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Performance of Tesla Turbine using Open Flow Water Source

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Abstract:

Water for agricultural purposes were usually supplied either in a weir canal or through a hose flowing as an open-flow water system. To explore the possibility of utilizing these resources into energy this study was conducted to determine the performance of Tesla turbine using open flow water in a hose and in a weir canal. The performance of Tesla turbine was observed at different angles of inlet positioning from tangential or 0^0, 30^0, and 45^0 with respect to the flow of water. For a 10 minutes observation, results shows that the speed, power and efficiency of the machine is increasing as the time increases at all angles both for weir and flowing water in a hose. The relation of power and efficiency shows a straight line relationship at 0^0, 30^0, and 45^0 angles. The straight line result reveals that the power and efficiency of the machine is directly proportional to each other. Highest recorded Tesla turbine's efficiency was at 00 angles of 34.42% for water flow using the hose and 29.45 % for rectangular weir. The result conclude that at angle 00 with respect to the flow of water is more efficient compare to 30^0, and 45^0 as it is (efficiency) decreases as the angle of inlet positioning increases with respect to the flow of water.

Keyword: Tesla turbine, open-flow, water flow, efficiency

1. INTRODUCTION

Conventional turbines are mainly divided into two types. These are the reaction or impulse turbine. Often, a lot of technical challenges are faced by conventional turbines because of sediment erosion. The feasibility of power plant generation includes financial aspect and is dependent mainly on innovations to prevent wear and tear of mechanical equipment. And for a better condition, some new alternatives were handled. Among the unconventional turbines, Tesla turbine uses mainly fluid properties like boundary layer and adhesion of fluid. Fluid is applied to a smooth discs which are serially keyed in to a shaft. It has been gaining interest. It provides a simple design which can be produced easily and maintained at a low cost. This Tesla turbine can be a useful in plants for pumping of water and other viscous fluids [8].

Tesla turbine was invented and patented by the famous scientist, Serbian mechanical and electrical engineer Nikola Tesla in the early 20th century. This bladeless design makes use of the viscous effect in the boundary layer flow between the rotating discs. A Tesla turbine consists of a set of smooth disks, with nozzles applying a moving fluid to the edge of the disk [2, 18]. The nozzles are located at the outside edge of the discs, through which the working fluid flows nearly tangentially into the rotor. A series of flat discs distribute parallelly and co-axially along a shaft hence small gaps are formed between any two adjacent discs [1, 2, 3, 7, 8, 13]. This bladeless Tesla's turbine uses series of rotating discs to covert fluid flow energy into mechanical energy whose rotation shaft was driven by the viscous fluid force [3]. The fluid drags on the disk by means of viscosity and the adhesion of the surface layer of the fluid [2, 18].

Bladeless turbine has a promising future as a new power generation system [3]. The fluid kinetic energy and pressure of a bladeless turbine could be converted into an energy of the rotating shaft, and the flowing energy loss would be less than in traditional turbines. Thus, the disadvantages of traditional blade-type turbines may overcome to a certain extent and this type of bladeless turbines has the advantages of relatively longer life, good off-design performance, easy operation, cleaning and maintenance, a simple structure, no blade corrosion and low manufacturing costs [3].

Tesla turbine is one of the disc's turbine because the shaft of this turbine is formed by a series of flat, parallel, co-rotating discs, which are closely gap and attached to a central shaft. The fluid is passed tangentially to the rotor by means of inlet nozzle. Fluid is injected passes through the narrow gaps between the discs, approaches spirally towards the exhaust port located at the center of each disc. The viscous force, created due to the relative velocity between the rotors and the working fluid, causes the rotor to rotate [5, 10]. Other article named this turbine as Tesla Disk Turbine (TDT), a harmless mean of energy conversion from high pressure non-polluting fluid (compressed air, water, and steam) to form of energy such as electricity, mechanical power which can be used in various applications [9].

The utilization of small-scale water resources for hydropower generation was not given attention. Same thing happen that Tesla turbine was not considered for the selection of turbines when energy from water is studied. With this, the experimental study on the performance of Tesla turbine was conducted. The result of this experimental study will be considered to the design of Tesla turbine to be applied in the irrigation canals and to high rise buildings tap water domestic use.

1.1 Concept of Tesla Turbine

The reason for considering Tesla turbine is its simplicity in the design and concept. Tesla turbine is not as popular compare to other turbines. The Tesla's simplicity is understandable to all and has a place to harness wasted energy which may considered as small-scale energy generation applicable to remote areas.

