International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 12 (2018) pp. 10150-10154

Experimental Study: The Influence of Shaft Slope on Rotation of the Three-Bladed Archimedes Screw Turbine

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Abstract

A study of the Archimedes screw turbine which is applied to microhydro power plants is being developed specifically regarding fluid flow characteristics associated with the performance of the three-blade Archimedes screw turbine. Flow discharge is an important factor in the study of the performance of the three-bladed Archimedes screw turbine. The purpose of this study is to determine the influence of the shaft slope on the rotation of the turbine shaft. The independent variable determined is the flow velocity of the channel of 1.88 m/s; 1.77 m/ s; 1.66 m/ s and 1.54 m/s, then the slope of the turbine shaft of 10°, 20°, and 30°. The method to be used is experimental method by making prototype or model of the three-bladed Archimedes screw turbine was made by using flexyglass material with laboratory scale. The geometric shape of three blades, 30 ° threaded angle, a radius ratio of 0.54 with a pitch of 2.4Ro. The result of this research is the slope of 30 ° screw turbine shaft, resulting in the highest turbine rotation of 416 rpm which occurs at 8 cm flow depth. While at a flow depth of 10 cm to produce turbine rotation of 402 rpm. This happens because the flow is more wasted when the flow enters the turbine.

Keywords: Experimental, screw turbine, slope shaft, rotation

INTRODUCTION

The use of electrical energy is growing as the population grows and the various facilities that depend on electrical energy. However, the availability of electrical energy from State Electrical Compani (PLN) is not sufficient to meet the needs of the people of Indonesia. Therefore, it is necessary to conduct research on the utilization of renewable energy sources which are widely owned by our country Indonesia one of which is the flow of rivers and irrigation channels. Potential river flow/irrigation can be made microhydro power plant (PLTMH). The types of well-known water turbines applied to microhydro power plants are the crossflow turbines, the Kaplan turbines, the propeller turbines, the turgo turbines, the francis turbines, and the pelton turbines. The screw turbines are a new type of water turbine under study this decade, adopted from the Archimedean screw theory. The advantages of screw turbines, among others, can operate at low head (H <10 m), do not require fast pipe, easy installation, easy maintenance and not damaging river ecology or fish-friendly (David Kilama Okot, 2013). Threaded turbines are categorized as turbine reaction types that can be used in low head (Elbatran A.H. dkk 2014). The kinetic energy and potential energy of the water stream are transformed into mechanical energy on the screw blades resulting in a rotation of the tubin shaft which can be converted into electrical energy in the generator through transmission. The density of the water on the blade causes the thread to rotate. Assuming there is no loss all potential energy in the flow can produce a maximum efficiency of 100%, (Müeller Gerald 2009).

Some researchers have developed Archimedean screw turbine research, among others, on the optimization of numerical design of screw geometry by (Rorres 2000) states that the optimum range ratio depends on the number of blades and the radius ratio (R_1/R_0) is equal to 0.54. Then (Gerber Müeller 2009) simplified the Archimedes screw theory based on geometric parameters and the ideal energy conversion process for one helical spin. The results of his research states that the efficiency of threaded turbines is influenced by geometry and flow loss. Furthermore (Nuembergk Dirk M., Rorres 2013) introduces an analytical model of screw turbine inlet inflows taking into account the possibility of leakage flow in the gap between the thread and the outer cylinder (casing) as well as the excess water at the center of the pipe. MATLAB simulation of screw turbine for hydropower in low head is done by (Ali Raza et al 2013). Modeling and torque of (Müeller Gerald 2009), (Nuembergk Dirk M., Rorres 2013), and (Ali Raza et al. 2013) they compare with experiments from Brada (1996a) and Brada (1996b). Further research was conducted by Havendry Adly and Hendro Lius (2010) regarding the determination of optimum thread angle in threaded turbine with variation of screw angle 23o, 26o and 29o. In the report explains that the screw angle 29° produces better power and efficiency compared to thread angles of 23° and 26°. Then Hizhar Yul (2011) investigated the effect of pitch and slope differences on the performance of the two-blade screw turbine model in low head flow. The result of the research is the range of 2Ro produce rotation speed higher than $1{,}6R_o$ and $1{,}2R_o$. Saroinsong Tineke (2016) reported in a study on the effect of Froude Number on the efficiency of screw turbine where the greater the Froude Number the lower the efficiency of screw turbine. The largest Frode Number occurs on a 45° axis inclination.

