DEVELOPMENT OF RUN-OFF PICO HYDRO GENERATION SYSTEM FOR LOW HEAD WATER RESOURCES

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“ I hereby declare that I have read this fully report entitled “*Development Of Run-Off Pico Hydro Generation System For Low Head Water Resources*” and found that it has comply the partial for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)”

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This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree in Electrical Engineering (Industrial Power)

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"I declare that this report entitled "Development Of Run-Off Pico Hydro Generation System For Low Head Water Resource" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree."

Signature : ………………………………………………………

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Date : 01/06/2015

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ABSTRACT

This project is concerned on the analysis performance of simple cross pipe water turbine with low-head (below then 20 meter) and ultra-low flow of water resource .The cross-pipe turbine is made of Galvanized Iron (GI) with half an inch. The cross pipe turbine is also called Z-Blade turbine. Theoretical investigation has shown the Z-Blade turbine has reasonable hydro as mechanical energy conversion of about 50% and this energy conversion efficiency would be improved when the blade spins faster. The Z-Blade turbine has shown good potential to be used for ultra-low hydro resources condition (less than 2 litter/second).When the diameter of pipe is smaller, it will spin faster under constant water head resource. The main advantages of this turbine are very cheap, can be locally made due to material easily to find and no expertise works needed. This project will analyse the performance based on experimental data collected from different test carried out on two simple reaction water turbine prototypes. The factors that will influence the experimental result includes the water flow, turbine diameter, and number of nozzles, size of the turbine and its rotational speed. The suitable design for layout of hydro system is presented to obtain a ultimate power output of the pico hydro generation.

ABSTRAK

Projek ini membincangkan prestasi analisis turbin paip silang mudah dengan kepala rendah (di bawah 20 meter) dan aliran pada kadar rendah sumber air. Turbin rentas paip diperbuat daripada Galvanized Iron (GI) dengan setengah inci. Turbin paip silang juga dipanggil turbin Z-Blade. Kajian teori telah menunjukkan turbin Z-Blade mempunyai jumlah yang munasabah sebagai penukaran tenaga mekanikal kira-kira 50% dan ini menyebabkan kecekapan penukaran tenaga akan bertambah baik apabila bilah berputar lebih cepat. Z-Blade turbin telah menunjukkan potensi yang baik untuk digunakan untuk ketinggian yang rendah ultra hidro sumber keadaan (kurang daripada 2 liter / saat). Apabila diameter paip semakin kecil, ia akan berputar lebih cepat apabila sumber ketingggian air tidak berubah. Kelebihan turbin ini adalah ianya mudah di buat, sumber mudah didapati, dan tidak memerlukan kepakaran untuk membina. Projek ini akan menganalisis prestasi berdasarkan data eksperimen yang dikumpul daripada ujian yang berbeza dijalankan ke atas dua reaksi mudah prototaip turbin air. Faktor-faktor yang akan mempengaruhi keputusan eksperimen termasuk ketinggian sumber air , aliran air, diameter turbin, dan bilangan muncung paip, Saiz turbin dan kelajuan putaran. Reka bentuk yang sesuai bagi susun atur sistem hidro dibentangkan untuk mendapatkan keluaran kuasa yang optimum dalam generasi Pico hidro.

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A Total nozzle exit area (m^2)

d_e Nozzle equivalent diameter (m)

D Nozzle diameter (m)

d Acceleration due to gravity (m/s^2)

H Water height in reservoir (m)

H_c Centrifugal head (m)

K_g Specific speed for turbines = $\frac{\omega\sqrt{Q}}{(gH)^{\frac{3}{4}}}$

$\dot{m}$ Mass flow rate of water through the turbine (kg/s)

$*\dot{m}$ Non-dimensional mass flow rate

Ƞ Efficiency of conversion of potential energy to work

P_c Centrifugal pressure (N/m^2)

Q Volume flow rate (m^3/s)

p Density of water (kg/m^3)

R Radius of the rotor (m)

T Torque ($N.m$)

T_s Torque when turbine is stationary ($N.m$)

$*T$ Non-dimensional torque

$\dot{W}$ Output power (W)

$*\dot{W}$ Non-dimensional power

ω Angular velocity of the rotor (s^{-1})

$*\,\omega$ Non-dimensional angular velocity

U Tangential angular

$*\,V_a$ Non- dimensional absolute velocity

$*\,V_r$ Non- dimensional relative velocity

$*\,U$ Non-dimensional tangential velocity of nozzles.

V_r Relative velocity of water with respect to the nozzle (m/s)

$\dot{m}_s$ Mass flow rate of water through the turbine when it is stationary (kg/s)

V_a Absolute velocity of water leaving nozzle with respect to a stationary observer (m/s)

CHAPTER 1

INTRODUCTION

1.1 Introduction

This part is about research on alternative ways to generate electricity is going aggressively caused by the dependence on non-renewable energy sources is diminishing. The Hydro generation is one of the energy sources that have yet to be fully explored.

1.2 Background

Hydropower can be an alternative, non-polluting and also environment not cancerous way to obtain vitality. Hydropower is founded on basic principles. Flowing water turns a turbine, the turbine will spins a generator, and an electricity is produced. Many other components may be in a system, but it all begins with the energy with the moving water. The use of water falling through a height has been utilized as a source of energy since a long time. It is actually the best sustainable electrical power system identified by any man meant for mechanized electrical power sales and even for the electricity generation. In the previous times, waterwheels were used extensively, but during the beginning of the 19th Century with the invention of the hydro turbines that the use of hydropower got attention.

Non-renewable power assets for example oil, fossil fuel, gasoline as well as nuclear era cannot be renewed as soon as it is been utilized. These kind of sources have an impact towards the earth as it can certainly trigger the green house effect as well as environment concern. Besides that, the renewable energy has been pointed as an alternative due to its limitless sources and environmentally friendly. Hydro-power is actually among green power and its particular be able to upcoming strength technology that cannot be underestimated.

Pico hydro generation system will operate using upper water reservoir within few meter from ground. This type of water in that case pass downhill to create “head” in the piping procedure and increase the speed of the best switching procedure. Consequently, a turbine is going to spin a alternator plus manufacture electric power. Pico hydro electricity generating is definitely ways to address a generating with electric power. The reaction turbine is considered inefficient and yet uncontrollable for low-head. This project will be focused with a design fresh layout of simple reaction turbine as a problem solver.

1.3 Problem Statement

Natural and unnatural disaster has occurred in environment due to the actions of human hand polluting it. Almost 50% of main contaminants on earth associated with polluted supplies mainly in the automobile exhausts, commercial as well as electrical energy era actions. The particular worst allergens regarding sulphur monoxide and also carbon dioxide monoxide suspending inside the oxygen due to use of non-renewable vitality options. Actually, 80% associated with electrical power produced through the energy vegetation make use of that utilizes fossil fuel, gasoline as well as nuclear in support of 20% created green power resources [1]. The actual Asian countries Off-shore area creates 32% associated with worldwide hydropower in 2010. Other than that, any level for opportunity electrical power is certainly endlessly on the market, even so the enactment connected with hydropower is usually underestimated plus underutilized. Theoretically exploitable prospective supplied will be 18, 000TWh/year as well as the cheaply exploitable prospective supplied will be 8, 000TWh/year [2, 3].

Besides an engineering with hydroelectric elaborate delivers virtually no waste material plus and also carbon emissions place is noticeably more affordable, nonetheless massive dams is going to cut off a pass of stream plus cause a problems in any local environment. It means, there are more simple and easy to handle hydro power generation invented. Pico hydro is a creatively invention that produce smaller output in power generation compared with other mega hydroelectric [4]. Smaller hydro technological innovation pledges good efficiency qualitative dividends to the economy while conserve the global environment. As a result, several nations around the world have taken the particular motivation in providing electricity to community [6]. According to date, almost all of the smaller along with tiny hydro sites are generally nevertheless to get looked into, meanwhile a lot of the huge hydropower sites happen to be used [5, 6]. As yet, the quantity of research still undergo for very low head water resource as during the drought season ,the flow rate of water produce within the head of water will be also decrease[4].

According to the all above statement, this project objectives is to develop a low head pico-hydro generation system with a small amount of water flow(run-off-river). Keeping the aspect in mind that the reaction of water turbine developed with low cost and simple manufacture.

1.4 Objective of Project

The following objectives of the project are:

1. To design a run-off Pico hydro turbine using a low head water resources.
2. To study the performance of Pico hydro by using Z-blade GI (galvanized Iron) material.
3. To determine the suitable length of turbine blade and the diameter of nozzle at the end of blade turbine.
4. To analyse the output run-off Pico hydro generation within suitable output variable.

1.5 Scope of Project

The scope of this project are:

1. The head is supplied by water reservoir for 4 meter .
2. The turbine material is GI type (galvanized Iron) will be tested for its performance for the suitable length and suitable diameter of the turbine nozzle.
3. The experimental process will be conducted on the test rig that has been built.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will integrates mainly on the theory and current development in Pico hydro generation system. The chapter is divided into two parts which is Concept of turbine, Revolution of Z-blade and basic design.

2.2 Pico Hydro Generation System

For hydro generation system, there is a classification of hydro according to its output range of power generated as shown in figure 1. Pico hydro is a type of hydro generation as its can generate maximum power less than 5 kW.

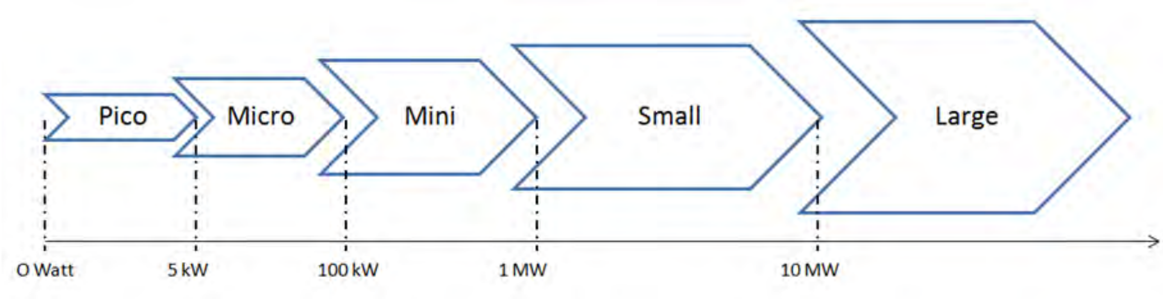


Figure 2.1: Classification of hydro power according to power output [4].

According to S.A. Abbasi and Naseema Abbasi [7], sources such as ocean waves, tides and sea water does not fall within the renewable energy sources even use water as a medium of power generation. According Sopian K [4] also recognize hydropower generating more than 1MW be classified as non-renewable energy. This is caused by factors such construction of reservoirs and dams that cause environmental damage.

Hundreds of years ago, the construction of large dams is the only way to generate electricity. However, the construction of large dams would cause disruption to the natural flow of small rivers. Besides, rampant deforestation that is used to create a vast reservoir can lead to a significant impact on the greenhouse effect. This proves that there is no difference between fuel consumption and hydropower to generate electricity. Pico-hydro is one alternative way to generate electricity without damaging the environment. Due to several factors, the use of pico-hydro is the right choice for assisted with smart technology and cost-effective and helps to supply energy to remote communities of the electrical grid.

2.3 Head and Flow

Head and flow is a main part of pico hydro power systems. Both are important to spin the turbine and produce electricity. The output power is directly proportional to the head and flow of the water. So, when the head of water increase, the flow of water increase thus the output power generation will be increased. Fig 2.2 shows the characteristic of head and flow of water connection that relates to the output power as described by M. F. Basar. No output power will be obtain if there is no flow nor head of water [4].

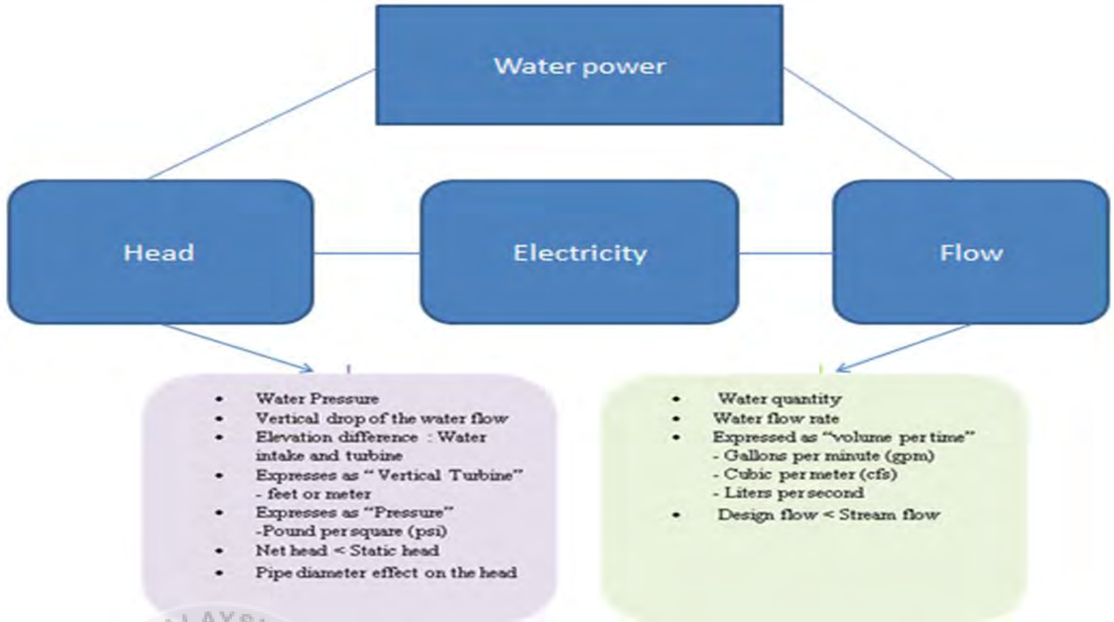


Figure 2.2: Head and flow in water power [4].

