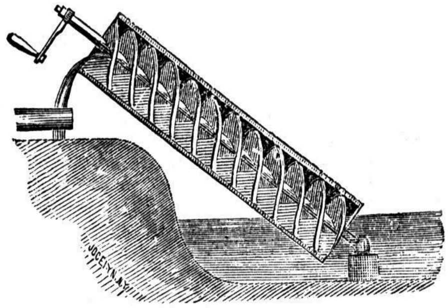

Fig. 2: Archimedes Screw Turbine

Beside known as screw turbine, corresponding with a first concept, these turbine is also called Archimedes Screw. Screw turbine is a better use of low head or different elevation between low flow even zero upstream and downstream. Archimedes screw turbine can be used in low water hydro site as a tool producing electric. This can be done with operating Archimedes Screw reversely, is dropping water from above and let screw rotates when water is drop down. This is an economical way and efficient to generate an electric from a small flow. The screw is rotated and generate electric because of hydrostatic pressure from water in screw surface. When water is filling screw from entrance line in a top of the slope, a pressure at helix field's screw makes possible to screw rotation. These Archimedes screw's work principal is, water from top end flowing into the space between blade screw range and flow out from the bottom end, so will inflict water gravity and hydrostatic pressure difference in the bucket around rotor that pushing blade screw and rotate a rotor in its axis. Then the turbine rotor will be rotates electric generator which is connected with a screw turbine's top end axis.

D. Archimedes Screw Turbine Advantage

There is an advantage of Archimedes Screw Turbine compared of another turbine is :

1) Good developed to an area which has bigger water source debit but has a small head.
2) Not need a complicated control system just like other turbines.
3) Water pressure of the turbine is not damaging ecology, in other words, impact to water species (fish).
4) It does not need draft tube so can reduce the cost to draft tube installation dig.
5) Has a high efficiency, with a big debit variation and very good to small debit water.
6) It does not need to use fine nets as a barrier of debris to a turbine, so can reduce maintenance cost..

E. Hydrolic Power and Efficiency

Water debit is a magnitude that declares how many waters flowed at one time which passing a wide cross-section. Testing of water debit is purposed to know how much water that flow in volume unit per time unit. to calculate water debit value, can use the equation below : [5]

$$\text{Debit} = \frac{\text{Vessel Volume}}{\text{Vessel Fulfilled Time}} \quad \text{……….} \ (3)$$

Hydraulic power is a power generated from flowing water from some heights. From this, hydraulic power can get from water power which generated from a pump: [5][6][7][8]

$$P = \rho.Q.h.g \ \text{………………………………..} \ (4)$$

Explanation:

P = Hydrolic Power (Watt)
ρ = Fluida/water density (kg/m^3)
Q = Water Debit (m^3/s)
g = Gravity (m/s^2)
H =*Head* or High water drop (m)

Efficiency System (Ƞ Micro Hydro Power Plants) is a plant tool ability to change kinetic energy from flowed water to electric energy. To calculate efficiency can use an equation 5: [9][10]

$$\eta_{PLTMH} = \frac{P_G}{P_H} x100\% \ \text{atau} \ \frac{P_{OUT}}{P_{IN}} x100\% \ \text{…} \ (5)$$

Explanation:

η_{PLTMH} = Micro Hydro Power Plants Efficiency System
P_G = Generator Power
P_H = Hydrolic Power

F. Torque

Torque is a magnitude which declares how much force that is working at the object so causing the rotating object. To calculate torque, can use an equation below:

$$T = \frac{P}{2\pi \frac{N}{60}} \quad \text{.............................} \quad (6)$$

Explanation:

T = Torque (Nm)
P = Power (kW)
N = Rounding Speed (rpm)

III. RESULT AND DISCUSION

A. Micro Hydro Power Plants System Model Design.

Designing Micro Hydro Power Plants System and designing turbine design which would use in this research, and design turbine which would use in this research. This is a planning table which can be seen in Table 1 and Table 2 about modeling system of Micro Hydro Power Plants in this research:

TABLE1.