The study of screw turbine in experimental method still need to do to get real information for screw turbine therefore it can be applied optimally. The focus of this research is how the influence of the turbine slope on the turbine rotation of the three-bladed Archimedes screw turbine. This research is important because the slope of the shaft is a factor of head in the hydraulic power calculation. Hydraulic power is the source of power generation in the Archimedes turbine turbine. $P_{hyd} = \rho.g.Q.H$. The slope of the turbine shaft (α) is the head factor (H) of the hydraulic power calculation, where L is the length of the turbine. H = L.sin α

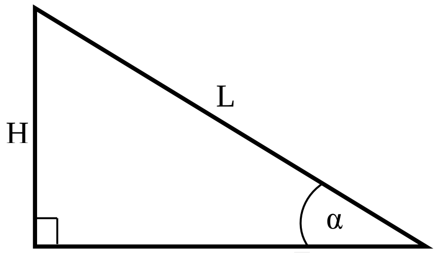

Figure 1. Sketches laying turbine shaft

2. Research Methods

This experimental research was made by simulated model of the three-bladed screw turbine as shown in Figure 2. The working fluid is water. Threaded material is made of flexyglass with pipe size for 60 mm shaft, 25 mm blade height, pitch of $2.4R_o$, radius ratio (R_1/R_o) is 0.54 and 30º threaded angle. How to get data is first setting installation according to specified parameter and calibration measuring instrument. Test running water flow from the container is flowed through the pump to the container tank by setting the discharge through the valve. Furthermore, the water entering into the tranquilizer through the pipe connection is set up until steady flow conditions. Then the flow velocity of the tank of sedation towards the rectangular channel is regulated through the high water gate by measuring the water level in the tank. The turbine inlet depth is set at the sluice gate and measured at the end of the turbine inlet. The flow of water then enters the turbine causing the screw blades to rotate and the flow back flowing to the container tank through the pump continuously. After that start the data retrieval process by adjusting the position of the shaft slope α, Measurement data taken is turbine rotation (n) using tachometer. Measurement data were taken for each variation of 0.1 m inlet depth; 0.08 m; 0.06 m; and 0.04 m with flow rate variation of 1.88 m/s; 1.77 m/s; 1.66 m/s and 1.54 m/s on each variation of α axis of 10°, 20°, 30°. The measurement data is repeated five times on each variable.

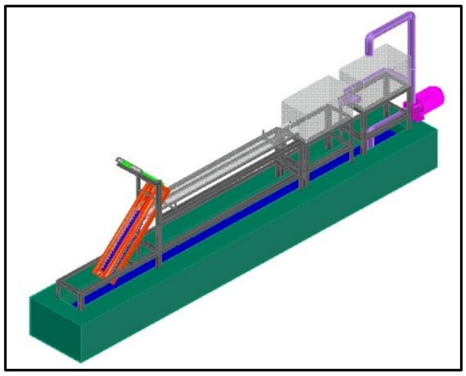

Figure 2. Three-bladed Archimedes screw turbine installation

Description of Archimedes screw turbine installation:

1. Threaded turbine model	8. Water reservoir tank
2. Pulley and belt	9. Pipe
3. Spring balance	10. Control valve
4. Measurers of inlet flow depth	11. Pumps
5. Open channel	12. Measurers depth depth in the tank
6. Water gate	13. Container
7. Water tank	14. Position tachometer

Parameter model of the screw turbine:

Parameter	value	description
Ro	0.055 m	outside radius
Ri	0.030 m	inner radius
S	0.132 m	pitch
N	3	number of blades
m	21	the number of threaded windings
β	30°	threaded angle
λv	0,059	volume ratio of each thread loop (Rorres 2000)
α	10 °, 20 °, 30 °	Turbine shaft slope

RESULTS AND DISCUSSION

The results of the experimental data retrieval can be presented through graph between the Shaft Turbine and Turbine Rotation at the Flow Rate of 1.88 as shown in Figure 3. The graph shows that the highest turbine rotation of 416 rpm occurs at a flow depth of 0.08 m with a 30 ° axis inclination. at a flow depth of 0.1 m yields a turbine rotation of 402 rpm. This occurs because the flow is more wasted when the flow enters the turbine.

