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INVESTIGATION ON THE EFFECT OF DRIVE TRAIN SYSTEM FOR ARCHIMEDES SCREW TURBINE

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ABSTRACT

Nowadays, the Archimedes screw turbine has become one of alternative in generating electricity. It is low in terms of cost and sourceful as the Earth is covered more than 70% of water. The objective of this study is to investigate the effect of the drive train system that may influence, power generated from the Archimedes screw turbine. This paper focused on studying the relationship between drive train system and rotational speed. An experiment was conducted with two different types of drive train system to compare the rotational speed of the turbine at the same flow rate range from 0.012 m^3/s to 0.016 m^3/s (diameter of driver Pulley A is 102mm and diameter of driver Pulley B is 150mm). By increasing the diameter of the driver pulley up to 150mm, the maximum power generated of 0.444 Watts at low rotational per minutes (RPM) of 70. In conclusion, increase the diameter of driver pulley requires low RPM to produce maximum power output.

Keywords: archimedes screw turbine, rotational speed, experimental study.

1. INTRODUCTION

Recently, renewable energy has become a major concerned due to the growing of fossil fuels demand which is estimated to decline by 2020 [1, 2]. Several types of renewable energy that are commonly are wind, wave, solar and hydro energy. Hydro energy is currently demanding in developing countries as it is environmentally safe. The energy is not depleted throughout time. In general, hydropower plants can be classified into a numerous category, such as large, small, mini, micro and Pico which can contribute more than 100kW, 500 to 1000kW, 100 to 500kW, 5-100kW and 100W to 5kW respectively [3-5].

The Archimedes screw turbine is one of the potential selections due to its maintenance costs, environmentally friendly and good efficiency for high flow rates and low head[6, 7]. This Archimedes turbine is classified as reaction turbine as the ratio of static pressure drop across the rotor to the static pressure drop across the turbine state [8, 9]. The primary features of the Archimedes screw turbine are the weight of water that enclosed by screw's blade make the blade rotating, which is due to kinetic energy, while the turbine turns the generator rotor to exchange mechanical energy into electrical energy [10]. Theoretically, the Archimedes screw turbine can achieve 100% efficiency by assuming no losses [11].

The performance of the Archimedes screw turbine was affected by several parameters which can be classified into two, such as external and internal parameter. An internal parameter consists of outer diameter, a length of screw, slope inclination angle, flow rate and head difference, whereas external parameters including of inner diameter, pitch and number of flight [12]. Previously, the researcher concerned more on internal parameters. Thus, the objective of this paper is to investigate the effect of the drive train system(external parameter) towards the flow rate and rotational speed towards power output produced.

2. RESEARCH QUESTION

Electricity can be generated by using the Archimedes screw blade. The basic function of screw blade is to transport water by rotating the blade on an inclined plane [12]. Nowadays, the function of screw blade was enhanced to meet today's needs, such as act as an energy converter in low head difference.

Several researchers conducted experimental works related to these Archimedes screw blade turbines. For example, Lisdiyanti[7] presented an experimental research to investigate the effect of flow rate by using 2 bladed screw. From the experiment, it can be concluded that the flow rate increase with rotational speed, meanwhile the power generated from the moving blade achieved maximum energy at the average rotational speed. Lyons [13] presented an experimental study to determine the relationship between power, rotational speed and torque. Based on the experiment, the change of power generated was affected by head different which simultaneously influence the water level. The rotational speed causes consequent limits in volume flow through the screw blade.

3. METHODOLOGY

a) Archimedes screw turbine design

In this study, the Archimedes screw turbine is design to have an outer diameter of 284mm, an inner diameter of 154mm, duct diameter of 300mm, the thickness of a blade of 1mm, the length of a blade of 1000mm and slope inclination angle of 30 degrees as presented in Table-1.

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Table-1. Specification of archimedes screw turbine.

Parameter	Value with units
Outer diameter, D_o	284 mm
Inner diameter, D_i	154 mm
Duct diameter, D_d	300 mm
Thickness of blade, t	1 mm
Length of blade, L	1000 mm
Slope inclination angle, α	30 degree
Helix turns, N	2-bladed screw

b) Drive train system design

Two types of drive pulley system used in this study are Pulley A (Figure-1) and Pulley B (Figure-B). The parameter specification for this drive train system is presented in Table-1. Figure-1 indicates the driven and driver pulley with the same diameter while Figure-2 indicates the driver pulley bigger than the driven pulley. The differences between these two types of the pulley are only the diameter of driver pulley.

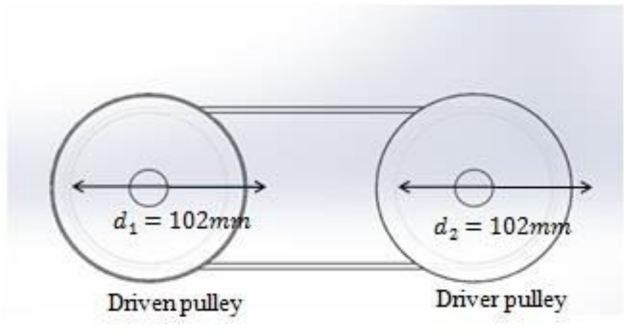

Figure-1. Pulley A.