The head is referred to water pressure as the difference of water intake and the turbine and can be known as vertical distance. The pressure P, can be assumed as head and it is quantified in Newton's per square meter (N/m2) . Defining the pressure as the force F, that produced on per unit area A. Then, force is the product of mass, m (kg) times acceleration, a (m/s2). Acceleration from the water is equal to the gravitational. The following equation(2.1) till (2.7) are used to calculate the force, pressure and head [4].

The force can be calculated by using Newton's law:

$$F = ma \tag{2.1}$$

or

$$F = \rho V a \tag{2.2}$$

The acceleration of water equals to gravity constant as water move freely. So, the force calculation equals to:

$$F = \rho V g \tag{2.3}$$

Pressure can be calculate as:

$$P = F / A \tag{2.4}$$

or

$$P = \rho V g / A \tag{2.5}$$

As volume is equal to height times by area, pressure can be calculated by using this formula:

$$P = \rho\, hg \tag{2.6}$$

Manipulate the equation parameter will give:

$$h = P / \rho\, g \tag{2.7}$$

Research state that low head site is not optimum enough as only small output power produce. Low head water resources need more water flow compared to high head. Table 2.1 show a classification of head according to class.

Table 2.1: Classification of hydropower according to head range[2].

Class	Head
Ultra Low Head	H < 3 meters
Low Head	3 meters < H < 30 meters
Medium Head	30 meters < H < 75 meters
High Head	H < 75 meters

2.4 Concept of turbine

This project is quite similar to the concept of water sprinkler that implanted in the turbine; the brief reaction turbine. This concept also have also been discussed by Abhijit Date and Aliakbar Akhbazadeh [8]. Generally, Such a turbine could performs while using pressurised water involving substantial along with minimal normal water. The water will go into the turbine by simply straight along with tangentially issue out of the turbine as well as could also be generated a new numerous presumptions inside investigation. Firstly the energy cannot be dissipated through viscosity and secondly, turbulence effect, compressible because water density (ρ) is considered constant and the air that can be compressed. The mechanical loses which is the bearing friction losses and wind age losses during the rotation rotor in generator should be ignored.

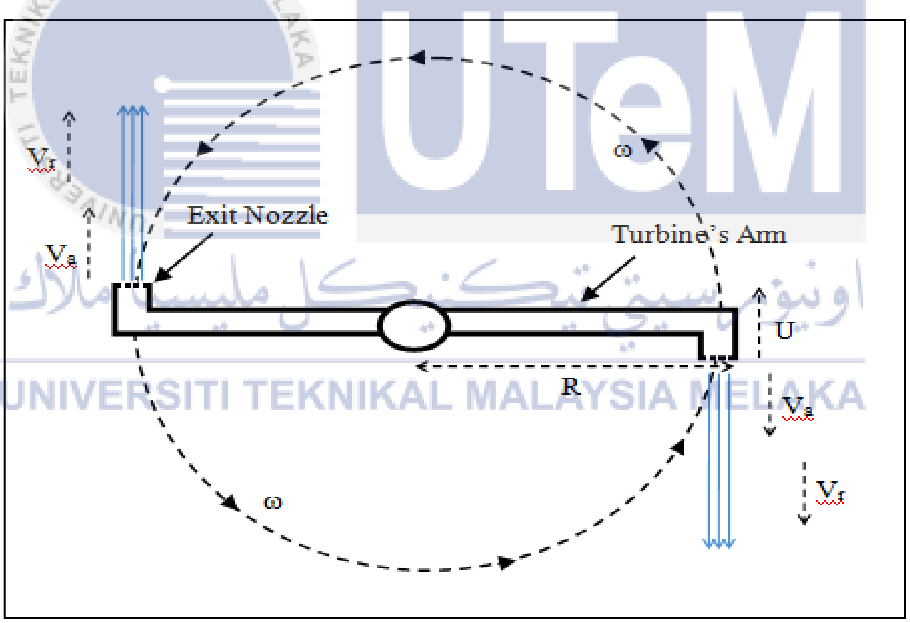


Figure 2.3: Rotor Schematic [9].

By referring figure 2.3, an appropriate equation which was obtained by the previous researcher [9] is applied as follows:

$$U = R\omega \tag{2.8}$$

$$V_a = V_r - U \tag{2.9}$$

Where V_r is the relative velocity of the water leaving the nozzle with respect to a stationary object in m/s and V_a is the absolute velocity of the water leaving the nozzle in m/s. U is the tangential angular. The kinetic energy of water according height of water reservoir H and centrifugal head H_c equation can be written as:

$$\frac{1}{2}\rho V_r^2 = \rho g(H - H_c) \qquad (2.10)$$

So, from equation 2.9 and 2.10, , the equation for ideal relative velocity can be written as:

$$V_r = \sqrt{2gH + R^2}\omega^2 \qquad (2.11)$$

In the equation 2.11, Vr is a water flowing out the nozzle of turbine in steady or rotary state. When the nozzle is at steady state, the head component will be equally to zero because there is no angular speed, ω, and the relative velocity, Vr can be state that it proportional to the square root of potential head, H.

The mass of water flow rate sprayed out the nozzle can be expressed as:

$$\dot{m} = \rho V_r A \qquad (2.12)$$

The water exit nozzle area A in m^2 and density of water ρ in kg/m3.

Hence,

$$\dot{m} = \rho A\sqrt{2gH + R^2}\omega^2 \qquad (2.13)$$

Torque is the product of mass flow rate, absolute velocity of water and radius of the turbine:

$$T = \dot{m}V_a R \qquad (2.14)$$

The output power produced by the turbine:

$$\dot{W} = T\omega \qquad (2.15)$$

Using the principle of conservation of energy, the total rate of hydraulic energy supplied at the inlet must be equal to the rate of mechanical work produced plus to the rate of loss of kinetic energy due to the absolute velocity of water that appear at the exiting water.

$$\dot{m}gH = \dot{W} + \frac{1}{2}\dot{m}V_a^2 \tag{2.16}$$

$$\dot{m}gH = \dot{W} + \frac{1}{2}\dot{m}V_a^2 + \frac{1}{2}\dot{m}V_r^2 \tag{2.17}$$

Finally, the efficiency of the system being able to convert potential energy to work can be written as:

$$\eta = \frac{\dot{W}}{\dot{m}gH} \tag{2.18}$$

By knowing the value of radius of the turbine R, gravity constant g, density of water ρ, angular velocity of turbine ω and height of water reservoir H, the parameters such as tangential angular U, absolute velocity of water leaving nozzle V_a, velocity of water leaving nozzle V_r, torque T, output power W and efficiency η can be determined and it is considered as the theoretical value.

The viscous loss, k-factor can be calculated by rewriting equation 2.13 as follows:

$$k = \frac{2gH + R^2\omega^2}{\left(\frac{\dot{m}}{\rho A}\right)^2} - 1 \tag{2.19}$$

The parameter in equation 2.19 can be experimentally obtained in order to get the value of k-factor. If the water supply held is constant, then the viscous losses will depending on the rotational speed and also water flow rate. The potential energy produce in the water from the reservoir or tank can be converted to mechanical power in order to get the efficiency η and also can be written as:

$$\eta = \frac{W}{\dot{m}gH} \tag{2.20}$$

The optimum diameter expression can be derived as:

$$\eta = \frac{R\omega}{gH}\left[-R\omega + \sqrt{\frac{1}{(1+k)}}\ x\ \sqrt{2gH + R^2\omega^2}\right] \tag{2.21}$$

By equating the differentials of turbine radius R equal to zero for the maximum efficiency condition dη/dR = 0 will get:

$$D_{opt} = 2\,R_{opt} = 2\,\frac{\sqrt{gH}}{\omega}\;x\,\sqrt{\left(\sqrt{\frac{1+k}{k}}\right) - 1} \tag{2.22}$$

2.5 Revolution of Z-blade

The actual yearly worldwide hydropower manufacturing is extremely little when compared with the actual worldwide energy usage. Nevertheless, the officially exploitable hydro energy possible obtainable around the world is actually much more compared to is really already been utilized. Pico hydro is hydro generation system that can generate power up to 5 kW. Electric power generated is driven by the use of gravity to the water fall or water flow in hydro machine. The increased interest towards this system is due to the potential and capability of pico-hydro turbines to be alternative and ideal solutions to increase the demand for electrification in remote communities. Many investors have developed new water turbines with huge output amount of energy that can be produce at different level of water head with gain of high efficiencies. The classification of water turbine can be divided into two main categories according to their working principles which is reaction and impulse. The Z-blade turbine hydro generation is considered as a reaction turbine as it will be conduct the experimental testing by using low head water resource. The revolution of Z-blade turbine is organized according to timeline stated in figure 2.4.

2.5.1 Pelton, Crossflow and Turgo turbine

Waddel [10] and Date [9] mentioned that the particular impulse turbine mastered a lot of the lower head and also small hydroelectric products designed for vitality the conversion process. In addition, Harvey mentioned that turbine like Pelton, Crossflow and Turgo were always used in low head sites due to low cost of design. Abhijit Date [11] explained that, the kinetic energy delivered and contained from water jet that hits the runner is utilized by the impulse turbine in producing the mechanical energy state. It again takes advantage of typically the forceful the water head as platform to produce the mechanical power. From low head condition, the jet velocity of water is slow. It can be state that the impulse turbine cannot produce a rotation with a ultimate speed. Thus it shows that impulse turbine only suitable enough for high head of water. The efficiency will drops drastically at low head condition. It can be conclude that, Pelton and Turgo turbine not suitable to operate when the water head is below 4m height.

2.5.2 Reaction Turbine

Whiteland [12] stated, for the reaction turbines, the characteristic of flow rate and the water pump is inversely propotional. Water coming into any passageway at the larger end and exiting through the lesser end move just after expelling many of the vigor altered in the diminishment with tension while in the rotating condition. Akbarzadeh and Date [13, 9] mention that, the reaction turbine uses the reaction that produced by an acceleration of a fluid through nozzle to make object moves forwardly. The reaction turbine produced the pressure according to the head supply water in producing energy of mechanical. The pressure will drops as it expelled out through the turbine [9]. Researcher name Daughtery [14] stated, the actual liquid may floods all the runner pathways totally in which the impeller situated, as well as any kind of alter or even stress decrease may happen within the impeller. This particular attribute causes it to be ideal for a wide range of heads through really low in order to moderate condition.

2.5.3 Hero's Turbine

This great generation relating to hydropower continues to be creating fresh means of extracting and also changing energy coming out from water. Date [15] mentioned that, 2000 years ago, a young mathematician from Alexandria Greece, named Hero has built the first reaction turbine that operate by using boiler steam. This concept is similar to Newton's third law of motion which state for every action ,there will be a reaction consumed by it.

Hero's turbine is made up of hollow metal sphere with using nozzles aiming throughout complete opposite route tangentially on the field down the very same axis. The covered central heating boiler creates the actual vapor along with 2 pipes attached to both end and also the central heating boiler. A brand new created heater produces water utilizing a set of tubes linked to the two areas as well as the heater. This will likely bring about the water to stream in the field along with being subtracted from the nozzle, therefore providing a revolving in the round field. Even though the turbine failed to generate electrical energy, this individual proven in which heavy steam strength could possibly be utilized to function other mechanical.

Researchers name as Wilson [16] , Duncan [17] and Date [15] stated that, Dr Robert Barker reinvented along with revised the Hero's turbine design and style to use probable electricity involving normal water located throughout water reservoir, which namely as Barker's mill. The type have been just like Hero's turbine with the exception of the resource has been water as opposed to heavy steam. Early layout gets the access regarding way to obtain energy originated in any conduit provided in to the the top of turbine creating the particular rotor to be able to move. Any effect push is established if the smooth making a profit the particular nozzle tangentially creating any movements in reverse course and also creating the particular rotor to be able to move in the identified axis the location where the turn device can easily generate output power.

2.5.4 Pupil, Scotch Mill and Whitlaw Mill 's Turbine

Wilson [18] and Date [15] explained that, Pupil make further modificationss by modified the entry point of the fluid switching from top to bottom entry. Differ from early design, which usually any time every one of the problem borne from the central (bearing) for relocating elements. Nonetheless, this kind of advancement permits the strain (head regarding water) to be in the contrary course to be able to insert the particular relocating the turbine. That works being a safety net the location where the water strain boosts coming from under the particular wind turbine able to withstand the particular strain from turbine. Additionally, they mentioned that will, "Scotch Mill", the man named John Whitlaw conceived which in turn in addition got pretty equivalent traits on the Barker's mill with the exception of nozzle supply. Whitlaw designed the arm by curving shape, to make a high velocity exiting the arm. It also increases the efficiency.

2.5.5 Kaplan's Turbine

Kaplan turbine is a propeller type which categorized as a pure axial flow turbine. The blade of Kaplan can be adjusted within suitable load and through gearing. Kaplan turbine considered has more efficiency than Francis turbine although Kaplan turbine more complex than Francis. These two type of turbine is highly cost than other turbine [17].