The theoretical design of Tesla turbine is considered as a non-conventional bladeless turbine. It works on the principle of viscous boundary layer concepts. As per literature review explanations for different performances and efficiencies of Tesla turbines varies at various parameters [5]. Though simple, Tesla turbine is highly efficient rotary engine which has an amazing power [9]. The impact of water on the plates exerts a centripetal boundary layer effect causing its rotation. Water creates vortex inside the casing escaping through the center of the plate and out of the turbine. The versatility of Tesla turbine tend it to be used for different applications. Since the design by Tesla is highly efficient, this turbine is a very much stable at high rotating speeds [1]. This type of turbine is recommended when there is a shortage of electricity or no power supply is available, such as remote areas. It can also be used to regenerate the lost power in pumps. It has also major advantage for various domestic applications. Since it is portable it can be carried easily and used where a source of water is available to generate power [2].

The basic principle of Tesla turbine which works on boundary layer principle and has no requirement of head as well as high jet force to run shows its relevance to the topic. It further discusses that the Tesla turbine is not bounded to particular fluid for operational purpose. The formation of the large boundary layer creates more rpm hence require large surface to do so, by providing grooves and more numbers of discs could counter this problem [10].

When the implementation technique of this turbine is applied, it was considered as very simple. The good thing in this application is that this turbine does not require the high head of water [25] and it offers several points of attractiveness when applied to lower power applications. Indeed, it is a simple, reliable, and low cost machine [11].

1.2. Tesla Turbine as Green Energy Generator

Unlike other conventional ways of power generation, it is environmental friendly as it makes the use of non-polluting fluids such as compressed air, water, steam, etc. As fluid drags the disc, depends on viscosity and adhesion of the surface layer of fluid are close to each other, the bit of difference is managed by other properties of fluid like adhesion. Hence, it is stated as the green energy source [9].

Losses had being tried to be eliminated among the conventional turbines which is due to the viscosity and boundary layer formation. But based from the present work, experiment proves the successful utilization of these two fluid properties into an altogether new system, named as 'Bladeless Turbines'. It has an added benefit of reduced or no cost of blade maintenance, simple and cheap construction with compact units at use [20]. Tesla turbine uses water or air as its fuel so, it is one of the greenest sources for the generation of power [24].

Another highlight for the application of Tesla Turbine is when it is use for the distributed Generation system. In distributed generation the heat obtained from any generating source can be used to heat up the fuel of the Tesla turbine and thus, make it more efficient. Particularly in case if fuel cell generation is being used than the heat which is a side product of fuel cell can be used to increase the temperature of water or the air (fuel for Tesla turbine). This heat can be utilized to heat up the fluid and provide this fluid to the Tesla turbine the waste heat of a thermal power plant and the heat obtained from the operation of fuel cell, be used to raise the temperature and thus cohesive capability of the fuel for the Tesla turbine [25].

The concept of Tesla turbine could be a fundamental ideal to design household green energy generator. Installation of Tesla turbine along the waterways of household could generate green electricity. The critical issue of this green energy generator is converting energy store within household water supply without significant head loss [45].

1.3. Parts of Tesla Turbine

1.3.1. Nozzle

To control the direction or characteristics of a fluid flow, especially to increase velocity as fluid enters or exits, a device is designed called a nozzle. It is an enclosed chamber or pipe as shown in Figure 1.1 below [5, 15].

The design of the Tesla turbine is necessary to use the proper implementation techniques for the application of this turbine so that the optimum advantages can be taken from the performance of this turbine. Using proper techniques, the maximum efficiency can be obtained which will be probably near to the theoretical values of the Tesla's efficiency. The angle of the nozzle providing the fluid to the rotor of Tesla turbine is very important. Nozzle must be easily adjustable so that it can be adjusted any time to any angle according to the conditions, and requirements. The space between the discs of the rotor is also an important factor, and it must be properly adjusted depending upon the size and the area of the turbine. Another important factor is the exit way of the fluid. The torque of the turbine is very a much dependent on the exit way of the turbine [24].