MICRO HYDRO POWER PLANTS PLANNING SYSTEM

Parameter	***Value***
Volume *Box*	220 liter
Head Netto	134 cm
Turbine building length	150 cm
Turbine building Diameter	28 cm
Diameter pipe	7.6 cm
Fast Pipe Length	300 cm

TABLE 2.
TURBINE SPECIFICATION

Parameter	***Value***
Turbine Diameter	26 cm
Turbine Spoke	13 cm
Blade screw thick	0.25 cm
Blade screw range	17 cm
Blade Screw height	10 cm
Blade screw amount	1 buah
Twisted screw amount	10 buah
Blade screw angle	24^0
Main Axis Diameter	2.5 cm
Outer Axis Diameter	6 cm
Main axis length	215 cm
Outer axis length	150 cm
Turbine Heavy	24 kg

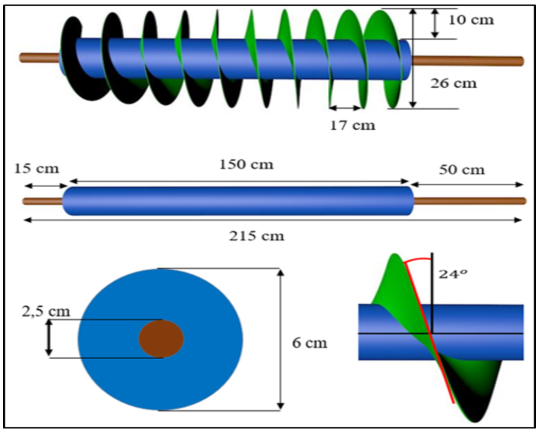

Fig. 3. Planning Design

B. Prototype Creation

In a later testing, prototype is formed within 2 type, it is to measurement of effect tubine head slope and effect of water pressure.

1. Slope Modelling dan how it works

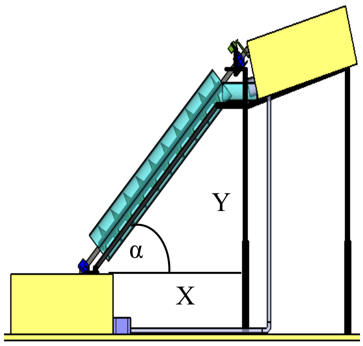

Fig 4. Turbine Head Modelling Position

The way work for this modeling is a pump will be drawn water in the bucket, and then water will be flowing through a pipe to water shelter, which it's installed in turbine head, collect it back to a bucket. The water will be flowing to the turbine strip and the turbine is rotating so will cause turbine mechanic energy to be rotates; a turbine is connected with a pulley turbine through an axis. With a belt, turbine pulley is connected with a pulley, which is already connected to generator rotor (pulley generator). The generator will change mechanic energy from the turbine into electric energy. To measure turbine spin and generator, it uses with a tachometer while voltmeter and amperemeter are used to measure voltage and current which generated through a generator.

2. Pressure Modelling

The way it works for this modeling is first, the water in the tub is pumped up (see fig. 5), then the water will flow to the Archimedes screw turbine blades. Water from the top end of the pipe flows into the space between the screw in the ranged blade and the lower end comes out. This will cause a difference in water gravity and hydrostatic pressure around the axis of the turbine and the turbine axis rotating on its axis. Then the pulley at the top end of the turbine axis rounds up the electric generator, which connects to the pulley in the generator. In a generator, he has installed a voltmeter and an ammeter to measure the voltage and current, which is produced from a generator. Manometer devices are installed in pipes to measure water pressure while tachometers are used to measure turbines and turbine generators.

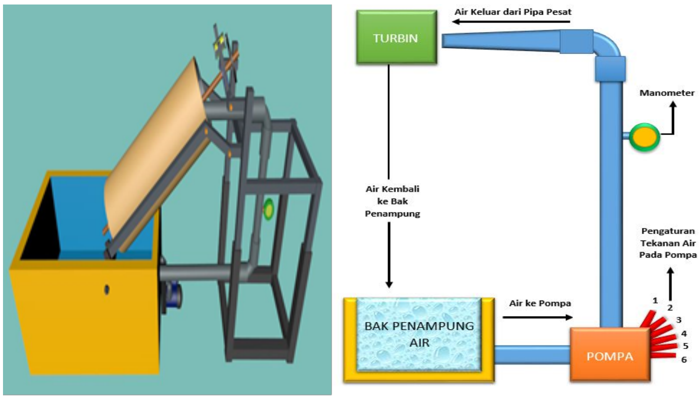

Fig. 5. Water Pressure Measurement Modelling

C. Realization Of Screw Mhp Prototype

a) Model of Slope Degree b) Model of Water Pressure

Fig. 6. Realization Of Screw Mhp Prototype

D. Measurement and Calculation Effect Of Slope Degree

Data analysis in this research using quantitative data. A quantitative data in this research is got from every testing result where the testing is done by 5 times measurements every parameter to get an accurate result with screw turbine head slope angle variation and water pressure. From five testing, its data result is an average of the testing. In this testing, angle α thus creating a variation with change heights corresponding with water drop at pinwheel from turbine head angle position at 0^0, 10^0, 15^0, 20^0, 25^0, 30^0, 35^0, 40^0, 45^0, 50^0, 55^0, 60^0, 70^0, 80^0 and 90^0