2.5.6 Barker Mill's Turbine

Duncan [17] told that, several modifications been made to increase efficiency of the Barker's Mill turbine design. But still, it does not economically. Akbarzadeh [19] had different point of view with Duncan by stating that the turbine differr than for garden sprinklers. The statement is misunderstood as Akbarzadeh [19] stated that out of date Hero's turbine layout inside in his paper name parametric study of the simple reaction water turbine. The researcher states that the absolute maximum torque manufactured by the machine is designed for the way it is in the event when turbine at stationary state would produce output power equally to zero. When turbine rotating, the power is produced and the torque would be decreased. It is shown that, when the load torque is reduced towards half the value of the torque at the stationary condition, then water mass flow rate, speed and output power approach infinity for an ideal no-frictional loss case. With this condition, the efficiency will equally be ideal.

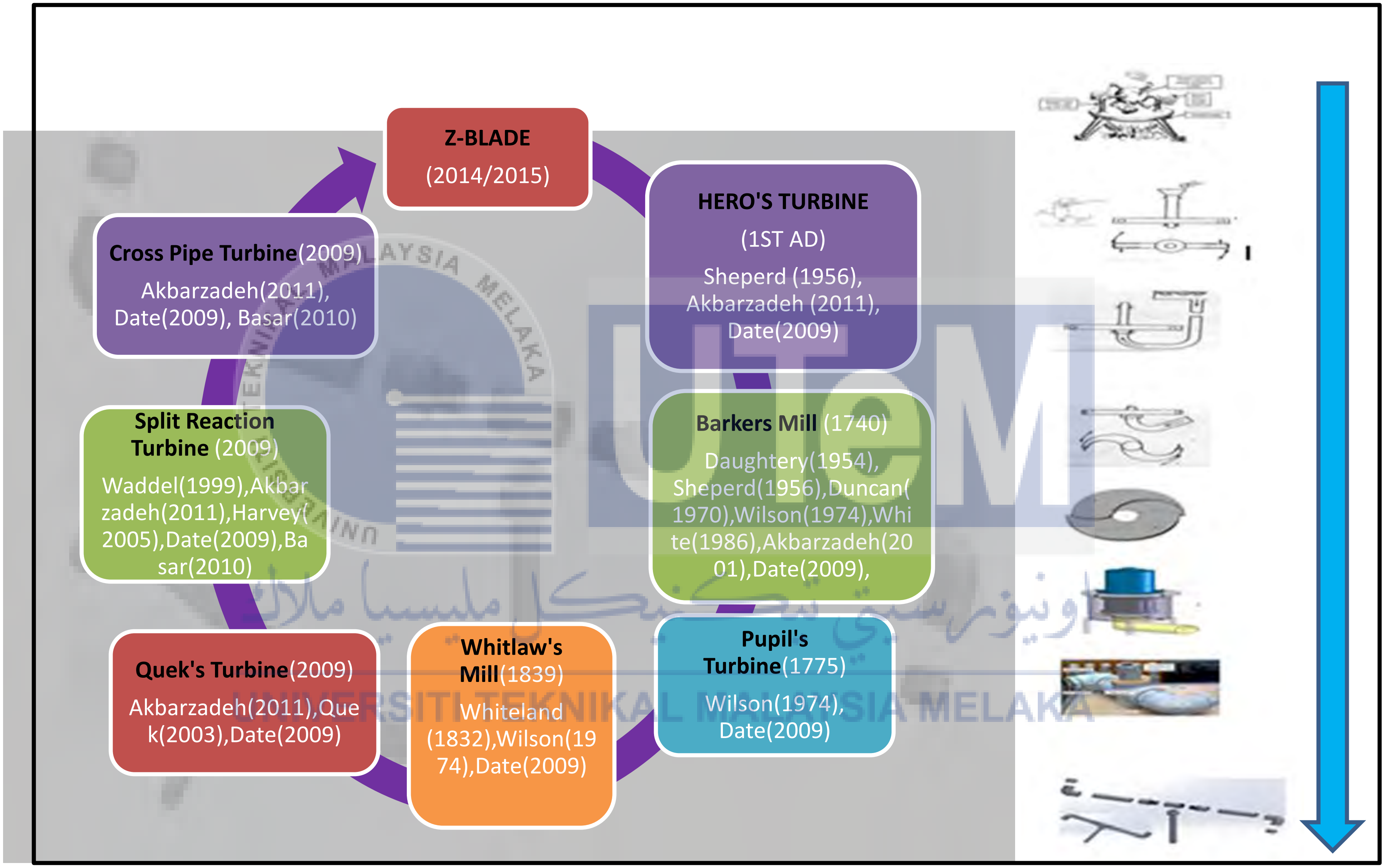


Figure 2.4: The Z-blade turbine Revolution Cycle.

2.5.7 Quek and Crosspipe's Turbine

Quek [20] and Akbarzadeh [19] built the simple of two reaction turbine Quek state that, turbine rotors had water passage in a solid metal disk with using a CNC machining process. The rotor design used in is very expensive and complicated to fabricate. The cross pipe reaction turbine is manufactured by using PVC pipe by set off the center and joint the top and bottom plates thus create a procedure for manufacturing a simple reaction turbine called "split pipe reaction turbine" [8].

2.6 Z-blade reaction turbine basic design

The concept of Z-blade turbine is inspired by lawn sprinkling system. The Z-blade type are based on the investigation on their split reaction turbine and the cross-pipe turbine were described previously in literature [10]. The split reaction turbine with a cylindrical shaped has proven that it is capable to gain high efficiency of energy conversion under low head range from 1 m to 4 m and under mass flow rate which the range is 6 kg/sec to 20 kg/sec. To gain the optimum rotational speed at low head water resource less than 4 m., the turbine diameter should be very small as it can cause volumetric capacity to reduce.

In this project, the Z-blade is made from galvanized iron type material. The material used for the blade is considered to make the lifetime for piping system of turbine is more longer. Typically, Pipe longevity depends on the thickness of zinc in the original galvanization, and whether the pipe was galvanized on both the inside and outside, or just the outside. Galvanizing is the process by coating zinc cladding to steel or iron, to prevent rusting.

However, in this project, the Z-blade reaction turbine considered that the flow rate used not as high as 20 meters like the researchers previously used. The water head used in these experiments is less than 4 meters. This is still considered as low as researcher state before. Only water with maximum 2 kg/s or 2 L/sec will tend to be used to test the operation and the compability of the turbine within ultra-low flow and low head condition. This ultra-low flow of water is considered as it is correspond to this lowered variety of water while in drought season.

The split reaction turbine has been informed in the literature [8] as the simplest water turbine to be made off. Some specification of description about the manufacturing process of this turbine that has a capacity ranging from 0.5 kW to 1.5 kW is described by Date [11]. The galvanized iron type pipe (GI) with a nominal diameter of 250 mm; wall thickness value of 6.5 mm and be split into two, off-set the centre by 6 mm and joint it with the upper and lower lids . The SRT was manufactured after its discoverer experimenting the cross-pipe turbine (CPT) as shown in figure 2.5 with the capacity range 0.25 to 1.0kW.

Figure 2.5 Cross pipe turbine (CPT)[10].

The CPT will be use 3” standard galvanized pipe fittings with four important turbine parts such as 1 unit of 3” cross-pipe at the centre, 2 unit arms made out of 3” male adapter fittings, 2 unit reduction elbow 3” to 2” and finally 5/8” solid stream jet nozzles fixed at the exit of both elbows through the reduction bush. The nozzle is mounted on both ends of the pipes to make the direction of the water flow out tangentially to the diameter of the rotor and to maximize the thrust of the water flowing out of the nozzle. The CPT design is not fully described when seeing to constraints such as the diameter of the turbine, the nozzle exit area of turbine and the turbine inefficiency stemming from dimension of standard pipe fitting. During rotation of CPT, the turbine will has a potential in facing a loses of energy as both turbine arm must overcome the air drag. Moreover, the main objective of this research is to design and develop run-off Pico hydro turbine generation using low flow water resources and using inexpensive materials. To achieve this objective, the CPT is referred back so that the new turbines are highlighted later able to overcome the problems that occur on CPT. The Z-Blade turbines proposed is very cheap in which the goods are used for the turbines are easily available in the local market and it is easy fabricate where it only requires basic knowledge and expertise of the plumbing system.

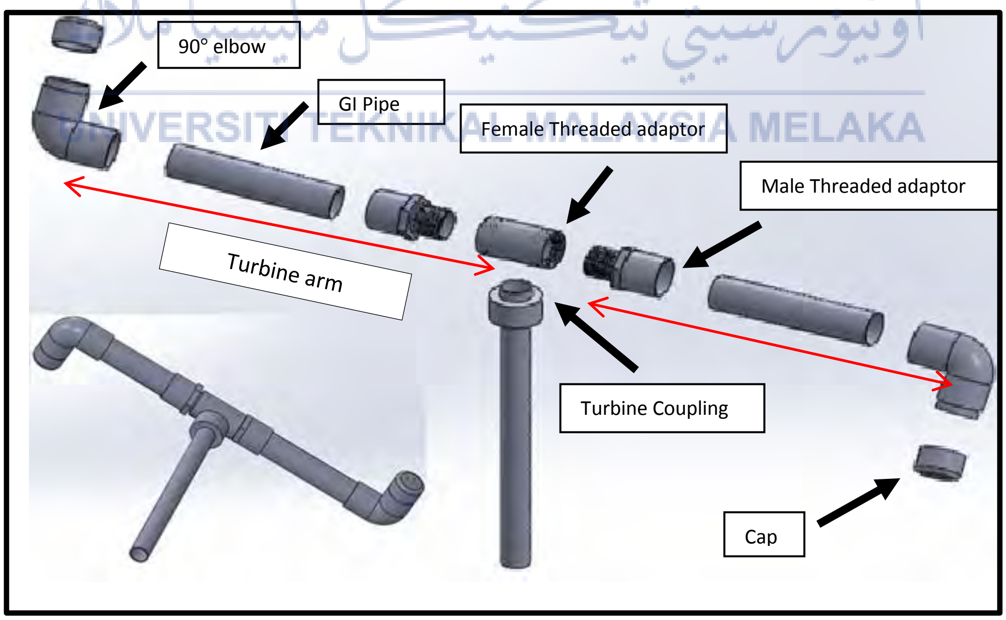


Figure 2.6:Z-blade reaction turbine part.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter discusses the methodology for this project. Figure 3.1 shows the flow chart of the project. Details for each part in the flowchart are discussed in the next section.

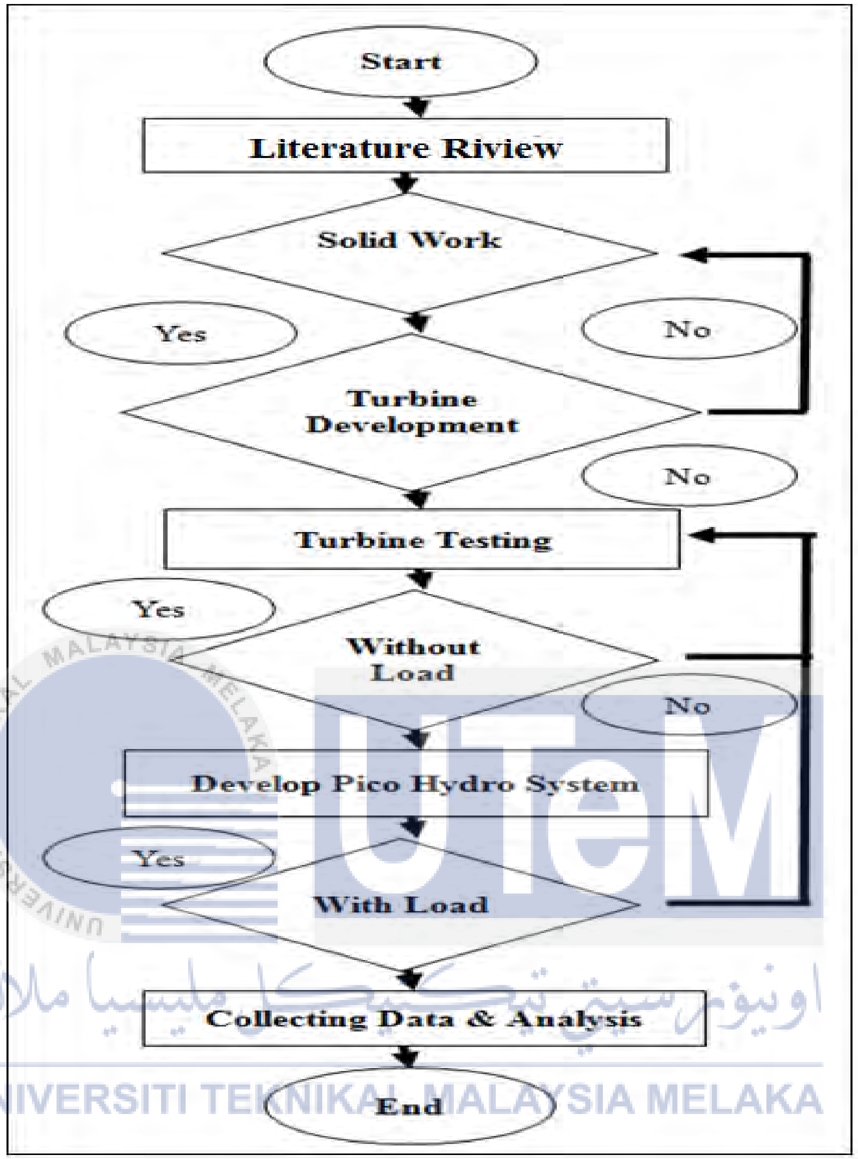


Figure 3.1: Project flow chart.