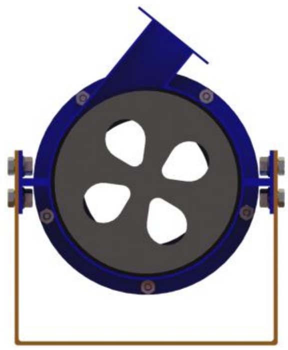

Figure 1.1. Side view of a Tesla turbine with its nozzle above

1.3.2. Annular Discs

Annular discs are the main parts of the Tesla turbine which are mounted on the center shaft. These are the components in which the steam coming out of the nozzle is allowed to impinge on the disc surface. The disc should be high enough to withstand the steam pressure and temperature. Annular discs can be of different types as shown in Figure 1.2 below [5].

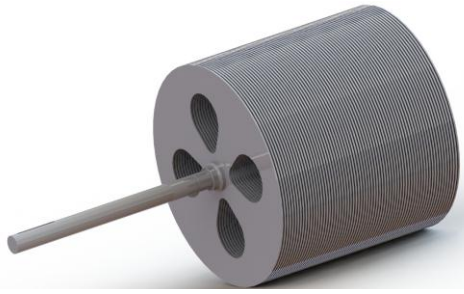

Figure 1.2. Number of angular discs of Tesla turbine mounted on the shafting

1.3.3. Assembly Model

The rotor of this turbine is formed by a series of parallel, discs, which are very close spaced and attached to a central shaft as shown in Figure 1.3. The working fluid is sending tangentially to the rotor by means of inlet nozzle. Fluid is injected which passes through the narrow gaps between the discs, approaches spirally towards the exhaust port located at the center of each disc. The viscous force, produced due to the relative velocity between the rotors, and the working fluid, causes the rotor to rotate. Housing surrounding the rotor with a small radial and axial clearance [5].

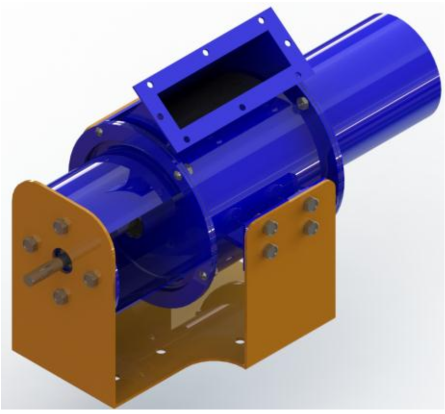

Figure 1.3. Perspective view of a Tesla turbine assembly

1.4. Application of Tesla Turbine

Below are the suggested areas the Tesla turbine may apply. Almost suggested areas are considered as a small to medium application but all of them are applications where utilizing both wasted energy and uncommon existing resources are converted to the possibility useful energy. These are through the use of unconventional turbine the Tesla turbine.

1.4.1. Open Canal (irrigation canal)

For further investigation, some following topics would be interesting: it will be interesting to analyze the influence of the number and positions of the inlet nozzle; the analysis for the influence and the effect of the disc holes, and the outlet nozzle size; the performance of the turbine concerning the influence of the composite material used for the discs; and the compressible analysis of the multiple discs turbine [7].

The Tesla turbine can be used on the way of the water flow like canals and river. But to increase the speed and torque, some special measures are to be taken. A proper place should be made where turbine can be adjusted such that the maximum water flows though the rotor discs of the turbine, and that to on the most suitable angle with an appropriate speed. Some arrangements are necessary to increase the speed of the water. For this the way of the water can be narrowed near the turbine and also the path of the water can be made in a slope shape to increase the speed and thus the energy of the water. A group of Tesla's rotor discs can be connected in series on a common shaft for the generation of electricity at higher level. In a single canal, this turbine can be used as many times as the requirement of power generation. For this purpose the system of tesla turbine must be arranged at different place on certain distance, so that the performance of one turbine will not affect its subsequent turbine [24].

Another proposed application of tesla turbine is especially for rural areas and agriculture lands where numerous tube-wells and canals exist. The tesla turbines of relatively large size can be rotated by the extremely heavy pressure of the water of tube-wells and canals to generate relatively large amount of electricity which can be provided to home. Also, this turbine can rotate a motor of many horsepower which can run another tube-well. Hence, a huge amount of energy can be used without any serious cost [25]. Multiple turbines can be installed in a single canal at different places both in series and parallel. Some arrangement must be made to make the path or water a bit narrow or slope like so that the speed and pressure of the water can be increased [25].

1.4.2. Home Based Hydropower

The flexibility of a Tesla turbine can be utilized as a part of Pico hydropower which can be privately created and oversaw by village communities [8, 18]. It has been garnering interest as Pico turbine where local communities could manage such stations in low capital. It provides a simple design which can be produced locally and maintained at a low cost [18].

