Preliminary Design of Micro Hydro Portable Screw Archimedes with Transmission System in Small Irrigation Channel

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Abstract: The purpose of this research was to find an optimum design of micro hydro screw Archimedes for use in small irrigation channel. This type of turbine has advantages including low head, easy maintenance and friendly to fish. From the design, the screw Archimedes turbines made with three screw blades, the thread range is 492 mm, the outer blade radius (Ro) is 112.5 mm and the inner radius (Ri) is 55 mm and uses materials from stainless and has an inclination of 20°. The frame has a dimension of 1m long, 30cm wide, and 30cm high using aluminium. The generators with an output of 0 – 24V, 3Ah battery capacity, and inverters with 500W. The rotation speed and the power generate from screw Archimedes turbines will observed with the variation. The test result showed that the screw Archimedes turbines work properly. The average rotation of turbine was about 259.4 rpm and the average generator rotation are about 768.6 rpm. The power output that produces from the system was about 27.37 Watt at 0.443 m^3/s water debit.

1 INTRODUCTION

The development of new and renewable energy is currently quite rapid. This is based on the awareness of the fact that the main energy source so far, namely fossil fuels is increasingly becoming scarce. New sources of fossil energy such as petroleum, coal was increasingly difficult to obtain. Some of the new and renewable energy sources that are quite widely used include solar energy, wind energy, water energy, biomass, and so on, all of which are energy that will never run out because they can be renewed naturally and more importantly energy. The energy is environmentally friendly because it produces low emissions and produces fewer waste products that can have a negative impact on the environment. (Garg H.P, 1995).

Hydropower system was one of the commonly renewable energy developed to produces electricity. Hydropower has a different type of turbines that used to generate electric power from the generator. A small hydropower system usually known as micro hydro. Micro hydro turbines also had many types of turbines, which the most recently studied were the screw turbines (screw Archimedes). Screw turbines have an advantage of low head operated screw turbine (H <10m) (Okot, 2013). Several studies on the development of screw turbines (screw Archimedes turbine) as a driving force for the generation of electrical energy have been carried out. Other experimental studies to optimize the design and performance of the screw Archimedes turbine were also carried out by optimizing the inner radius of the turbine and the pitch ratio of the screw (Rorres, 2000). Another method was carried out by Saroinsong, et al, 2016, by making a laboratory-scale screw turbine from acrylic material with three turbine blades, a blade tilt angle of 30° and a radius ratio of 0.54. The results showed that the screw turbine performance was maximized at low turbine shaft tilt, which automatically resulted in a better turbine when operating at low head and rotation. Many others research about development of screw Archimedes turbines also have been done, Lyon, M., 2013 made experimental results report examining the relationship between torque, rotation speed and power. The laboratory screw maintained reasonable efficiency over wide ranges of operating conditions,

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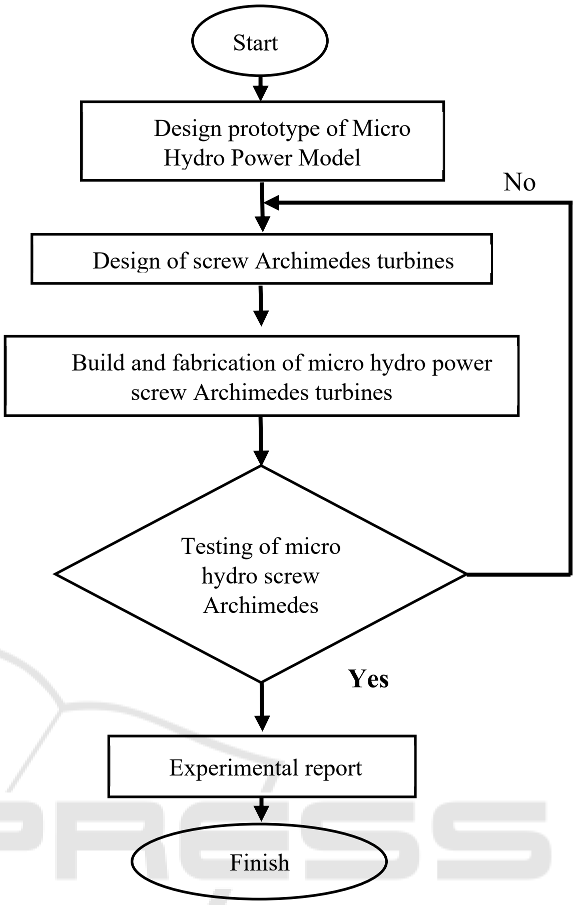
although distinct efficiency peaks were found to occur. The screw Archimedes generator power output identified changes over the varying of water level outlet. Kumar, U., 2016 also had research about screw Archimedes for used in India. The screw Archimedes generator in Micro-hydro power plant At Kabitkhedi, Indore, India was observed and the result showed that The results show that significant potential exists for energy recovery in the water industry, The water will run straight through the turbine and back into the river or stream to use it for the other purposes. This has a minimal environmental impact on the local ecosystem.