3.2 Simulation Development

The Z-blade type reaction turbine is designed by using software development called SolidWorks.

3.2.1 SolidWorks Simulation Design

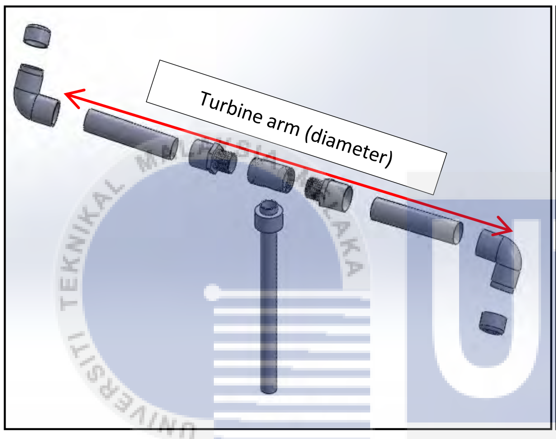
SolidWorks is a software that integrates easy-to-use tools with design during the product development and can verify the operation clearly. SolidWorks can reduce the number of physical prototypes needed. The look evaluation improve item development since it decrease dangers within style, and may aid reduce materials along with cost.

Style evaluation as well as simulation performance SolidWorks three dimensional CAD in order to separate through 5 part:

1. **The Basic Structural Analysis** — a basic linear part-level structural analysis of forces and pressures with fixed restraints; resultant displacement, plus animation of results, outputs for stress, factor of safety (FOS), and eDrawings® output.
2. **The Basic Motion** — a taking into account simple contacts between parts, Make designs move, as well as gravity.
3. **The Assembly Motion** — which can capture and edit motion key frames and can save as animation. Calculate the movement assembly based upon the applied SolidWorks mates and motors.
4. **The Basic Flow Analysis** — The water flow analysis for assemblies with single inlet and single outlet; plus animated results showing flow lines, outputs for velocities and pressures, and color plots or Perform basic air (standard atmosphere).
5. **The Basic Environmental Impact Analysis** —The Quantify the environmental impact optimize material selection, part geometry, design, and sourcing.

3.3 Galvanized Iron (GI) Z-blade Reaction Turbine Development.

In this stage, the fabrications of the Z-blade turbine has been undergo and conducted by using test rig with 4 meter value of height of water head and water flow would be less than two litre per second. The Z-blade design consist of turbine arm which the diameter selected would be a 0.4m, 0.6m, 0.8m, 1m and 1.2 m. The turbine size selected is ½ inch and 1 inch. Experimental testing has been made and analyse for the best performance. Fig. 3.2, 3.3 and 3.4 shows the variation of turbine design that has been construct in SolidWorks simulation and the fabricated.



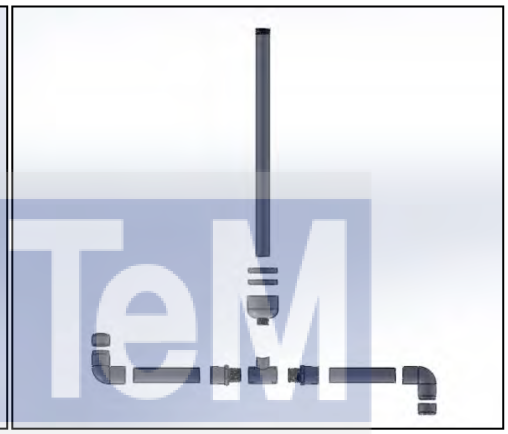


Figure 3.2: 1st model turbine design. Figure 3.3: 2nd model turbine design.

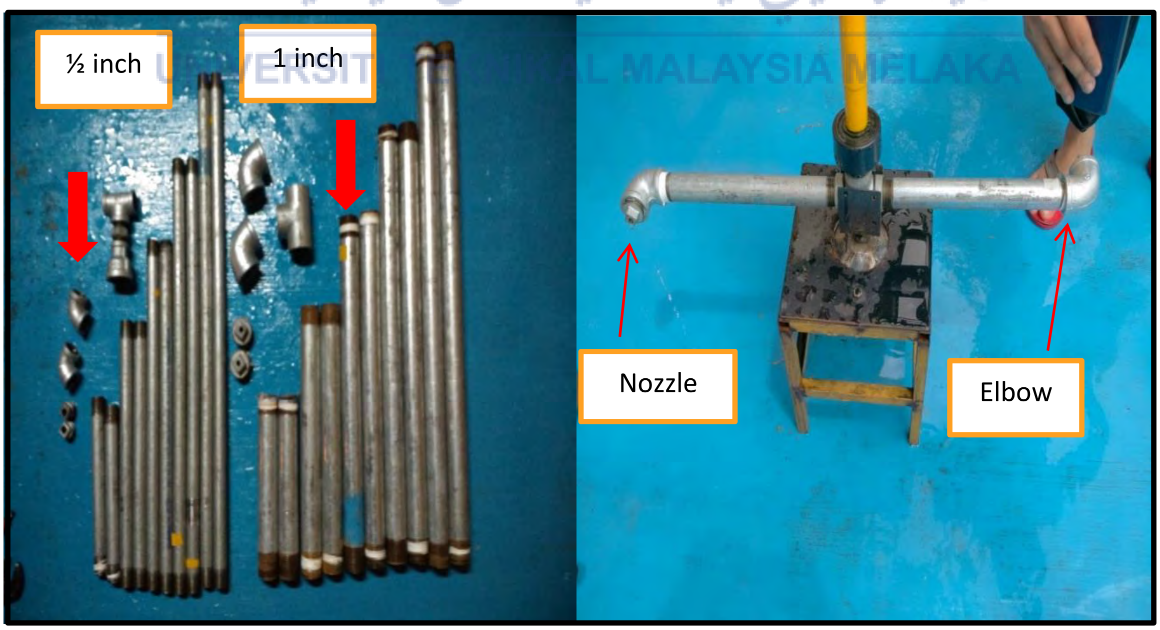


Figure 3.4: The fabricated turbine blade and nozzle.

3.4 Experimental setup

The water test rig has been built previously and some modifications have been done to meet the objectives set for this project. The water is filled through the bottom of the turbine and the generators installed at the top of the water turbine. Conversely, the generator is installed at the below the turbine and the water is filled from the top to the tank in order to maintain the gravitational potential energy density and the output power. In this experimental work as shown in Figure 3.4, the water flow from the tank (reservoir) with head of 4 meter and fixed pressure recorded as 15 psi. The flow rate supplied to the turbine can be controlled using a control valve on the main supply line. Mechanical flow meter (operates 2 L/min to 100 L/min) and the pressure gauge with range 0.1 bar - 0.2 bar is setup after the control valve on the supply line to compute the flow rate and the pressure (18 - 24kPa) throughout the turbine.

Figure 3.5: The Experimental testing rig design and actual mode.

In this experiment, the electrical power generated using a 250 W DC-540 Low Wind Permanent Magnet Alternator (PMA) from Wind blue and the output directly in the form of DC with the help of a bridge rectifier. The motors can produce 24 volt in 260 rpm. Therefore, some modifications have been made where the motor (central hub) was being put below the motor stand. Then, the turbine and the motor is paired with a simple way using a cable ties and screw arrangement as shown in Figure 3.6. This generator also categorized as the permanent magnet synchronous motor where the movement of magnetic field is synchronous with the rotor. This generator is able to perform likes DC generator with brushless DC, water resistant and robust. A voltage reading is recorded with the circuit open (No Load) while Amperage is recorded with output shorted (Max Load). Permanent Magnet Alternator does not need a battery to generate power.

Figure 3.6: The arrangement of GI Z-Blade turbine and generator.

A number of assessments happen to be completed about the Z-blade generator to supply a much better knowledge of the entire program, particularly when it comes to optimum size generator, the actual rotor effectiveness as well as energy producing capability. Assessments completed will also be carried out to look for the degree of performance as well as capacity for the actual generator towards the reduced mind as well as reduced circulation water situation. Generally, the actual assesment is going to be completed through environment water head associated with four meter in order to two meter having an optimum water circulation is actually two litters each minute.

3.4.1 Development of GI Z-blade Coupling

The coupling is the part where the Z-blade connects to it and considered it as a platform to make the smoothness of the turbine to spin. There are several design and development on Z-blade coupling been made and tested for its performance. The first design of coupling as shown in figure 3.6 was design by using 3 bearings which two of them weld by GI pipe for its connection to the Z-blade. However, there were several disadvantages for the first design of the coupling which is the bearing cannot support the weight of the turbine with 1 inch of size, too much water sprayed out from the mid -section of coupling, and the bearing used is not a static type of bearing as the bearings will move rightwards and leftwards when the turbine starts to spin.

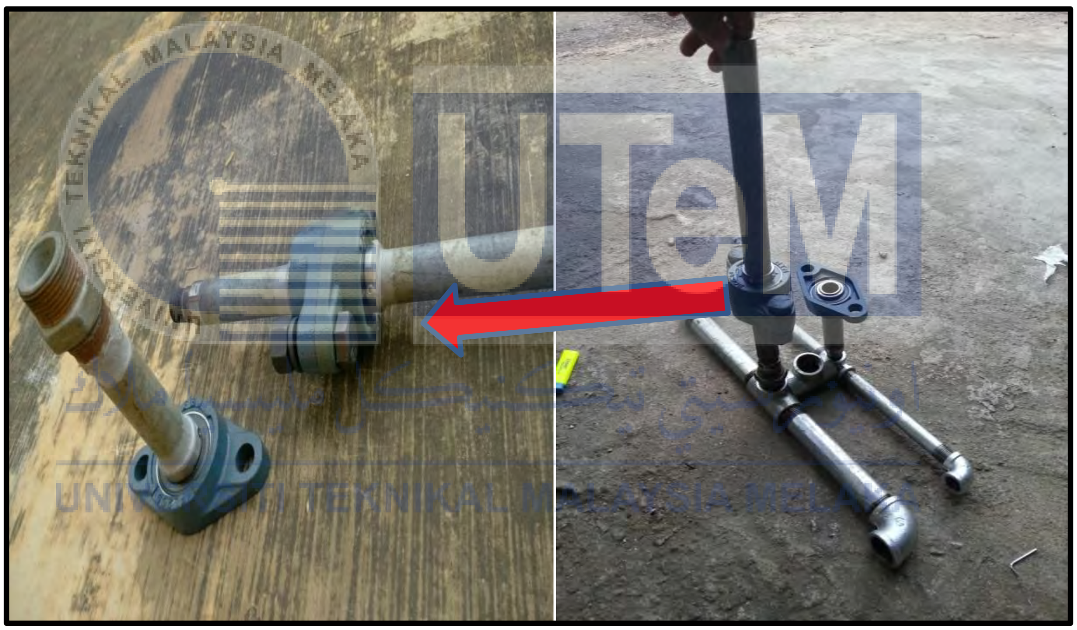


Figure 3.7: The first design of GI Z-blade coupling.

After the first design of the coupling have so many disadvantages, the second design of coupling has been made as shown in figure 3.8 and it is quite suitable with the turbine. The coupling only equipped with 1 bearing only which socketed with casing. The coupling design also has oil seal which can block the water from spray out from it. This base design is developed to reduce the water losses efficiently by the specific construction and also suitable for other use. The leakage of water prevented and this coupling cost affordable to fabricate. The second coupling also gave a good performance to the turbine in every aspect. So, the second design of coupling was selected to be tested along with turbine as it comply with the performance compared to the first design.

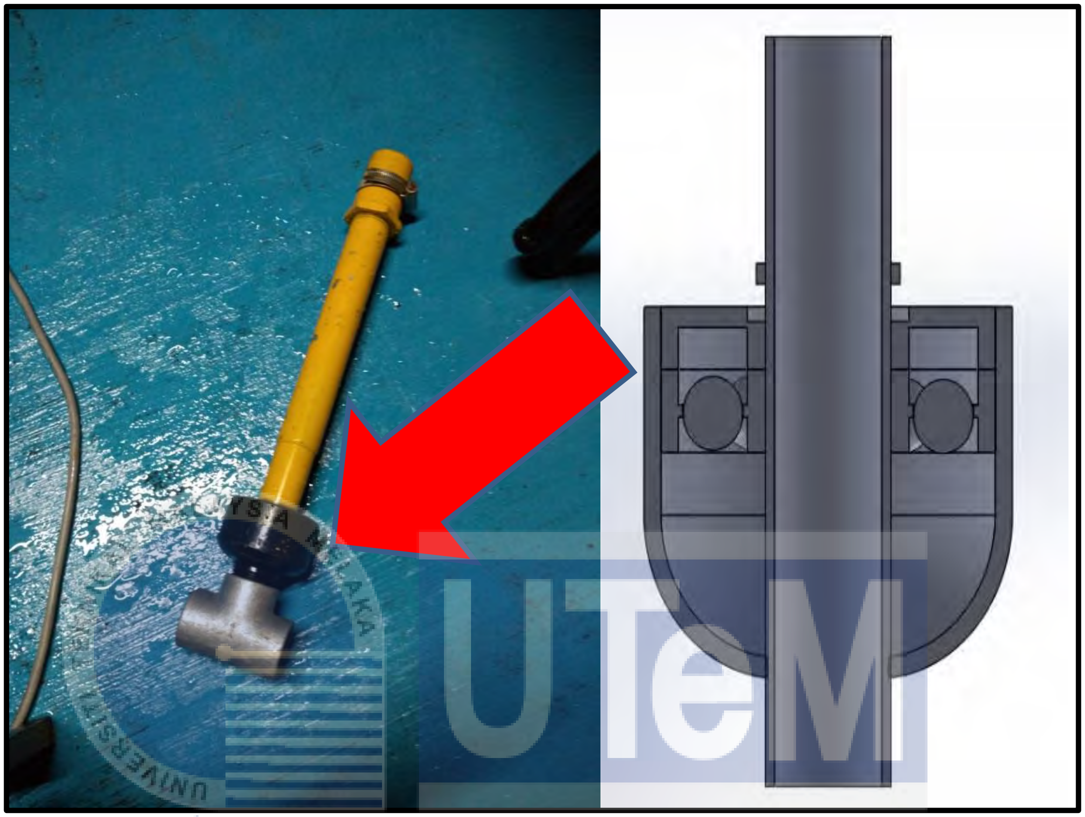


Figure 3.8: The second design of GI Z-blade coupling.