In homes, Tesla turbine can be rotated by the water which is circulating by pressure from water reservoir tanks to the common use water tabs. To increase the pressure of water the pressurizer can be used. Thus, the turbine will rotate at high-speed and if its shaft is connected with the small generating unit via gears, a sufficient amount of power can be generated to charge the batteries. Then using inverter circuit it can provide an AC desired voltage. Thus, the running cost of Tesla Micro Generation System will be zero as free of cost fuel is used to run the turbine and even the water is not wasted and is used without any loss. This application can be very useful in remote areas where electric utilities cannot reach [25].

2. MATERIALS AND METHODS

The evaluation of the performance of the Tesla turbine was analyzed based from the result of the testing. The flowing water of different angles were observed and replicated in the testing, and evaluation. There are two types of flowing water that experimentally performed. These are the free flowing water at the rectangular weir and from the hose using the centrifugal pump.

2.1. Experimental Observation

There are two types of flowing water used in this study to observe experimentally the performance of the tesla turbine: the rectangular weir and the hose using the centrifugal pump. The water in each water source was supplied to the tesla turbine at angles 0^0 (tangential), 30^0 and 45^0. The data taken from the performance of Tesla turbine was continuously observed every minute continuously for 10 minutes per trial.

2.2. Parameters for observation and Evaluation

2.2.1. Tesla Turbine's Speed

To measure the speed of the tesla turbine, a tachometer was used. Method of data gathering of speed is by projecting the device's sensor into the rotating shaft in revolution per minute. The data was observed every one minute interval for 10 minutes continuously.

2.2.2. Tesla Turbine's Torque

The generated torque of Tesla turbine was observed using the brake dynamometer. The torque of the Tesla turbine torque was calculated using the equation (1).

$$T = FR = WL \qquad (1)$$

Where;
T – torque, N.m
F – force, N.
R – Perpendicular distance, m
W - Load, N.
L – length of the lever arm, m.

2.2.3. Head (height difference) and Water Flow Rate (Q)

The volumetric method formula to compute the water discharge is shown in Equations (2) and (3). The volume of flow rate Q of water or any fluid is defined as the volume of fluid passing through a given cross-sectional area per unit of time.

Different methods were used to determine the water flow rate. Some of these methods considered in this study was the weir formula and by taking time to fill the known volume of a container or called as bucket method or sometimes known as volumetric method. During the observations, the water flow rate was kept constant both in centrifugal pump and weir canal water sources experiment. Using bucket method and Equation (3), the water flow rate using the centrifugal pump was determined while the water flow along rectangular weir was calculated using Equation (2).

$$Q = \frac{2}{3} C_d L \sqrt{2g} h^{1.5}, \ (m^3/s) \qquad (2)$$

$$Q = \frac{Vol}{t}, \ (m^3/s) \qquad (3)$$

Where;
Q – water discharge, m^3/s
A – cross-sectional area of the water source, m^2
C_d – discharge coefficient = 0.60
L – weir width, m.
h – water overflow head, m.
Vol – known volume of container
t – time to fill the container with a known volume, sec.

2.2.4. Power Measurement

Dynamometer is a device used to measure the torque of the machine's shaft. The torque was measured about the rotating shaft and the mechanical power is computed using the Equation (4). The rotating speed of the machine N is observed and measured using Tachometer.

$$P = 2\pi TN \qquad (4)$$

Where;
T – torque, N.m
N – shaft rotating speed, rpm

Power generated driven by extracting the potential energy from the water over the height difference is called the hydropower. Hydropower or energy from the water is could be converted into mechanical energy and can be used directly as it is converted into electrical energy using the generator. This hydropower which could be extracted from the water and is directly proportional to the head or height of flow and flow rate was computed using Equation (5).

$$P_h = Q_t H \delta g \qquad (5)$$

Where;
Ph – hydropower, W.
Qt – volumetric flow rate, m3/s
H – head of water, m.
g – gravitional acceleration, 9.81 m/s2
δ – density of water, 1000 kg/m3

2.2.5. Tesla Turbine Efficiency

Using the gathered data that was observed in the evaluation of Tesla turbine, mechanical power of the turbine was computed. To determine the efficiency of the tesla turbine, Equation (6) was used.

$$\eta = \frac{P}{P_h} = \frac{2\pi TN}{Q_t H \delta g} \qquad (6)$$

3. RESULT

The result of the performance of the Tesla turbine was evaluated using the two (2) water flow sources; the water flow in a rectangular weir and water flowing in a hose using the centrifugal pump. Result shows the machine's performance at different angles of water flow specifically at 0^0, 30^0, and 45^0.