Another study on Archimedes screw turbines is also carried out numerically. (Kotronis, 2016) has carried out numerical model of the Archimedes screw turbine by developing a mathematical model using CFD by varying the geometry of the turbine, water flow velocity, upstream and downstream water levels of the turbine, and the efficiency of devices such as gearboxes and so on. Waters S, et al, 2015 conducted a review of the parameters for the optimization of the Archimedes turbine screw using CFD. Various types of applications (submerged, inclined and horizontal), were investigated, because each application method will generate electrical energy potential in different ways. The ideal conditions for micro hydro power are geographically an area that has river flows that flow throughout the year with a slope angle that is not too high, for example mountainous areas. Another requirement is high rainfall throughout the year and island areas with a maritime climate with high humidity levels. Thus, Indonesia can be said to be ideal to be a place for the development of this micro hydro power.

Bali as a developed province in Indonesia with a lot of rice field with traditional irrigation system called "***subak***" has a great potential for micro hydro system. Due to this situation in this research, there will be develop an optimal design for micro hydro screw Archimedes using small irrigational water system that suit in Bali.

2 RESEARCH METHODOLOGY

The methodology in this research were divided into two sections, the first was calculate and designing the prototype model of screw Archimedes turbines based on the topography of the irrigation channel, and the second was build and test the screw Archimedes turbines to find the performances.



3 RESULT AND DISCUSSION

The Archimedes screw type hydro power generator, as described in the background, has advantages compared to other turbine types. The working principle of the Archimedes screw turbine is:

a. Water from the top end flows into the space between the blade range (bucket)and out from the bottom end
b. The gravity of the water and the difference in hydrostatic pressure in the bucket along the rotor pushes the screw blade and rotates the rotor about its axis
c. The turbine rotor rotates an electric generator which is connected to the top end of the screw turbine shaft.

Before designing the optimum model for the micro hydro, the first step was measuring the average size of the irrigation channel.

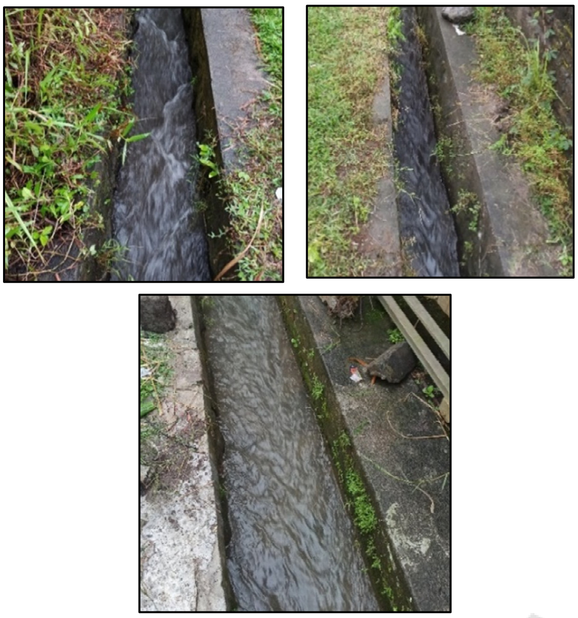


Figure 1: Irrigation water channel in Gianyar, Bali.