Yet another portion of critical along with important throughout receiving a top rated turbine can be water line jointing as well as coupling involving inlet water line along with turbine. It can be pretty exclusive since this specific place is often a getting together with place involving a pair of pipelines; an example may be standing plus the various other moves. Ultimately, normal water is just not permitted to drip out and about with the coupling place hence the furnished probable electricity can be managed without electricity loses. Mentioned previously ahead of, the intention of this specific undertaking should be to develop an economical turbine using straight forward manufacturing. Thus, using the bearing (1/2 " to 1 ") and oil seal (1/2 " to 1 ") and 1" pipe (50mm length), all parts is easily found locally, an efficient coupling has successfully been developed. From the observation, this coupling is capable of sealing the water when the water pressure is below 10 kPa.

3.4.2 Alternator and Rectifier

The alternator can be considered as generator that it produce an output power when the turbine spin. For this project the alternator, DC-540 Low Wind Permanent Magnet Alternator (PMA) from Wind blue has been used as shown in figure (). This generator produce an output of 24 volt in 260 RPM , which is suitable for this project. A voltage reading is recorded with the circuit open (No Load) while Amperage is recorded with output shorted (Max Load). This alternator can generate power by itself with using any output source. This can be used to generate power supply in a remote area and the alternator has a low cost of service. From the alternator, the output will be connected to the 3-phase bridge rectifier as shown in figure 3.10. The rectifier is an electrical device that produced a DC current which flow only in one direction. The process also can be known as rectification. The data collected was from the output of the rectifier.

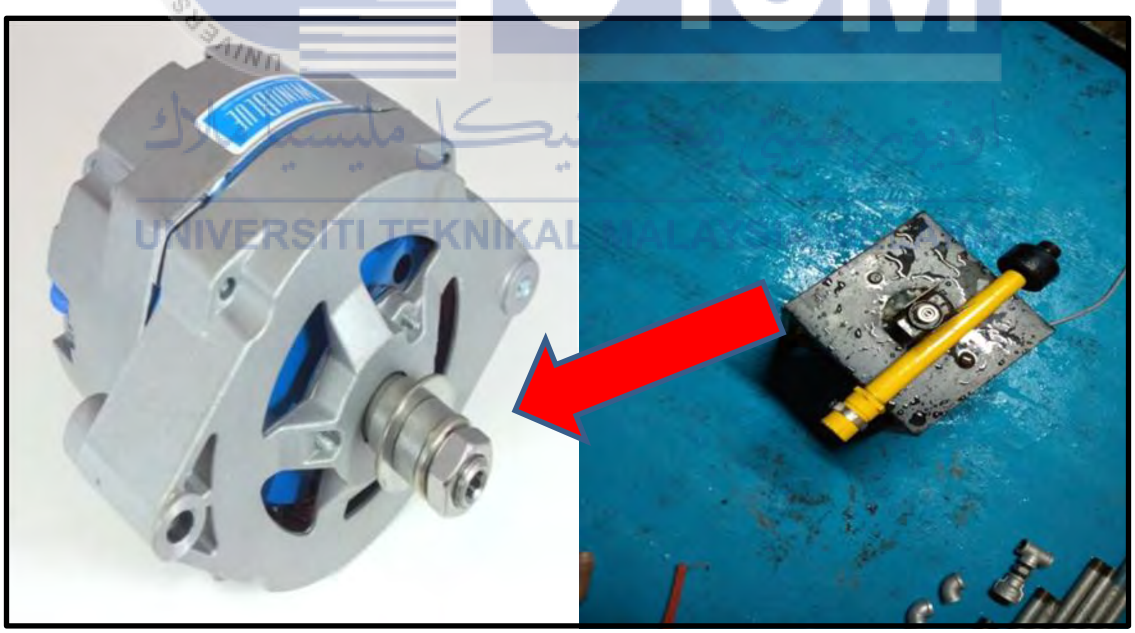


Figure 3.9: The DC-540 Low Wind Permanent Magnet Alternator (PMA).

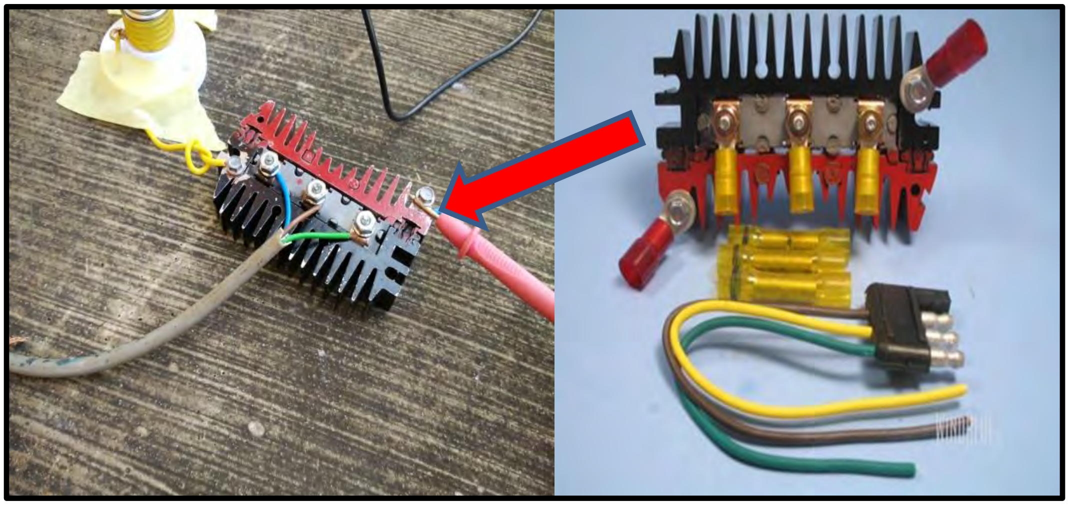


Figure 3.10: The 3-phase Bridge Rectifier.

3.5 Experimental Procedure.

The procedure of this project can be state as follows:

1. The turbine was installed in the test rig between penstock and the rotor shaft and all the jointing of the turbine was covered with white tape to prevent any dripping of water.
2. The turbine must be installed parallel between penstock and shaft of the motor. Use level scale ruler to check the angle of the turbine to prevent any unwanted vibration and unbalanced during the turbine spin.
3. The tank filled with water until it reaches maximum level.
4. The reflector was stick at the tip of the turbine blade as shown in figure 3.11.

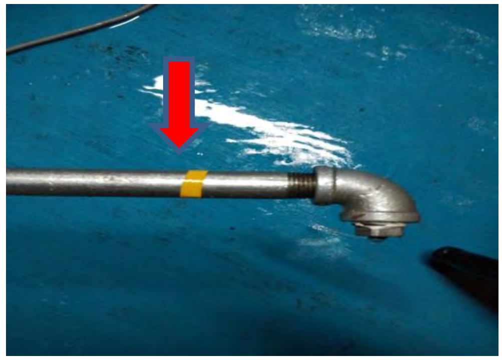


Figure 3.11: The Position of reflector.

5. The turbine in Z-Blade must be set position where the nozzle is against each other (clockwise position).
6. Connect the bridge rectifier to the alternator and connect the multi-meter probe to positive and negative terminals.
7. Install the ½ inch of turbine with 0.4 meter length and 6.5mm nozzle. Turn on the stopcock to run and wait until the rotation speed of the turbine is stable. The average time taken for turbine to stabilize is about 10 second.
8. Record the reading of the rotation speed by using tachometer. The angle of the tachometer must be perpendicular to the reflector. Avoid reading in a bright condition as it will affect the value of the tachometer.
9. Record the voltage and current value at the same time.
10. Reset the flow rate meter to zero value during running conditions, and then start simultaneously with stopwatch for 30seconds.
11. After 30 second, stop the water flow using stopcock and take the value of the flow rate.
12. Repeat the step 8 till 11 for 3 times in order to get the average value.
13. Repeat step 7 till 12 using 7mm and 7.5mm of nozzle.
14. Once it is complete for nozzle set, repeat step 7 to 13 by using 0.6m, 0.8m, 1.0m and 1.2m diameter of the turbine.
15. When the ½ inch size of turbine complete, repeat step 7 to 14 by using 1 inch of turbine size.

3.6 Analysis based on the theoretical prediction and experimental output

Data gathered in the theoretical prediction which has been developed during the parametric analysis is compared with the experimental works. In this stage, it will demonstrate that the experimental works output by using Galvanized Iron (GI) type material Z-blade type turbine conducted and analysed.

3.7 Parameter Analysis

To obtain the optimum result, some relation must be consider as it will affected the experimental part. The equation of gaining the optimum diameter of turbine must be considered in order to obtain the optimum rotational speed as it is correspond to a maximum efficiency of the turbine.

The water flow and rotational speed also will give an effect of the process obtaining the equation and also gaining the optimum diameter of galvanized iron Z-blade reaction turbine. Other than that, the parameter should be applied as a way to establish the project. The parameter such as voltage output V_o, current output I_o, power output P_o, and Speed of turbine RPM is considered as output parameter of the project that need to be measure in order to gain the optimum generation. To conduct an analysis of this experiment, Microsoft Excel 2010 is needed as a platform needed for graph plotting and calculation based on result obtained.

3.8 Report Findings

Findings of proposed research will be documented in technical papers and research report for publications.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

In order to achieve the objectives, This chapter will discuss the performance of galvanized iron Z-blade turbine by do the analysis. The test has been done and the data gathered will be discussed and compared. In this chapter, the result test will be shown in graph..

4.2 Test Result Analysis

As the data done collected, the result will be interpreted in graph illustrations to establish the relationship and also comparison of several performances of the turbine. When the test began, the voltage, current and speed are measured in 1 minute mark and the rate of water flow was measured as it plays important role in this experiment. From the equation 4.1, the water pressure, P (pa) can be calculated by using the head of water, H (m).

$$P = H / 0.704 \tag{4.1}$$

The flow rate of water will be different value as the turbine used was different in turbine size, nozzle size, and also the diameter of the turbine (turbine arm). The flow rate was measured for 30second sharp. When it reaches 30 second, the water stopped by turn off the stopcock at the penstock. To determine the flow rate, Q (l/s) equation 4.1.2 can be used where V is the volume of water flow out from nozzle.

$$Q = V/30s \tag{4.2}$$

From the data gathered, the table 4.2 and table 4.3 shows that the data collected from the test by varying the reading of rotational speed (rpm), water flow rate (l/s), ac voltage (V), ac current (A), dc voltage, and dc current as it measured by a varying the nozzle size, turbine diameter (turbine arm) , and turbine size. The head of the water is fixed by using 4m head of water. The test was connected to rectifier kit with assuming 1kΩ of resistor as load value to gain the current value. The test generator used is DC-540 Low Wind Permanent Magnet Alternator (PMA). The test run by three times to gain the average value of data.

Table 4.2 : Performance ½" turbine size with 4m head.

Turbine diameter(arm) (m)	Angular Speed (RPM)				AC Current (mA)				AC Voltage (V)				DC Voltage (V)				DC Current (mA)				Flow rate l/s			
	6.5	**7**	**7.5**	**12.7**	**6.5**	**7**	**7.5**	**12.7**	**6.5**	**7**	**7.5**	**12.7**	**6.5**	**7**	**7.5**	**12.7**	**6.5**	**7**	**7.5**	**12.7**	**6.5**	**7**	**7.5**	**12.7**
0.4	123	145	169	50	0.47	0.53	0.6	0.14	10.5	13.4	13.9	2.5	9.6	12.6	13.4	2.5	9.6	12.6	13.4	2.5	0.49	0.78	1.04	1.31
0.6	174	182	188	77	0.65	0.59	0.5	0.11	12	12.4	12.8	5	11.1	11.2	11.4	4.3	11.1	11.2	11.4	4.3	0.60	0.89	1.12	1.31
0.8	156	158	164	61	0.59	0.64	0.39	0.06	10.7	11.5	11.9	4.7	9.2	10.1	11.3	3	9.2	10.1	11.3	3	0.65	0.95	1.14	1.34
1	119	128	132	53	0.53	0.45	0.32	0.06	8.2	8.9	9.1	4.3	7.1	7.7	8.5	2.9	7.1	7.7	8.5	2.9	0.70	1.00	1.18	1.33
1.2	110	119	121	45	0.41	0.39	0.25	0.05	7.2	7.8	8.2	3.3	6.7	7.2	7.8	2.4	6.7	7.2	7.8	2.4	0.71	1.01	1.18	1.32

Table 4.3: Performance 1" turbine size with 4m head.