3.1. Performance using Water Flow in a hose of centrifugal pump

Water discharge using hose of a centrifugal pump as a source of water was maintained constant with an average flow of $1.50x10^{-3}$ m^3/s. The water elevation was computed to be 0.87 meter and the water power or the input power calculate to be 12.8W.

Figures 3.1, 3.2, 3.3, and 3.4 below shows the characteristics of turbine's speed, torque, power and efficiency as the time increases. The data was observed continuously every one (1) minute interval within the ten (10) minute duration. Figure 3.1, shows that both at 0^0, 30^0 and 40^0 offset has a speed increases as time increases until it reaches its peak speed. Among these three (3) offset angles, the 0^0 recorded a high-speed increasing pattern.

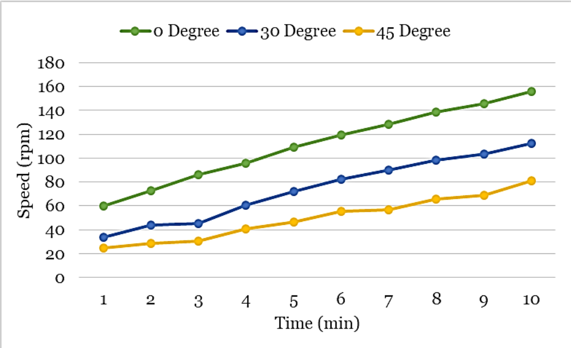

Figure 3.1. Speed and time relationship in a hose water flow

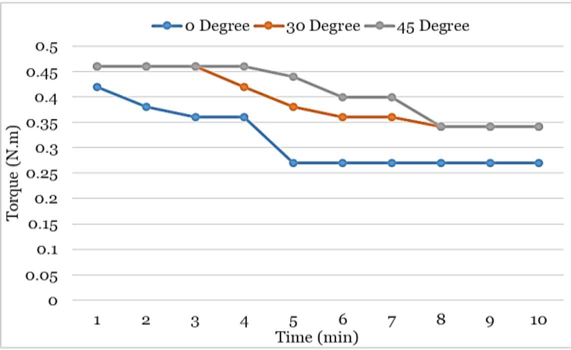

Figure 3.2. Torque and time relationship in a hose water flow

The torque versus time graphical presentation in Figure 3.2 above. Considering Figure 3.1 offset angles have different speeds, while Figure 3.2 resulted a decreasing trend. Though speed of 30^0 is higher than 45^0, the result shows the same torque at different speeds in Figure 3.2. This further implies that torque was also affected by the applied load.

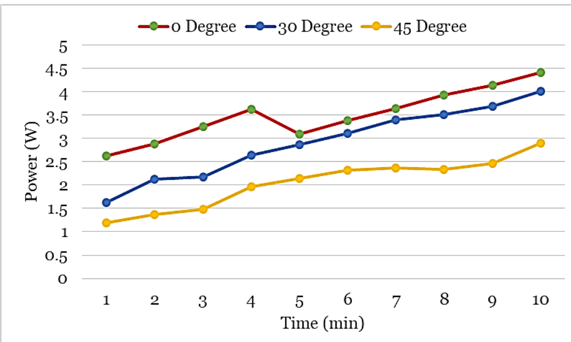

Figure 3.3. Power and time relationship in a hose water flow

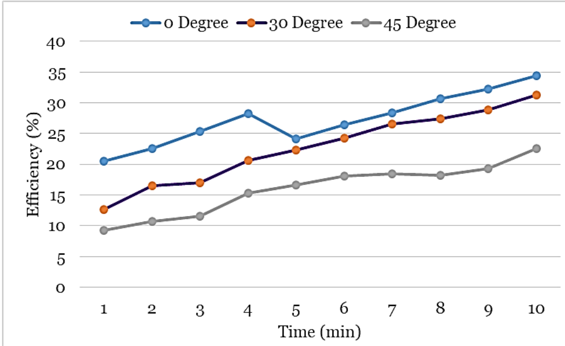

Figure 3.4. Efficiency and time relationship in a hose water flow

The specific figures of the lowest and highest speed of each offset angles were shown in Figure 3.5 below. The same result shows that efficiency is directly proportional to the speed and it was 0^0 recorded most efficient offset angle.