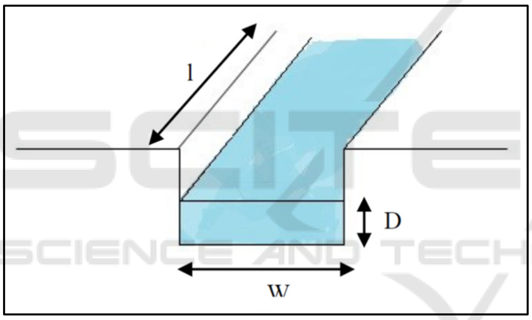


Figure 2: Schematic of water irrigation.

The irrigation channel has a rectangular shape. The dimension of the irrigation channel shown in table 1 below.

Table 1: Dimension of the irrigation channel.

No	Irrigation channel	l (m)	w (m)	t (s)	d (m)
1	Banjar Sawan	0.42	0.09	4.46	5
2	Banjar Sawan	0.38	0.05	4.44	5
3	Banjar Taruna	0.48	0.07	5.12	5

From the measure of the water velocities, can be obtain the debit of the water flow in the irrigation channel.

I. Irrigation channel 1

$Q = A \, . \, v$
$Q = 0.038 \, m^2 . \, 1.121 \, m/s$
$Q = 0.043 \, m^3/s$

II. Irrigation channel 2

$Q = A \, . \, v$
$Q = 0.019 \, m^2 . \, 1.126 \, m/s$
$Q = 0.021 \, m^3/s$

III. Irrigation channel 3

$Q = A \, . \, v$
$Q = 0.034 \, m^2 . \, 0.977 \, m/s$
$Q = 0.033 \, m^3/s$

3.1 Design of Screw Archimedes Turbines

The design of the screw Archimedes turbine was developed using the optimal design by rores. Figure 3 shown two blade turbines made by rores

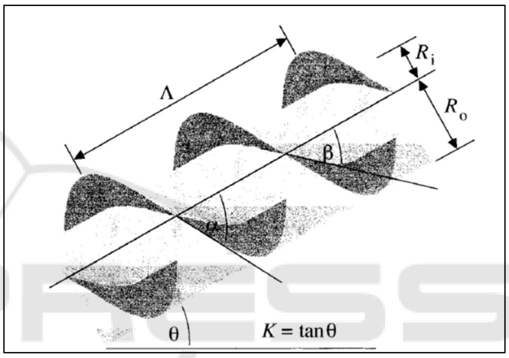


Figure 3: Two blade turbine.

The screw turbine which is designed based on the potential of available water energy sources is as follows:

- Head = 24 cm
- Debit = $0.043 \, m^3/s$

The tilt angle of the screw turbine that will be made variable is from an angle of 20°, turbine shaft length used are measure by:

$L = \frac{H}{K}$

$L = \frac{24 \text{ cm}}{0.363970234}$

$L = 65.939 \text{ cm} \quad L = 660 \, mm$

In determining the dimensions of this turbine blade, the number of threads N is 3. Referring to table 2 for N=3 is selected:

$N = 3$
$\upsilon^* = 0.2697$
$\rho^* = 0.5357$
$\lambda^* = 0.2217$

For the outer radius of the screw turbine Ro in the design selected 10 cm, which is 20 cm in diameter. As for the radius in the screw turbine Ri, the design is based on equation:

$$R_i = \rho^* R_o$$
$$R_i = 0.5357 \ x \ 10 \text{ cm}$$
$$R_i = 5.35 \ cm$$

The range of the blade Λ can be calculated. Because the angle uses below 30 then the Λ is:

$$\Lambda = 2.4R_o \ for \ \theta < 30^\circ$$
$$\Lambda = 2.4R_o$$
$$\Lambda = 2.4 \ x \ 10 \ cm$$
$$\Lambda = 24 \ cm$$

Table 2: Optimal Ratio Parameters of Archimedes Screw for Various Numbers of Blades.