Turbine diameter (arm)(m)	Angular Speed (RPM)				AC Current (mA)				AC Voltage (V)				DC Voltage (V)				DC Current (mA)				Flow rate l/s			
	6.5	**7**	**7.5**	**25.4**	**6.5**	**7**	**7.5**	**25.4**	**6.5**	**7**	**7.5**	**25.4**	**6.5**	**7**	**7.5**	**25.4**	**6.5**	**7**	**7.5**	**25.4**	**6.5**	**7**	**7.5**	**25.4**
0.4	188	202	204	90	0.57	0.7	0.65	0.14	16.4	17.8	17.6	5.5	12.2	13.7	13.2	5.2	12.2	13.7	13.2	5.2	0.61	1.0	1.35	1.87
0.6	190	205	223	77	0.54	0.66	0.57	0.11	15.32	16.5	15.3	5	11.48	13.5	12.36	4.3	11.48	13.5	12.36	4.3	0.72	1.12	1.43	1.91
0.8	160	141	154	53	0.42	0.46	0.44	0.06	11.8	12.7	12.6.	4.7	9.5	11.25	10.3	3	9.5	11.25	10.3	3	0.72	1.14	1.48	1.87
1	131	141	154	53	0.32	0.37	0.34	0.06	8.8	10.1	9.5	4.3	7.8	8.7	8.4	2.9	7.8	8.7	8.4	2.9	0.71	1.24	1.36	1.97
1.2	117	126	127	45	0.29	0.33	0.31	0.05	8	8.7	8.6	3.3	7.9	7.5	7.3	2.4	7.9	7.5	7.3	2.4	0.71	1.01	1.17	1.92

4.3 Data Comparison Between ½ inch and 1inch of GI Pipe Turbine According Parameter.

The graph in figure 4.1 shows that the comparison between angular velocity. The figure clearly shows that 1inch GI pipe is greater than ½ inch pipe of turbine size. The optimum of nozzle for ½ inch turbine is nozzle 7.5mm at 0.6m turbine arm same as 1 inch turbine and the nozzle 7.5mm at 0.6m turbine arm has the highest compared to the other nozzles. The highest value of angular velocity for 1 inch of turbine is 223rpm at nozzle 7.5mm from 0.6m of turbine arm and ½ inch turbine is 188rpm at 7.5mm nozzle from 0.6 m turbine arm.

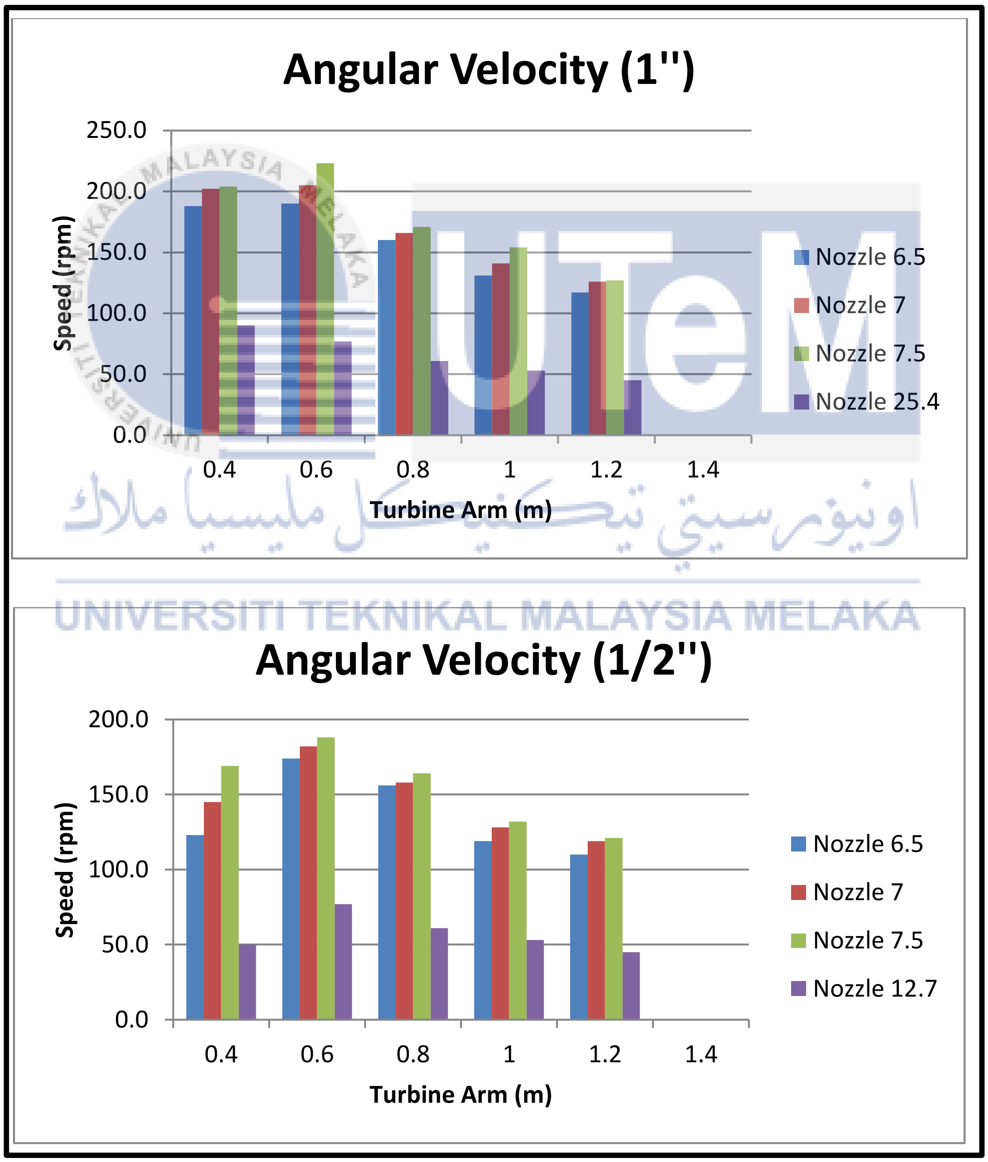


Figure 4.1: Comparison angular velocity between turbine 1/2" and 1".

Figure 4.2 shows the comparison of output Ac voltage between 1 inch and ½ inch size of turbine. The 1 inch graph shows that the 7 mm nozzle reaches the highest value of output voltage followed by other values. For ½ inch graph, it shows that the nozzle 7.5mm have the highest values of output AC voltage compared to the other nozzle. Both of the graph shows linearly decrease as the size of nozzle increased. The nozzle size 6.5mm and 12.7 mm for ½ inch graph shows that the increase of output AC voltage occur at 0.4m and 0.6m of turbine arm and drop back. The 1 inch graph shows that the AC output voltage is higher than ½ inch where the nozzle 7mm for 1 inch graph is the most optimum nozzle and the nozzle 7.5mm for ½ inch graph is most optimum. The optimum value output AC voltage produce for 1 inch and ½ inch is 17.9V when the turbine arm is 0.4m and 13.9V when the turbine arm is 0.4m respectively.

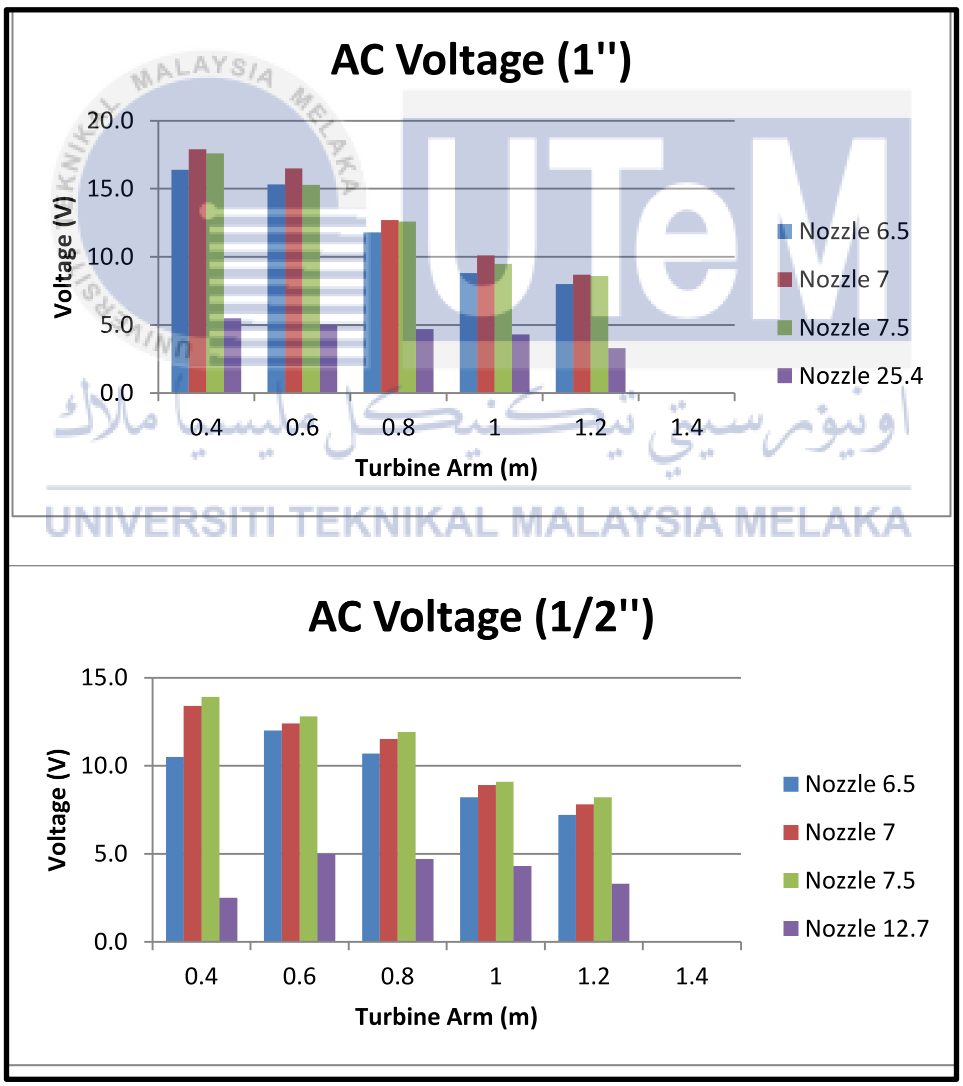


Figure 4.2: Comparison AC voltage between turbine 1/2" and 1".

The Figure 4.3 shows the behavior of AC current for turbine size ½” and 1”. There is a significant decrease for AC current output except for nozzle 7mm and 6.5mm for both graph because a bell shape behaviour where the optimum point occur at 0.6 m turbine diameter size (turbine arm) for both turbine size. The graph ½ inch have the most output AC current which is 0.65 A for 6.5mm nozzle. The 1 inch graph shows that the 7mm nozzle produces the most output AC current which is 0.66A. This can be concludes that the 1 inch GI pipe produce the slightly highest current value compared to ½ inch of pipe. The 7.5mm nozzle shows the linearly decreasing of output AC current for both graph.

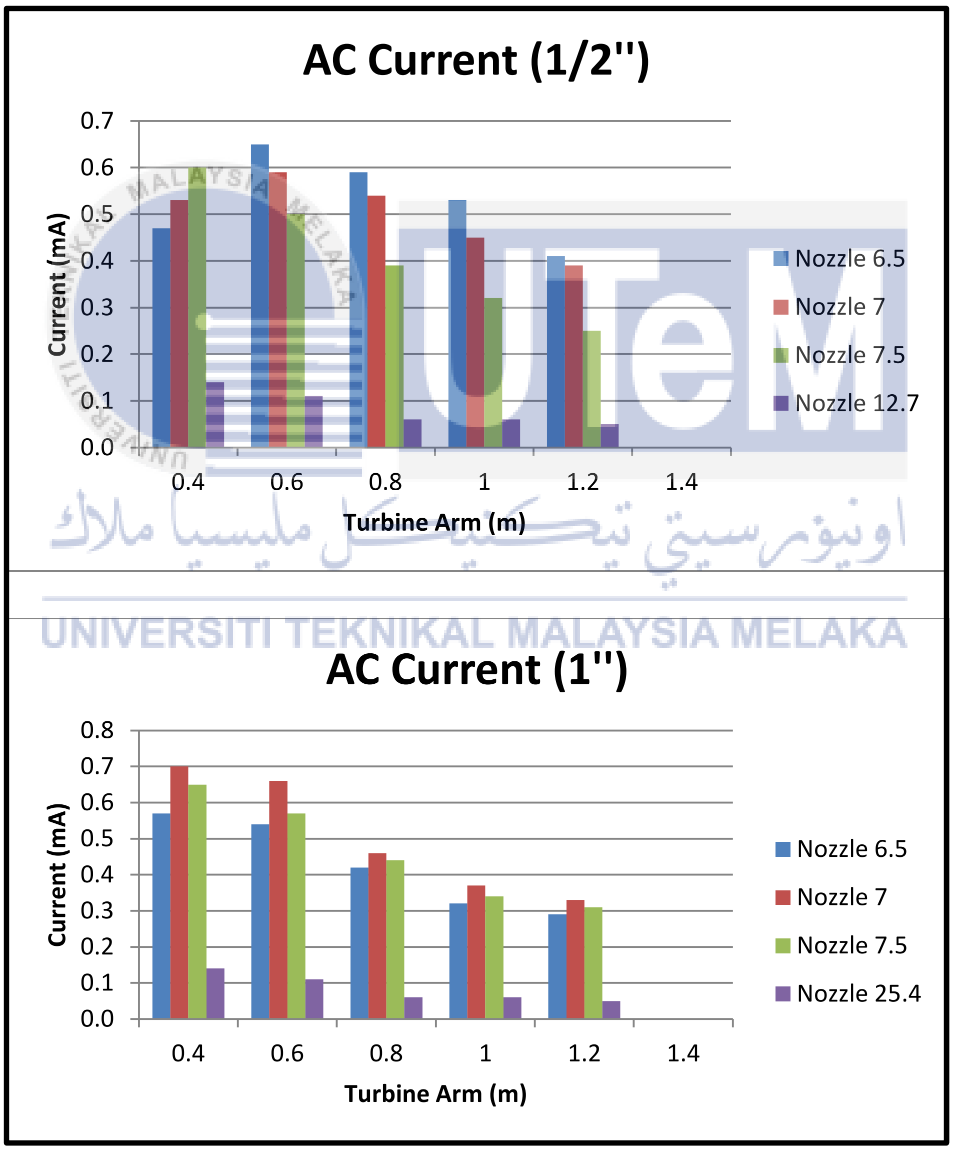


Figure 4.3: Comparison AC current between turbines 1/2" and 1".