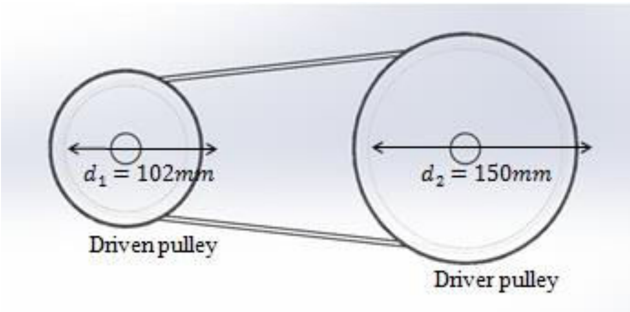

Figure-2. Pulley B.

c) Experimental setup

A full experimental setup is illustrated as in Figure-3 and Figure-4. Equipment used in these experiments which consist of a lower tank, upper tank (acts as a reservoir), pump (transfer water from the bottom to upper tank) and DC geared motor (as a generator). The experiment was conducted in Fluid Dynamics Laboratory, University Malaysia Pahang with various flow rates. The tested flow rate is between 0.012 m^3/s and 0.016 m^3/s. Flow sensor was used to determine the flow rate of water while the load is applied when the water hits blade and rotates.

Meanwhile, rotational speed and power generated were measured using tachometer and DC geared motor. A Red sensor at the back of tachometer will indirectly contact with reflective marks that attached to the pulley rotation surface. Driver pulley was connected to the shaft of the blade, and when the blade starts rotating, the driver pulley will make the driven pulley rotates.

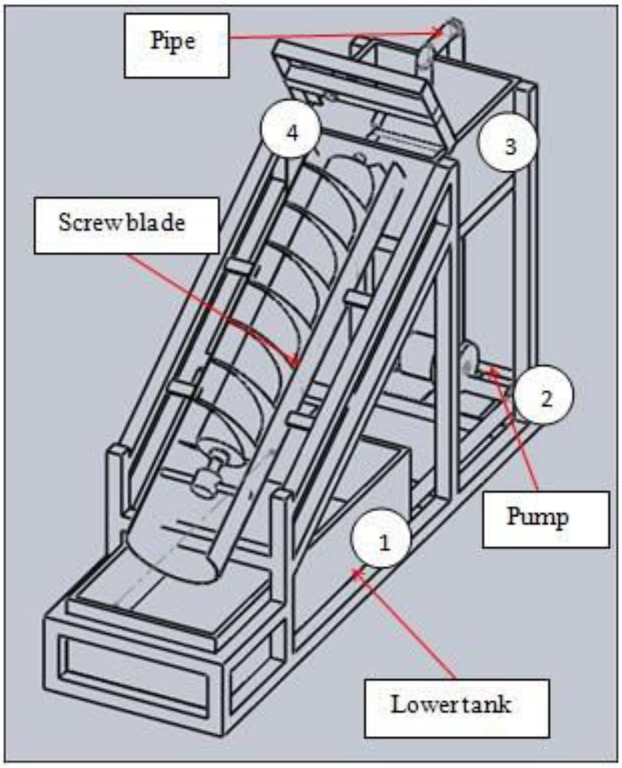

Figure-3. Set up for Archimedes screw turbine.

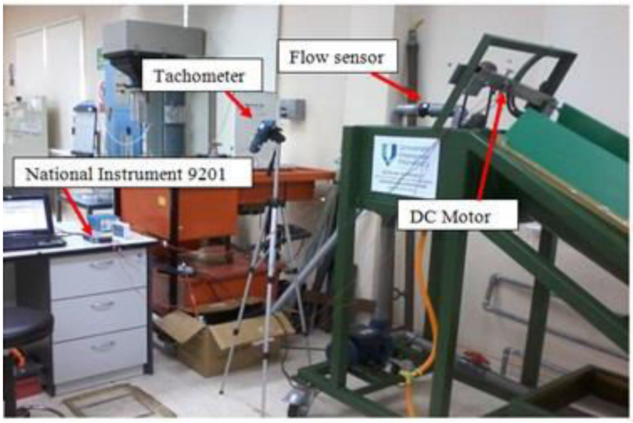

Figure-4. Instrument setup.

A DC geared motor (SPG50-20K)with 170 RPM at free run was used to measure the voltage and current produced by the rotating blade. The experiment was conducted when water from the bottom tank (1) passing through the connecting pipe (2) into the upper tank (3) as labelled in Figure-3. Water flow from the upper tank (3) and hits the screw blade (4).Simultaneously rotate the

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blade in a clockwise direction of the DC geared motor. As a result, power will generate.