Number of blades N (1)	Optimal radius ratio ρ^* (2)	Optimal pitch ratio λ^* (3)	Optimal volume-per-turn ratio $\lambda^*\nu(N, \rho^*, \lambda^*)$ (4)	Optimal volume ratio $\nu(N, \rho^*, \lambda^*)$ (5)
1	0.5358	0.1285	0.0361	0.2811
2	0.5369	0.1863	0.0512	0.2747
3	0.5357	0.2217	0.0598	0.2697
4	0.5353	0.2456	0.0655	0.2667
5	0.5352	0.2630	0.0696	0.2647
6	0.5353	0.2763	0.0727	0.2631
7	0.5354	0.2869	0.0752	0.2619
8	0.5354	0.2957	0.0771	0.2609
9	0.5356	0.3029	0.0788	0.2601
10	0.5356	0.3092	0.0802	0.2592
11	0.5358	0.3145	0.0813	0.2586
12	0.5360	0.3193	0.0824	0.2580
13	0.5360	0.3234	0.0833	0.2574
14	0.5360	0.3270	0.0841	0.2571
15	0.5364	0.3303	0.0848	0.2567
16	0.5362	0.3333	0.0854	0.2562
17	0.5362	0.3364	0.0860	0.2556
18	0.5368	0.3380	0.0865	0.2559
19	0.5364	0.3404	0.0870	0.2555
20	0.5365	0.3426	0.0874	0.2551
21	0.5370	0.3440	0.0878	0.2553
22	0.5365	0.3465	0.0882	0.2544
23	0.5369	0.3481	0.0885	0.2543
24	0.5367	0.3500	0.0888	0.2538
25	0.5371	0.3507	0.0891	0.2542
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
∞	0.5394	0.3953	0.0977	0.2471

The length of the threaded blade (L) is calculated using the Inventor engineering drawing software, resulting in a blade span length of 43.2718 cm.

3.2 Design of Transmission System

In the designing of this micro hydro turbine, it was decided to transfer the rotation from the turbine shaft to the generator shaft using pulleys and belts. The belt used is a V-belt, one of the choices for this belt is because the V-belt has a smaller slip factor than a rotating belt, the price is cheaper than a rotating belt

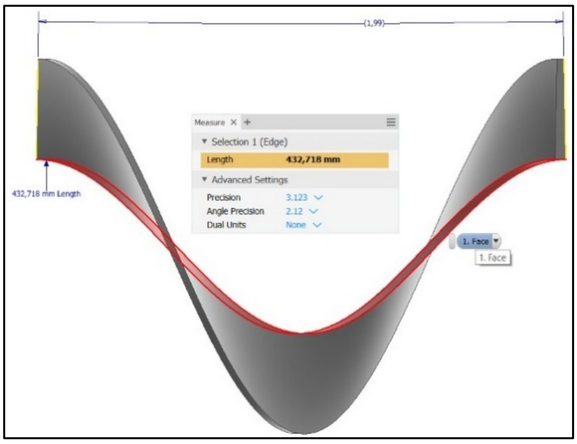
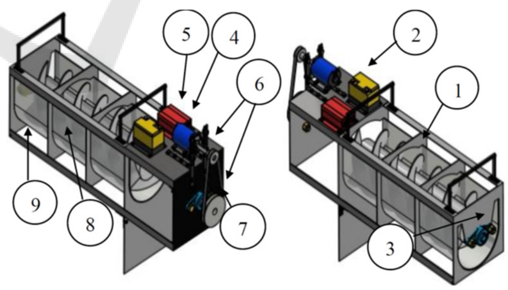


Figure 4: he length of the threaded blade, made with Inventor.

and it is easier to find in the market. The ratio of pulley was 1:3 in order to increasing the generator rotation. The frame of the turbine designed based on field surveys, most irrigation have a minimum width of 35 cm and a depth of ±12 cm, the turbine design is made as follows: length 1 m, height 30 cm, and width 30 cm.

3.3 Build and Test of the Micro Hydro Screw Archimedes

Due to the detail geometry of turbine and screw that has been calculated, then a design of micro hydro system created using CAD. Detail of the CAD system shown in Figure 5 below:



1. Screw 6. Pulley
2. Battery 7. V-belt
3. Bearing 8. Bucket
4. Generator 9. Chasing
5. Inverter

Figure 5: Design of micro hydro screw Archimedes.