Figure 4.4 show the comparison of DC Voltage output between ½inch and 1inch turbine size. DC Voltage output of turbine size 1 inch has the larger output DC voltage than turbine size ½ inch which the value is 13.7V for the 1 inch at 0.4m turbine arm and 13.4V for ½ inch at 0.4m turbine arm. The output DC voltage of 1 inch is linearly decreases within increase of diameter of pipe(turbine arm). The nozzle 7mm and 7.5mm of 1 inch turbine also shows linearity of decrease in voltage as the nozzle 6.5mm and 12.7mm increasing form 0.4m to 0.6m turbine arm of GI pipe turbine.

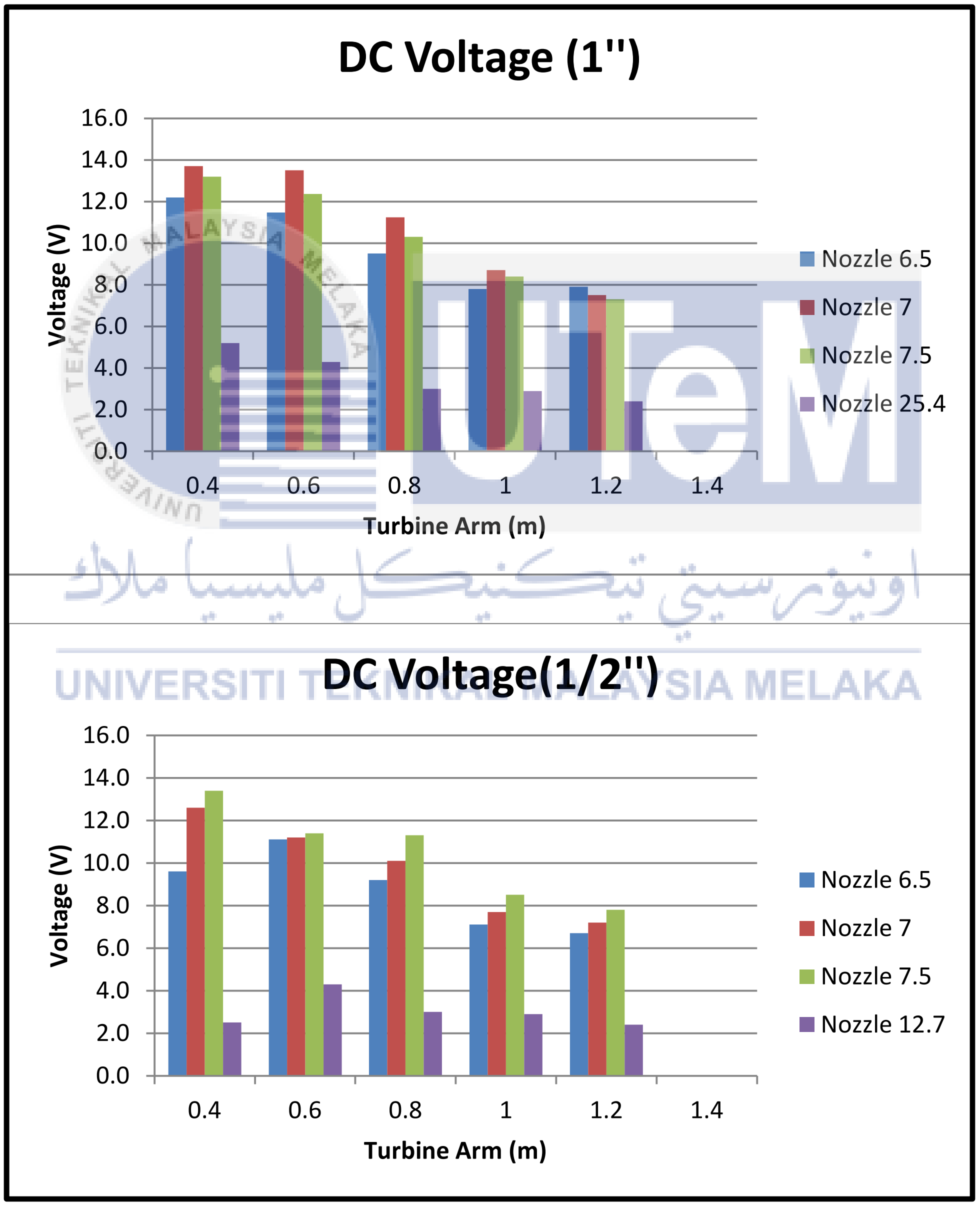


Figure 4.4: Comparison DC voltage between turbine 1/2" and 1".

The Graphs in Figure 4.5 show the comparison of DC Current between turbine size ½" and 1". There was an increasing in current in the output of DC current for nozzle size 6.5 mm, and 12.7mm from 0.4m to 0.6m turbine arm in graph ½ inch. The graph of 1 inch is linearly decrease in all nozzle regards to increasing of diameter (turbine arm) The optimum output recorded for ½ turbine size is 13.4mA which is nozzle size 7.5 mm with turbine arm 0.4 m and the minimum DC current is 2.4 mA which is occur at 12.7 mm nozzle size with 1.2 m turbine arm. The optimum current for 1 inch turbine is 13.7mA recorded in nozzle 7mm at 0.4m turbine arm and the minimum output DC current recorded is 2.4mA in the nozzle 25.4mm at 1.2 turbine arm.

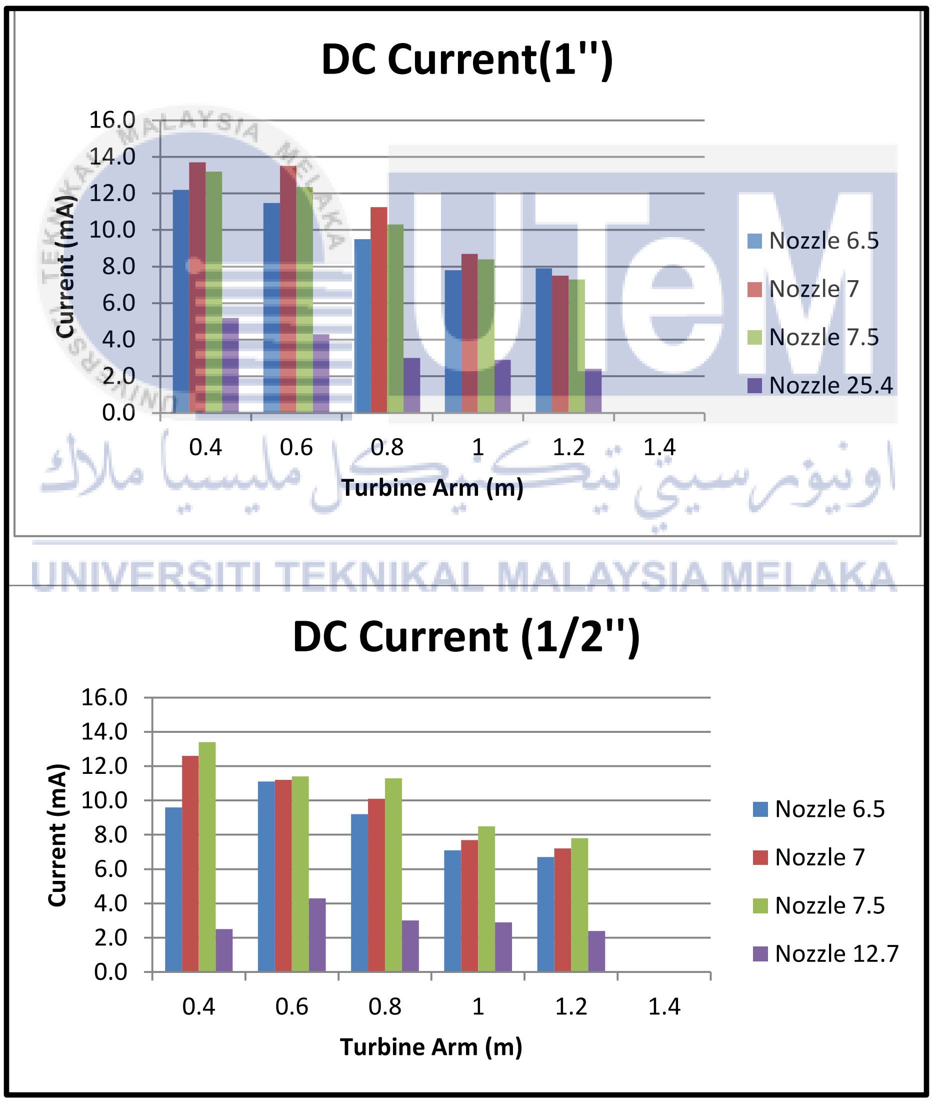


Figure 4.5: Comparison of DC current between turbines 1/2" and 1".

Figure 4.6 shows the flow rate comparison between 1 inch and ½ inch size of turbine. Graph on Figure 4.6 mostly shows same pattern which is gradually increase until it reach the optimum point then remain constant. The 1 inch turbine shows the higher flow rate compare to ½ -inch turbine size. The maximum flow rate recorded is 1.315/s for ½ turbine size and 1.98 7/s for 1 inch turbine size. The average of flow rate for each nozzle size for turbine 1 inch is 0.4 l/s which is larger compare to average different for ½ inch turbine size which is 0.2 l/s. This concludes that the 1 inch turbine consume more water than ½ inch turbine.

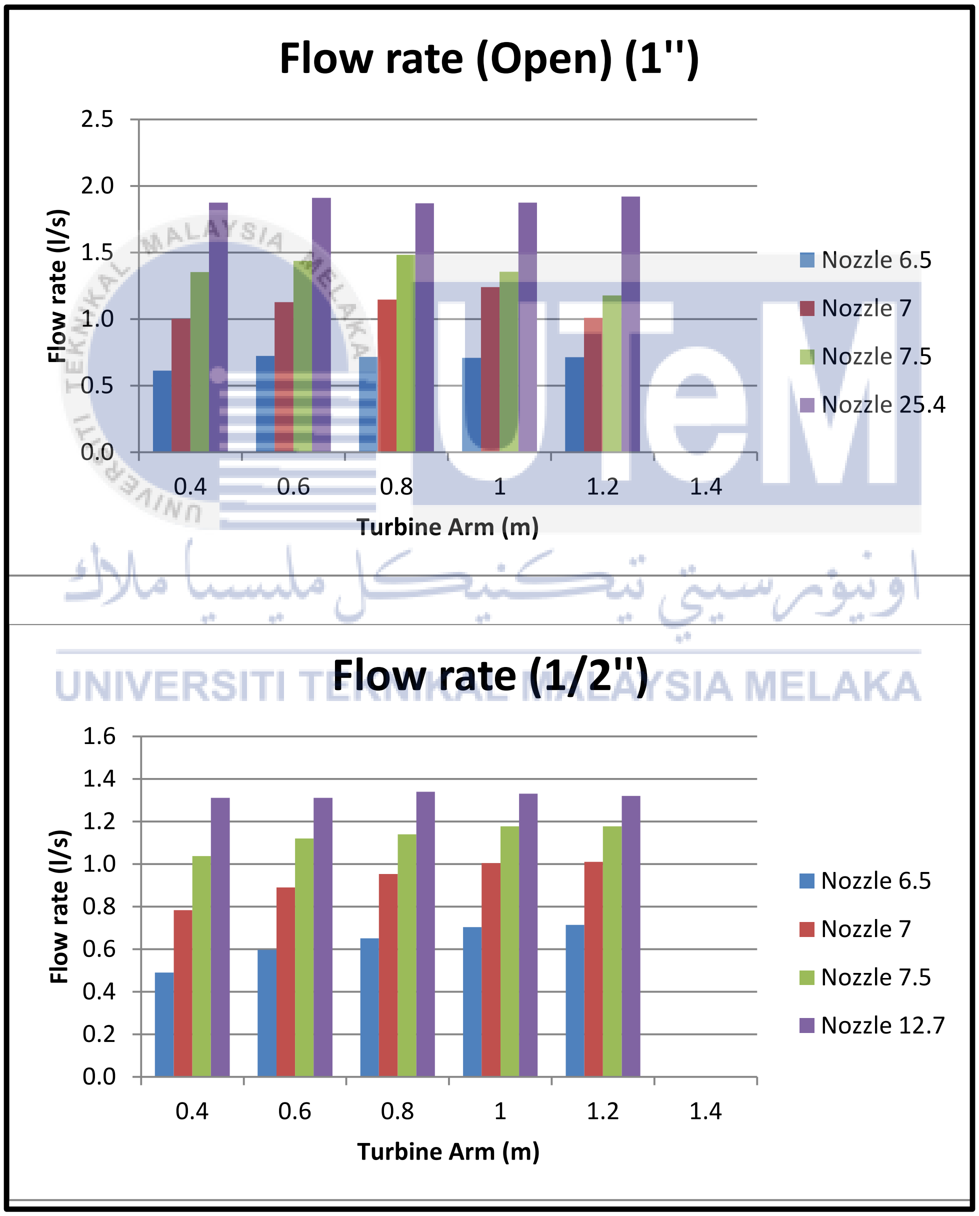


Figure 4.6: Comparison of flow rate between turbine 1/2" and 1".

