DESIGN & FABRICATION OF HORIZONTAL TURBINE FOR RURAL MICRO HYDROELECTRIC GENERATIONS

by

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the

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Approved by,

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(Mr Mohd Faizairi Mohd Nor)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

May 2012

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

SITI MARHAMAH BINTI MUSTAFHA

ABSTRACT

There are many types of turbine which can be identified as hydraulic or water turbine, gas turbine or steam turbine. For the study, the author need to design a prototype of hydraulic turbine which is in the end, can assist Sek Kg Sungai Tiang in Grik, Perak in receiving electricity. The hydraulic turbine will be place onto the river (not fully submerge) and the velocity of the river should be at least $3ms^{-1}$. Hydraulic turbine is a prime mover that uses the energy of flowing water (river) and converts it into the mechanical energy.

The turbine can be categorized into two types which are impulse turbine and also reaction turbine. Impulse turbine can be defined as a prime mover in which fluid under pressure enters a stationary nozzle where its pressure (potential) energy is converted to velocity (kinetic) energy and absorbed by the rotor. For this kind of turbine, the rotor will rotate freely in atmospheric pressure and never be submerged in water of the tail race. It is different from the reaction where the turbine's rotor remains immersed in water all the time and water acting on the wheel is under pressure which is greater than atmospheric pressure.

The design of the turbine can be classified into two types, horizontal and vertical. This project is focusing on more on simulation (by using Catia) and fabrication of the prototype for the horizontal one (cross-flow turbine). A lot of studies have been done which mostly cover the part of finding the formula for the calculations and understanding the theory of run river turbine working principle. The fabrication part is done and try as much as possible following the theoretical value that have been calculated at first.

ACKNOWLEDGEMENT

This final year project would not have been possible without the support of many people. The author wishes to express her gratitude to her supervisor, Mr Mohd Faizairi Mohd Nor who was abundantly helpful and offered invaluable assistance, support and guidance. Deepest gratitude are also for the members of the supervisory committee, Ir Idris Ibrahim and Dr Taib Ibrahim without whose knowledge and assistance this project would not have been successful.

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Last but not least, the author wishes to express her love and gratitude to her beloved families; for their understanding and endless love, through the duration of her studies.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

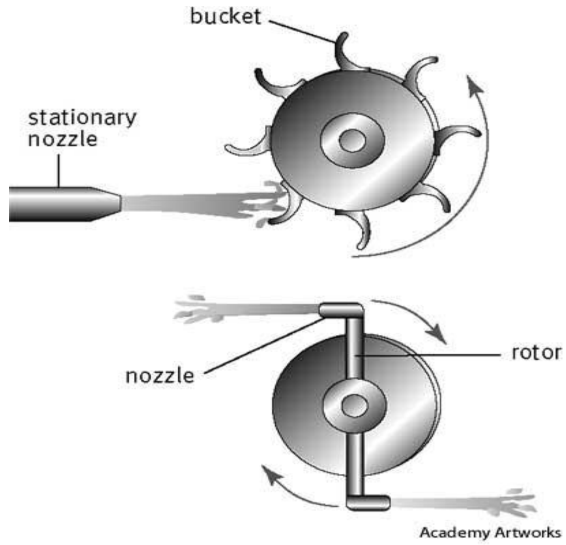
1.1 Background of Study

Turbine is a rotary engine that converts the energy of moving stream of water, steam or gas into mechanical energy. The basic element in a turbine is a rotor or wheel with propellers, paddles, buckets or blades arranged on its circumference in such a way that the moving fluid exerts a tangential force that turns the wheel and imparts energy to it. This mechanical energy is then transferred through a drive shaft to operate a compressor, machine, propeller or electric generator.

Hydro-electricity is usually associated with the building of large dams. In the 20th century, hundreds of massive barriers of concrete, rock and earth were placed across river valleys worldwide to create huge artificial lakes. While they create a major, reliable power supply, plus irrigation and flood control benefits, dams necessarily flood large areas of fertile land and displace many thousands of local inhabitants. In many cases, rapid silting up of the dam has reduced its productivity and lifetime. Hydropower on a small-scale, or micro-hydro, is the exploitation of a river's hydro potential without significant damming, and is one of the most environmentally benign energy options available.

Micro hydro is a valuable source of energy for rural industries and village electrification schemes. It has been a traditional method of grain processing throughout the world and played a major role in modernization and also industrial development in a well-developed country. Micro hydro now offers similar potential to most developing countries such as Malaysia, with applications in village lightning, mechanized food processing, and the supply of power to small scale industrial activities.

Last but not least, micro hydro turbine delivers some the positive aspects for better future development; reduced impact on the environment, there is no need for the civil constructions, the river is not changing its original course.



Impulse turbine

Reaction turbine

Figure 1.1: Type of Turbine

1.2 Problem Statement

For the final year project entitled design and fabrication of horizontal turbine for rural micro hydroelectric generations, we have identified several problems that arise during study the concept of turbine design. This kind of problems can be a solid reason for us in designing and fabricating the prototype;

1. Sek Kg Sungai Tiang in Grik, Perak is located in the rural area (Kampung Orang Asli) where there is no grid connection. The grid connection plays the important role as a main passage for the electricity. Currently, the school and also the villagers use solar energy and diesel generator as a main source for electricity.
2. The main disadvantage of using the solar energy as the main source of electricity is the high cost for the initial installment of the equipment use to harness the suns energy. In others, it is required a large area for the solar energy installation so that the system will be efficient in providing the electricity.
   The clouds also can degrade the energy of the sun rays and usually the efficiency of solar panel absorbs the sun rays just less than 10%. On the other hand, the weather in Malaysia is 'Khatulistiwa' which is hot but high humidity (high moist in the air). The weather of low humidity (low moist in the air) is preferable for

better absorption. Furthermore, the solar panel only function during daylight, and that expensive equipment will become useless at night. But, there is a battery charger which is keeping the energy.