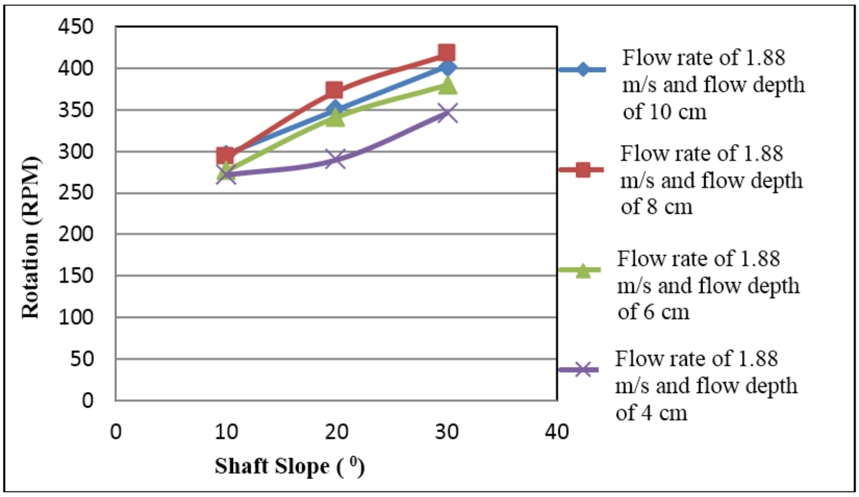

Figure 3. Graph between the Shaft Tilt and Rotation at a Flow Rate of 1.88 m/s

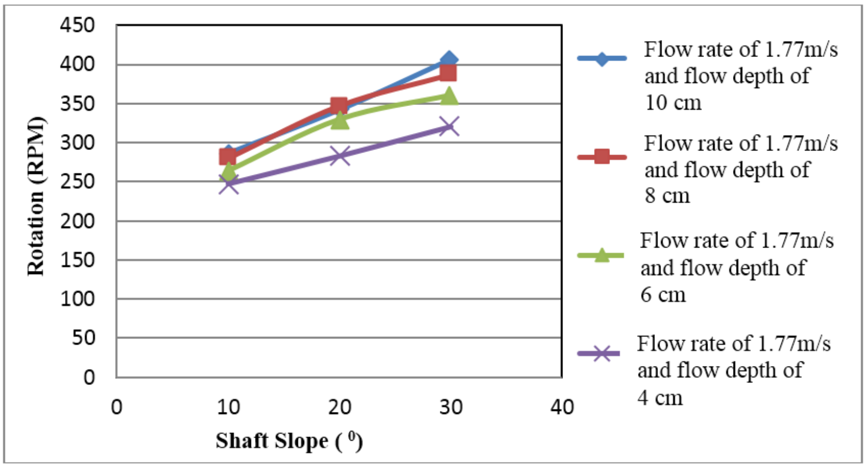

Figure 4. Graph between the Shaft Tilt and Rotation at a Flow Rate of 1.77 m/s

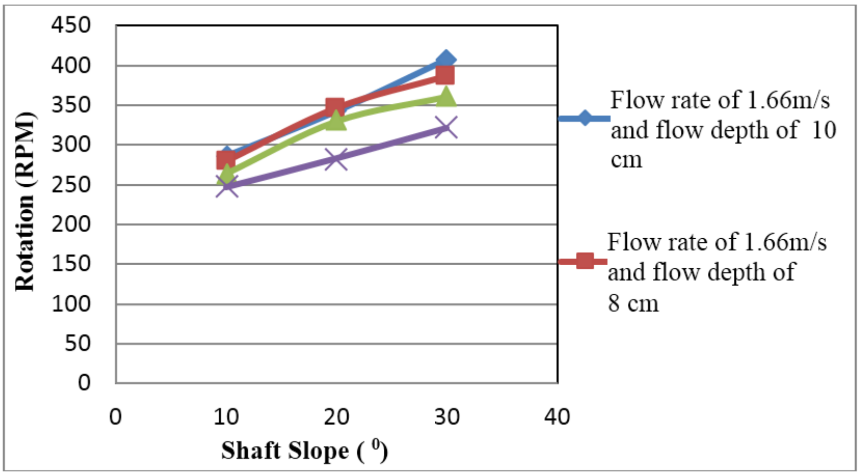

Figure 5. Graph between the Shaft Tilt and Rotation at a Flow Rate of 1.66 m/s

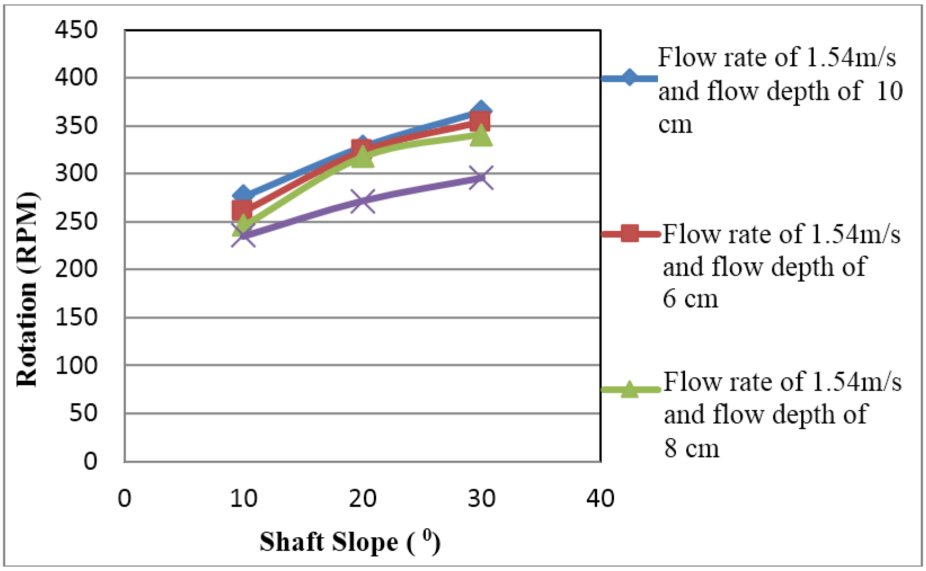

Figure 6. Graph between the Shaft Tilt and Rotation at a Flow Rate of 1.54 m/s

From Figure 3 to Figure 6 it shows that the graph shows the same tendency that the higher the shaft's tilt, the higher the turbine rotation. At a 30° of shaft slope, the maximum turbine rotation is 416 rpm. While at a 20° of shaft slope, the maximum turbine rotation is 350 rpm and at a 10° of shaft slope, it produces a maximum turbine rotation of 297 rpm.

CONCLUSION

Based on the result of this research, it can be concluded that:

1. The maximum rotation produced by the turbine is at a flow rate of 1.88 with the highest rotation of 416 rpm occurs at a depth of 8 cm flow with a 30 ° axis inclination.
2. The result of the hydraulic power calculation is 78.4 (watt), the head factor is influenced by the slope of the shaft where the greater the slope of the shaft, the greater the hydraulic power.
3. The slope of the screw shaft is good in its performance that is at 30 ° slope, which produces turbine rotation of 416 rpm which occurs at a depth of 8 cm flow. While at a depth of 10 cm flow to produce turbine rotation of 402 rpm. This happens because the flow is more wasted when the flow enters the turbine.

ACKNOWLEDGMENTS

On this occasion, the research team would like to thank the Directorate of Research and Technology and Higher Education (RISTEK DIKTI) who has provided research funding through decentralization of applied product research scheme. We also express our gratitude to the Manado State Polytechnic who has provided fund in kind in the implementation of this research.

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