1. Calculation Of Slope Degree

In this measurement needs to be determined a stable water debit in order the result of measurement is not changed. The capacity of water used is 210 liters and the time needed for filling is 36 seconds.

$$Q = \frac{210}{36} = 5.83\,\mathrm{lt/s}$$

Slope degree measurement is determined with knowing vertical range (y) and horizontal range (x) and determined with an equation which calculated from 10^0 :

$\tan\alpha = y/x \quad \alpha = \tan^{-1}(y/x)$
$\tan\alpha = 36/210 \quad \alpha = \tan^{-1}(36/210) = 10^0$

TABLE 3
CALCULATION OF SLOPE DEGREE

Vertical Range (y) (cm)	Horizontal Range (x) (cm)	Slope Degree α^0
0	215	0
36	210	10
55	205	15
72	200	20
89	195	25
104	190	30
120	185	35
134	180	40
147.5	175	45
160	170	50
173	155	55
186	145	60
196.5	100	70
205	65	80
215	0	90

2. Calculation Of Hydrolic Power

To know about hydrolisis power or power which resulted from water from some heights calculated from angle 10^0, because from an angle 0^0 it's have no heights, a calculation can be done with this equation :

$P = \rho.Q.h.g = 1000*0.0059*0.36*9.81 = 21.89$ watt

TABLE 4
CALCULATION OF HYDROLIC POWER

Angle α^0	Heights *(head)*	Hydrolic Power / Pin
0	0	0
10	36	21,89
15	55	31.83
20	72	41.67
25	89	51.51
30	104	60.19
35	120	69.45
40	134	77.55
45	147.5	85.37
50	160	92.6
55	173	100.13
60	186	107.65
70	196.5	113.73
80	205	118.65
90	215	124.43

3. Pout Calculation

Using equation 2 can be calculated Pout

TABLE 5

MEASUREMENT AND CALCULATION THE EFFECT OF ANGULAR HEIGHT

4. Calculation of efficiency and Torque

No	Turbine Angle α^0	Turbine Round (rpm)		Generator Round (rpm)	Without Loss			60 watt lamp		
		Before Coupled	After Coupled		V (volt)	I (mA)	P (watt)	V (volt)	I (mA)	P (watt)
1	0	-	-	-	-	-	-		-	-
2	10	183	14	344	18.2	-	-	-	-	-
3	15	211	44	525	25.1	-	-	12.5	72.41	0.905125
4	20	260	73	2141	42.1	-	-	24.32	104.51	2.541683
5	25	282	132	2573	66.38	-	-	42.38	120.44	5.104247
6	30	290	141	2816	70.32	-	-	51.47	129.36	6.658159
7	35	293	159	3516	84.33	-	-	58.54	137.44	8.045738
8	40	301	173	3765	101.53	-	-	73.43	148.59	10.91096
9	45	294	160	3562	98.65	-	-	69.42	146.44	10.16586
10	50	273	133	2626	60.69	-	-	48.53	118.14	5.733334
11	55	269	108	2591	55.71	-	-	28.33	94.44	2.675485
12	60	256	92	1862	45.29	-	-	22.6	90.53	2.045978
13	70	252	72	1841	38.36	-	-	20.32	81.41	1.654251
14	80	180	-	-	-	-	-	-	-	-
15	90	168	-	-	-	-	-	-	-	-

Using equation 5 and 6 can be calculated through Efficiency and Torque. To measure maximum efficiency at angle 40^0 :

$$\eta = \frac{P_{out}}{P_{in}} x100\% = \frac{10.91096}{77.55} x100\% = 14.07\%$$

To measure maximum Torque at angle 40^0

$$T = \frac{P}{2\pi \frac{n}{60}} = \frac{10.91096}{2 * 3.14 * \frac{173}{60}} = 0.60257 Nm$$

TABLE 6

EFFICIENCY CALCULATION

Turbine Angle	Input Power	Output Power	Efficiency (%)
0	0	0	0
10	21.89	0	0
15	31.83	0.905125	2.843622
20	41.67	2.541683	6.099551
25	51.51	5.104247	9.909235
30	60.19	6.658159	11.061902
35	69.45	8.045738	11.584936
40	77.55	10.91096	14.069581
45	85.37	10.16586	11.908000
50	92.6	5.733334	6.191505
55	100.13	2.675485	2.672011
60	107.65	2.045978	1.900583
70	113.73	1.654251	1.454542
80	118.65	0	0
90	124.43	0	0

E. Measurement and Calculation Effect Of Water Pressure

To water pressure is the same. it's data taken from an average of 5 testing. It's testing data taken from 4 psi, 8 psi, 12 psi, 16 psi, 20 psi, and 24 psi.