Based on figure 4.7, the graph shows the comparison between ½ inch and 1 inch of turbine according to the output AC power produce. The optimum power produce from 1 inch turbine is 12.53W from 7mm nozzle at 0.4m turbine arm. For the ½ inch turbine, the optimum output AC power produced is 8.34W from nozzle 7.5mm at 0.4m diameter of the turbine.

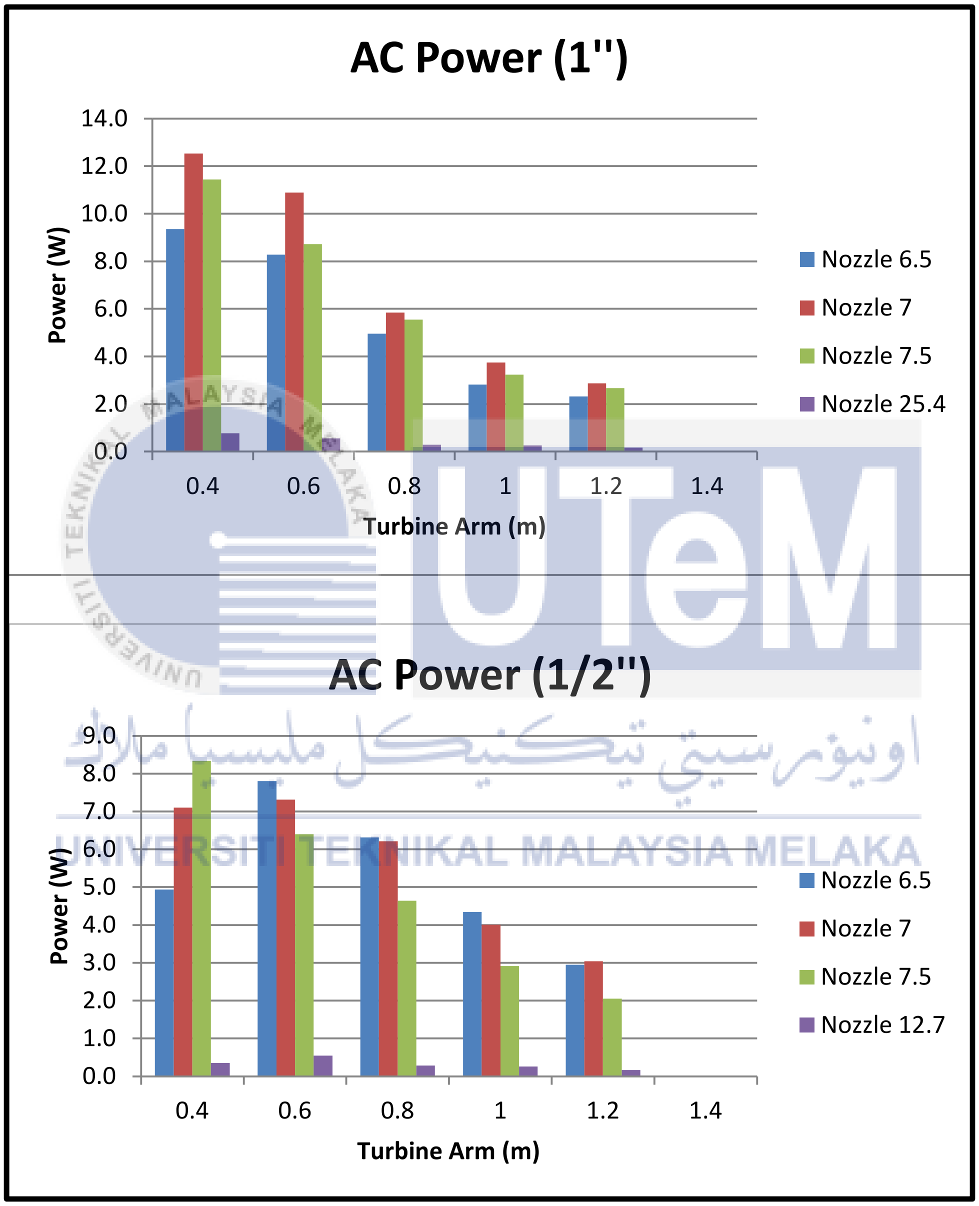


Figure 4.7: Comparison of AC power between ½'' and 1'' turbine.

Based on above, the graph shows the comparison output DC power between ½ inch and 1 inch pipe size. From graph 1 inch, the optimum power produce is 0.19W from nozzle 7mm at 0.4m diameter. From graph ½ inch, the optimum power produce is 0.16W from nozzle 7.5mm at 0.4m diameter of turbine. It can be conclude that 1inch DC power output produce is greater than 1/2 inch size of turbine.

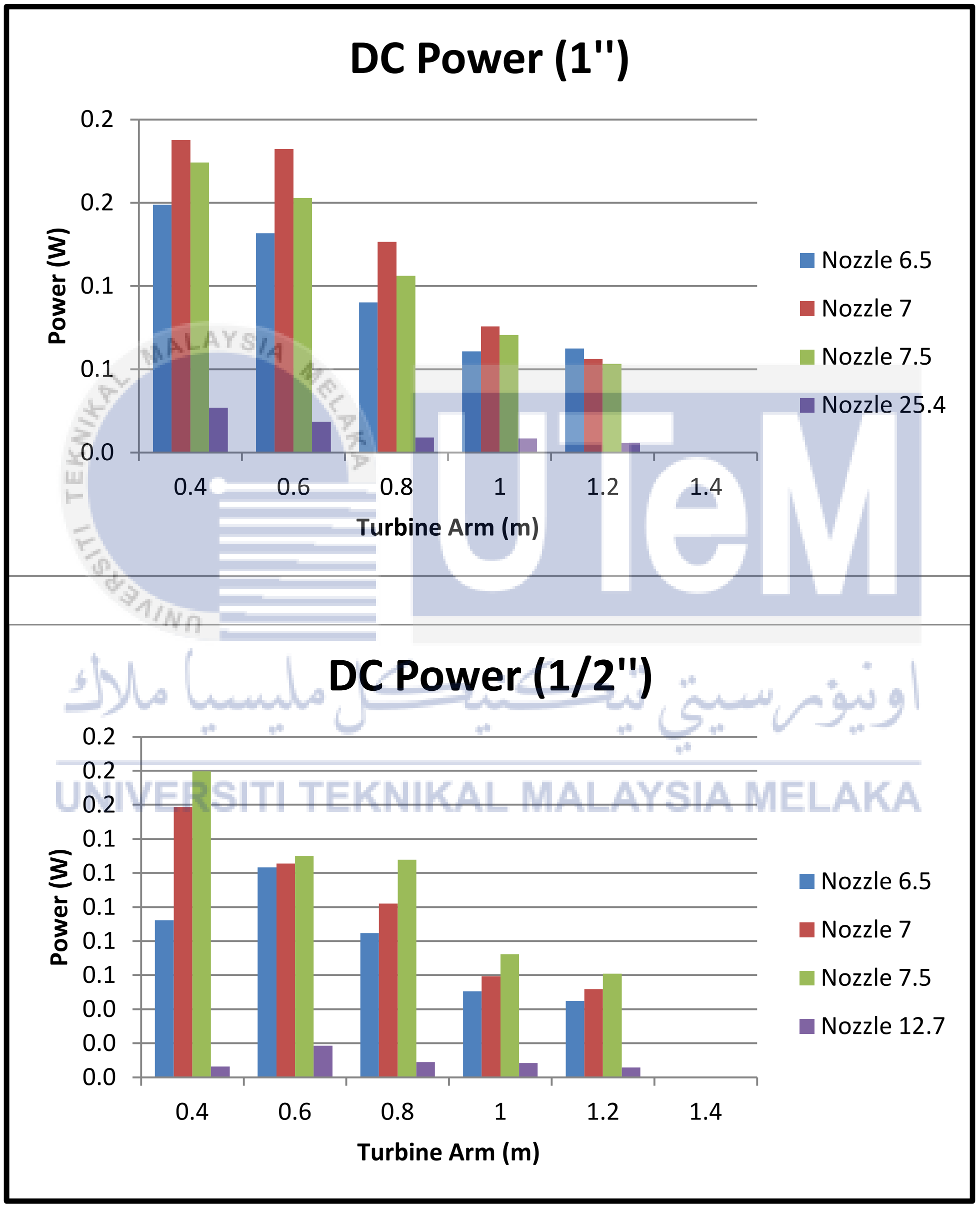


Figure 4.8: Comparison between ½'' and 1'' according output DC power.

4.4 Discussion

A fresh layout for a simple reaction water turbine with indicating problems of cost and controllability has been introduced. The key point within this analysis will be the investigation part wherever the idea can determine the feasibility along with functionality could possibly be reached via the proposed Pico-hydro system. There are numerous aspects in which decide the particular feasibility and also efficiency could be attained from the method. For instance, the amount of power produced from the flow of water through pipeline or penstock and dependable to availability of water, the pressure of the water, and also the friction occur in the pipeline. There are several factors affecting the feasibility such as the type of turbine, the type of generator use, capacity of electrical load to be supplied and also the cost of develop and design the project.

For this scope of project, some loss that normally can be occur is mechanical power of the turbine. For example, the power of water flowing out the nozzle in order to spin the turbine. Viscous loss also can be considered negligible as it is water flowing out through the penstock, nozzles and also rotor. The windage loses occurs from the rotation of rotor also negligible. The factors that produce a non-linear data are cause by mechanical loses and also vibration of the turbine and pipeline (penstock). The increase of mass flow rate is also related to the centrifugal pumping effect which increased together with the rotational speed. It is also seen that the mass flow rate increased as the centrifugal suction effect at higher rotational speeds. Air drag was measured for being very small as the rotor has a disk shape; losses are caused by friction at the seal lip and fluid friction losses in the turbine. Lastly, the weight of the turbine also must be considered to improve the linearity of data gained.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Introduction

This chapter discusses the conclusion and suggests future work to further improve the development of the system. It also stresses the significance and potential application from the research output.

5.2 Conclusion

In this project, the galvanized iron Z-blade turbine still has a momentum in creating a green energy in hydropower world. This project is about development of Pico hydro generation system for low head water resources. An improvement still can be made to analyse how far galvanized iron pipe turbine can produce the output power. The diameter and size of nozzle still can be understudy in this Pico hydro scope to make the output more reliable and efficient. For this test, the size of the turbine has two which is 1 inch and ½ inch type. The diameter (turbine arm) selected is 0.4m, 0.6m, 0.8m, 1.0m, and 1.2m .The head used is 4m from the water source. The nozzle selected was 6.5mm, 7mm, and 7.5mm. The nozzle 12.7mm and 25.4mm of nozzle is the sizes of the GI elbow for 1 inch and ½ inch that assumed as no nozzle which can be conclude less optimum of output power produced. The test was repeated by 3 times for each diameter (arm) and size of nozzle to produce an average data. So, it can be conclude that for 1 inch size of turbine, the turbine arm 0.4m at 7mm of nozzle produce the most optimum power output compared to the others. The most optimum for ½ inch turbine is 0.4m turbine arm at 7.5mm of nozzle.

The performance of GI Z-blade turbine is affected by several manipulation which is flow rate, head of water, the size of turbine, the flow rate, the diameter of the turbine and the size of nozzle. The development of Z-blade turbine shows a great potential in hydropower development for ultra- low head of water. From the analysis and the data gained, it can be stated that the Z-blade turbine GI material spins a lot faster when the diameter of turbine smaller. From the theory of reaction turbine, the smaller the diameter of turbine, the faster the movement of the turbine. So, this result gained is proven by the theory. By suitable head and water flow rate, The Pico hydro GI Z-blade turbine could powered more than others green energy innovations. With small turbine suitable for small stream and yet small water flow rate. When this condition meets, it would be good enough to produce green energy by using Pico hydro system.

5.2 Recommendation.

For the further study of this project, there are some recommendations that have been stated. To increase the performance of output power, a various scales of turbine arm and size of nozzles must be considered. Furthermore, this project also can be wider the scope by using various scale of head of water in order to gain more power. As stated, the more higher the head, the pressure of water will be higher. When this situation happen, the turbine will spin a lot faster due to the pressure of water and the power produce would be higher. For the observation part, the speed of turbine must be observed in the night time because the sunlight would affect the reading of the tachometer.

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