From the geometry and design using CAD in Figure 5, then the prototype of micro hydro power screw Archimedes turbines was built and developed. The rotor construction has 3 screw blades, the thread range is 492 mm, the outer blade radius (Ro) is 112.5 mm and the inner radius (Ri) is 55 mm and uses materials from stainless. The frame has a dimension of 1m long, 30cm wide, and 30cm high using aluminium. The generators with an output of 0 – 24V, 3Ah battery capacity, and inverters with 500 W power. The prototype of the turbine shown in Figure 6 below:

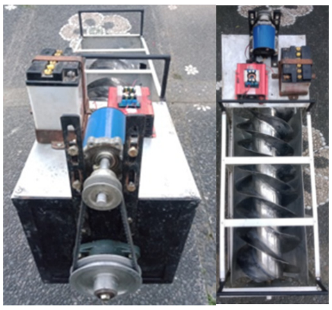


Figure 6: Screw Archimedes micro hydro.

The micro hydro power that has been built then tested in irrigation channel Voltage and current data were measured using an AVO meter, the turbine and generator rotation and were obtained using tachometer. The result shown in table 3 below:

Table 3: Micro hydro test result (Q = 0.043 m^3/s).

Time (min)	Rotation (rpm)		Output		
	Turbine	Generator	V (Volt)	I (A)	P (watt)
5	258.3	769.5	25.6	1.8	27.65
10	269.2	783.6	26.31	1.13	29.73
15	257.9	762.4	25.42	1.08	27.45
20	249.9	753.9	24.1	0.99	23.86
25	261.7	773.8	25.84	1.09	28.17

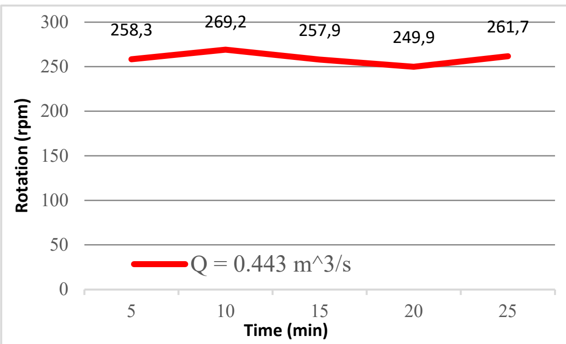


Figure 7: Turbine rotation by time.

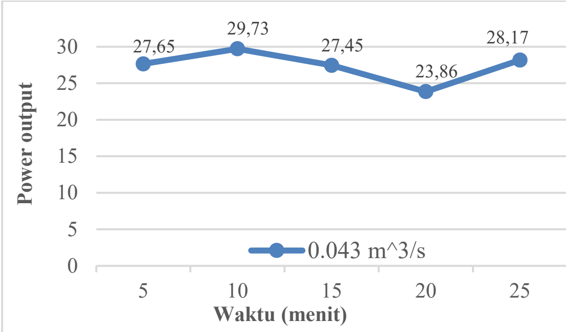


Figure 8: Power output by time.

Figure 7 and Figure 8 above showed that the micro hydro screw Archimedes that has designed and build can work properly. The micro hydro turbine can rotate in the irrigation channel and produce enough electricity. The rotation from turbine to generator increased by the transmission system. It is significant to increase the power output that generate by the generator. The average rotation of turbine was about 259.4 rpm and the average generator rotation are about 768.6 rpm. The power output that produces from the system was about 27.37 Watt.

4 CONCLUSIONS

From the discussion above about the optimal design of micro hydro screw Archimedes turbine for used in irrigation channel has a 3 screw blades, the thread range is 492 mm, the outer blade radius (Ro) is 112.5 mm and the inner radius (Ri) is 55 mm and uses materials from stainless. The frame has a dimension of 1m long, 30cm wide, and 30cm high using aluminium. The generators with an output of 0 – 24V, 3Ah battery capacity, and inverters with 500 W.
From the test result, we can conclude that the micro hydro screw Archimedes that has been build can work properly and had an efficiency about 30%.

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