1. Pout Calculation

Using equation 2 can be calculated Pout

TABLE 7
MEASUREMENT AND CALCULATION EFFECT OF WATER PRESSURE

No	Water Pressure (psi)	Turbine Round (rpm)		Generator Round (rpm)	Without Loss			Loss		
		Before Coupled	After Coupled		V	I	P	V	I	P
1	4	176	-	-	-	-	-	-	-	-
2	8	222	48	942	29.1	-	-	14.9	0.0873	1.3008
3	12	280	127	2250	57.8	-	-	30.1	0.1043	3.1394
4	16	319	181	3850	102.5	-	-	70.6	0.1492	10.534
5	20	352	202	4239	106.7	-	-	77.3	0.1611	12.453
6	24	380	220	4579	117.2	-	-	83.8	0.1932	16.19

TABLE 8
MEASUREMENT OF WATER PRESSURE AND WATER DEBIT

No	Tekanan Air (psi)	Volume *Box* (liter)	Waktu (s)	Debit Air (liter/s)	Debit Air (m^3 /s)
1	4	220	53	4	0.0040
2	8	220	49	4.3	0.0043
3	12	220	43	5	0.0050
4	16	220	34	6	0.0060
5	20	220	32	6.6	0.0066
6	24	220	31	7	0.0070

2. Calculation Of Hydrolic Power

Using equation 4 can be calculated Hydrolic Power

TABEL 9.
HYDRAULIC POWER CALCULATION

No	Water Pressure (psi)	Density of water	Gravity	Water discharge	High water falls *(m)*	Hydrolic Power (watt)
1	4	1000	9.81	0.0040	1.34	52.582
2	8	1000	9.81	0.0043	1.34	56.525
3	12	1000	9.81	0.0050	1.34	65.727
4	16	1000	9.81	0.0060	1.34	78.872
5	20	1000	9.81	0.0066	1.34	86.760
6	24	1000	9.81	0.0070	1.34	92.018

3. Calculation of efficiency and Torque

Using equation 5 and 6 can be calculated Eficiency and Torque.

TABEL 10
CALCULATION OF EFFICIENCY AND TORQUE

No	Water Pressure (psi)	Generator Power (Watt)	Hydrolic Power (watt)	Putaran turbin After Coupled	Efficiency PLTMH (%)	Torque (Nm)
1	4	0	52.582	0	0	0
2	8	1.3008	56.525	48	2.3012826	0.258917
3	12	3.1394	65.727	127	4.7764237	0.236175
4	16	10.534	78.872	181	13.355817	0.55604
5	20	12.453	86.760	202	14.353389	0.588999
6	24	16.19	92.018	220	17.594384	0.703098

The results of measurements and calculations from each table that the effect of water pressure increases the torque, efficiency also increases. The maximum torque and efficiency at 24 psi is 0.703 nm and 17.594 %.

IV. CONCLUSION

1. Test Results The microhydro prototype works well. In this study, the turbine angle at 40^0 is very effective to produce the largest rotation (rpm) 301 before being combined, 173 after being combined, the largest generator rotation is 3765 (rpm) and the highest power is the 40^0 turbine angle with 10.91096 watts. If the turbine slope angle is lower than 40^0, then some turbines will sink, so that the turbine rotation speed decreases, and vice versa, the turbine tilt angle higher than 40^0 water becomes lower than the turbine end the volume of water flowing into the turbine decreases thereby reducing thrust to rotate the turbine. The greatest efficiency can be obtained at an angle of 40^0 at the amount of 14.07% and the maximum torque is 0.60257 Nm.
2. Testing the change in water pressure on the Micro Hydro Power Plant model using Archimedes screw turbine, the result gets the best water pressure value of 24 psi, where the voltage, current, and power output generated from the generator are 83.88 Volt, 0.1932 Amperes and 16.19 Watts. For generator rotation speed generated 380 rpm before being combined with generator (before coupled) and 220 rpm after being combined (after coupled) with generator. The resulting torque is 0.73 Nm.
3. The biggest efficiency which got at this Micro Hydro Power Plants model is at pressure 24 Psi as big as 17.594 %. The water pressure improvement will cause Micro Hydro Power Plants system efficiency increased, where this efficiency is influenced by hydraulic power and generator power. Bigger the pressure is given, thrust force from water flow will increase further and water speed which came out from fast pipe keep increasing that hydraulic power will get bigger power. Hydraulic power which had bigger power will cause generator power output increase even more then the efficiency at Micro Hydro Power Plants system become bigger than before.

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