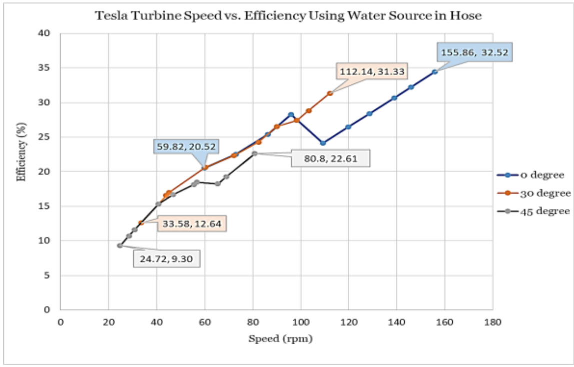

Figure 3.5. Efficiency and Speed relationship in a hose water flow

The increasing trend of power and efficiency versus time in Figures 3.3 and 3.4 during the experimental observation show a relation of proportional to the increasing speed of Tesla turbine at constant water discharge shown in Figure 3.1. The combination of the power and efficiency gives a straight line trend for all angles of entry of water as shown in Figure 3.6. This implies that the efficiency of the locally fabricated Tesla turbine is directly proportional to the mechanical power output. While the highest average efficiency was recorded at the final minute of testing generated at the 0^0 offset.

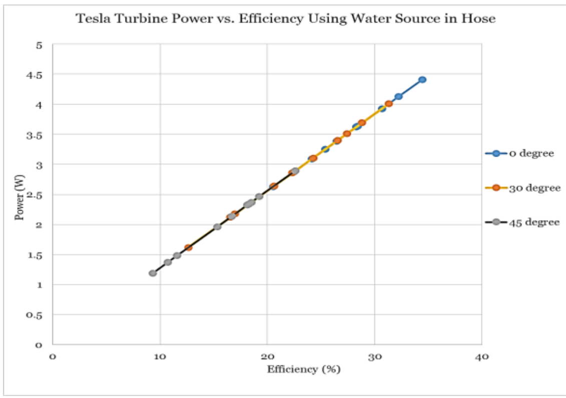

Figure 3.6. Power and efficiency relationship in a hose water flow

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3.2. Performance using water source in a rectangular weir

The performance of Tesla turbine was also experimentally observed using water flow in a rectangular weir. The water discharge of the rectangular weir serves as the water source of the turbine has a constant flow rate of 0.00755 m^3/s in a weir width L, of 0.29 meters. The total head of the experimental set-up was 55 cm, the considered coefficient of discharge was 0.06 and the calculated water power of 40.74 W.

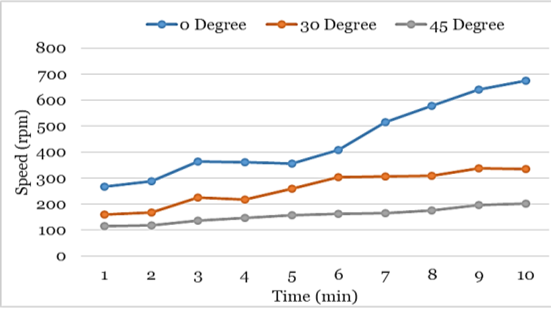

Figure 3.7. Speed and time relationship in a weir water flow

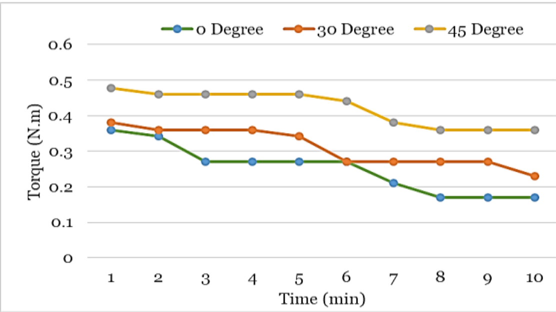

Figure 3.8. Torque and time relationship in a weir water flow

There was a fluctuating value in the three observed data at 0^0, 30^0, and 45^0 offset angles both for speed, power and efficiency shown in Figures 3.7, 3.9 and 3.10. At 0^0 offset angle the increasing pattern was observed at times of 1, 2 and 3 while a small amount of decrease at times of 3, 4, and 5 and significant increase at time 6. Since the load applied at times 3, 4, 5 and 6 at 0^0, times 6, 7, 8 and 9 at 30^0 and times 2, 3, 4, and 5 at 45^0 is constant, result implies that the speed, power and efficiency increases as the time increases until it reach its peak value. Among the three offset angles, 0^0 shows significantly efficient.