4. RESULTS AND DISCUSSION

a) Relation between the flow rate, drive train system and turbine rotation speed

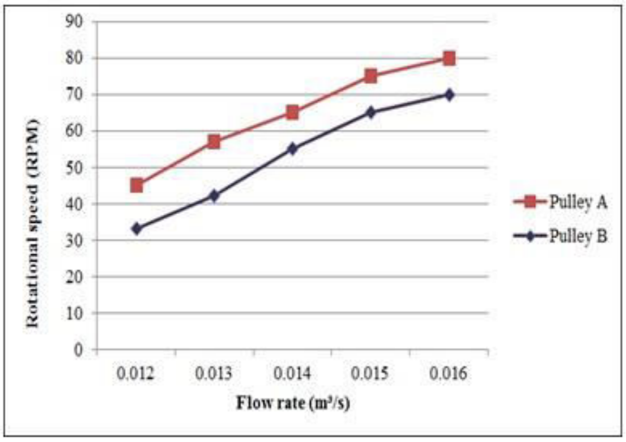

Figure-5. Rotational speed, S produced with various flow rates, Q values.

Figure-5 presents the comparison between Pulley A and Pulley B which have a significant difference in terms of rotational speed. For the first experiment, the flow rate used starting from 0.012 until 0.016 m^3/s and there are a relationship between the flow rate, rotational speed and power output of AST.

A linear relationship is observed between flow rate and the rotational speed for both pulleys. However, from the graph, it can be seen that Pulley B achieves 32 RPM and Pulley A is 45 RPM at the flow rate of 0.012 m^3/s.

The percentage change between these both pulley for flow rate of 0.012, 0.013, 0.014, 0.015 and 0.016 m^3/s are 29, 26, 15, 13 and 12 % respectively. The percentage change of rotational speed, highest at low flow rate and vice versa. This situation occurs due to the potential kinetic energy exerted within the blade rotation.

Another factor affected is due to the diameter of the driver pulley which justified with the relation equation between diameter and rotational speed equation as stated in Equation 1 below [14]. As the diameter of the driver pulley increased, then the rotational speed would decrease due to the inversely proportional trend between diameter and rotational speed.

$$D_1S_1 = D_2S_2 \tag{1}$$

Where D_1 is driver diameter, S_1 is the rotational speed of driver pulley, D_2 is driven diameter and S_2 is the rotational speed of the driven pulley.

This study has shown that the drive train system has a substantial effect towards the rotational speed of the turbine.

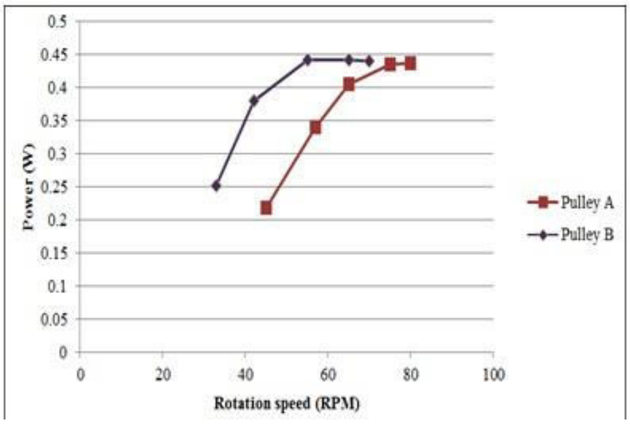

Figure-6. Relation between rotation speed, S and power output, P.

Based on the conservation of energy law, energy cannot be created or destroyed, but can be transferred from one form into another form. In this case, the mechanical energy is converted into electrical energy (due to the blade rotation turns the generator stator).

Using the voltage and current produced by these rotating turbine collected from the SPG50-20K DC motor, the power produced can be calculated by multiplying this voltage, V with current, I[15].

$$P_{out} = I.V \tag{2}$$

Figure-6 illustrates the power generated from the rotating Archimedes screw blade for a different range of rotational speed of 30 until 80 RPM. From the graph shown that Pulley B requires lower rotational speed to achieve higher power production compared to Pulley A.

The maximum power generated from Pulley A is 0.440 W at 80 RPM while Pulley B produced 0.444 W of power at 70 RPM. Although Pulley B has lower rotational speed, but it will generate higher power production compared to Pulley A. This might be due to the drive train system setting. The other will be the abundant losses at the bearing and water leakage while the Archimedes screw turbine blade is rotating. Potentially, it will decrease the pressure acting on each side of the Archimedes blade surfaces.

This finding suggests that, the rotational speed gives a noticeable impacts with respect to power production of the Archimedes screw turbine.

5. CONCLUSIONS

Drive train system in Archimedes screw turbine has not been fully investigated. The current research study by the previous researcher concentrates on parameters such as diameter ratio, pitch ratio and gap leakage. Thus, this paper is mainly focused on the drive train system that is highly influenced by the rotational speed of the Archimedes screw turbine. Overall, the study concludes that the rotational speed and the drive train system give a big impact towards power generated by the turbine at low flow rates.

In the next study, other design aspects of Archimedes screw turbine such as the gearing system should be acknowledged to increase and optimised turbine performance in electrical power generation

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