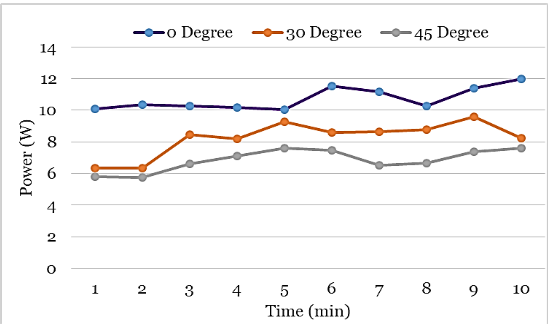

Figure 3.9. Power and time relationship in a weir water flow

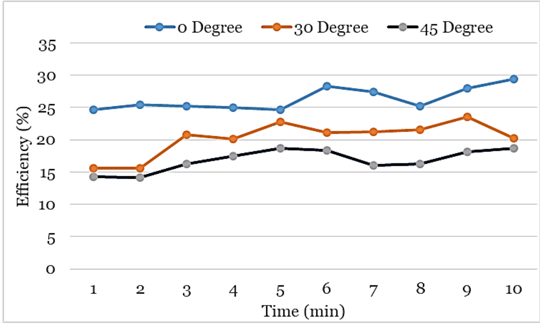

Figure 3.10. Efficiency and time relationship in a weir water flow

The relationship between power and efficiency is shown in Figure 3.11. The straight line trend for all offset angles of water entry show an evident that the efficiency of the turbine is directly proportional to the power output and further implies that efficiency increases as power increases. The highest average efficiency was recorded on the observation conducted for offset angle 0^0.

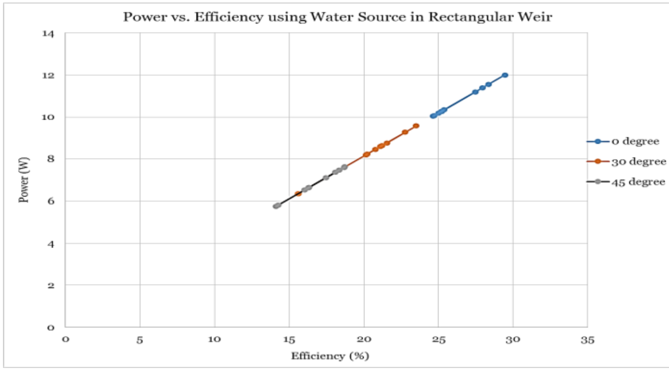

Figure 3.11. Power and efficiency relationship in a weir water flow

3.3. Overall Performance of Tesla turbine

The overall performance of the locally fabricated Tesla turbine compares its performance at three different offset angles 0^0, 30^0, and 45^0. The methods of performance observation was replicated using two types of open water source, the water flow using hose of centrifugal pump and weir canal water flow.

Table 3.1 shows the overall performance of Tesla turbine running at two different open-flow water sources. Result shows that the angle of water entry to the turbine is more efficient at 0^0.

Table 3.1. Overall performance of Tesla turbine

Position	Weir		Hose	
	Power	Efficiency	Power	Efficiency
0^0	10.73	26.34	3.50	27.30
30^0	8.24	20.24	2.91	22.75
45^0	6.85	16.83	2.05	16.03

4. CONCLUSION

With the increasing demand and cost of energy, the utilization of available and existing resources and exploration of efficient technology to harness those existing resources as energy source is important to study. To create an exploration of utilizing existing small-scale water resource, the locally fabricated Tesla turbine in this study was tested for off-axis application. Though result of the study shows that angles 30^0 and 45^0 also produced good average efficiency, the 0° offset angle consistently achieved the highest efficiency in both open-flow water applications.

To harness and utilize the existing available small-scale water resources such as agricultural irrigation canals as well as the rainwater harvesting into energy, this study recommends the energy generation with the application of Tesla turbine. Further study may include the electrical energy part of tesla turbine. Observation of the performance of this type of turbine may also consider the maximum or peak speed, power and efficiency this turbine can produce. It is also important if what head and discharge water flow this kind of turbine is efficient device for energy generation.

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