3. The other source of energy currently used by the villagers is the diesel generators. A diesel generator is the combination of a diesel engine with an electrical generator to generate electrical energy. The main problem of using the diesel generator is the high cost for the fuel. Currently, diesel has an actual price of RM2.66 and the RM1.80 retail price works out to a subsidy of 86sen, which works out to 32%.
4. Inconsistent river flow and vary from month to month also can affect the available power output of a hydro turbine placed in the stream. So the main point here; the good site selection and also hydro turbine sizing which is compatible with the stream are very important in order to keep the turbine efficiency.

Figure 1.2: Diesel Generator

Figure 1.3: Solar Panel

1.3 Objectives & Scope of Study

As the efforts have been put for the project, below are the listed objectives in order to achieve or accomplish the goal;

1. To develop the basic layout and conceptual design of a prototype run river turbine.
2. To develop standard size increments based on an analysis of off-the-shelf components and to suit turbine sizes (fin design) in the range below 100KW (micro hydroelectric generations).
3. To analyze the principle of turbine components in order to assess the level of standardization achievable across the range of machine sizes.

Scope of the study cover the area of Sek Kg Sungai Tiang at Grik,Perak. The nearest river has been used before as an experiment to determine the velocity of the river (3m/s at least). Block 21 of Mechanical Department is used for the prototype's fabrication and there are some model of run river turbine that has been done by the previous students which can be as main references, located at block 14, 18 and 21. After done with the fabrication, the prototype testing is done by using the air blower for the mechanical input, anemometer as to detect the velocity of the air, and also the digital multi-meter for measure the output voltage.

This project will be assist by the software of Catia for the design. But, there is software which is really helpful for engineers to decide on what type of turbine that can be used by just entering some details/data which is TURBNPRO. TRBNPRO determines hydro turbine sizing and type selection based on actual site data entered by the user. Typical performance and dimensional data of the hydro turbine size/type selected are developed by the program including speed, runaway speed and cavitation characteristics. The main problem is it is too expensive for us just to buy the original software and usually used by the experience engineer.

CHAPTER 2

LITERATURE REVIEW

2.1 Turbine Description

Run of the river turbine relies on the natural flow of the waterway, such as river. The water flow in a stream is directly proportional to the available power output of a hydro turbine which place on the stream. If water flow is reduce, the available power output also will be reduce and the vice versa. The placing of the small, mini or micro run river turbine into waterway involves no larger dam and just need a small dam which is done in a way that does not harm the marine life and no destruction to the land. There also other run river turbine which operates without the dams.

There are several methods in operating the hydro turbine. Some projects involve running a pipe down the stream and this pipe will be a Penstock that creates a head pressure which allows a hydro turbine to run efficiently. The other method use is by placing the hydro turbine in a strong current river which involved no visible structure at all. The turbine is place under the surface of the river, out of sight and also given minimal impact to the environment. They produce the power from the natural flow of the river.

Run river turbine is very reliable energy which can provide continuous power every day. But the problem that might be facing here is the inconsistency of the river flow and it is doing vary from month to month. So, the main criteria is the good site selection and also hydro turbine sizing which is compatible with the stream are very important in order to maintain higher turbine efficiency. Below are the classifications of the hydro turbine according to the power generation capacity:

Power generation capacity	Type of hydro power plant
Less than 100KW	Micro hydro power plant
100KW to 1000KW	Mini hydro power plant
1MW to 10MW	Small hydro power plant
10MW to 300MW	Medium hydro power plant
300MW and above	Large hydro power plant

Generally, micro hydro power plant does not involve dam construction or just require a small dam. Meanwhile, for the large hydro power plant, it usually needs a big size of dam which functions as a barrier that impounds the water and also used to collect water or for storage of water which can be evenly distributed between the locations. Basically, the functions of the dams are stated below:

- Domestic water supply
- Flood control
- Industrial water supply
- Power production
- Emergency domestic water supply
- Recreation
- Industrial cooling

In the previous section has been briefly explained about the category of turbine which are falls into two; impulse turbine (pelton, turgo,cross-flow) and reaction turbine (francis, kaplan). The cross-flow turbine has been selected as the main focus for the design prototype. It consists of a cylindrical water wheel with the horizontal shaft, composed of numerous radially and tangentially arranged blades. The ends of the blades are welded to disks, speed equally in the axial direction.

Currently, the cross-flow turbine did not attract any interest due to the small power range and relatively lower efficiency rates. Therefore, there is very limited published work on these kinds of turbines. Thus, special study or research is needed to increase the efficiency of these turbines while decreasing their cost.

Selection of the design variables and the objective function for the turbine optimization should be implemented with care. At the preliminary stage, many design variables can be considered for the turbine construction. However, some typical values for most of these variables are commonly set to achieve the highest efficiency. On the other hand, some of these variables are interdependent. For example, the size of the turbine determines the optimum number of blades on an assembly. Same goes to radial blade spacing and also the blade thickness values are all determined in accordance with the rotor diameter. Similarly blade entrance angle and length of the blade arc are all preset to maintain proper tangential contact between water jet and blade entrance. All of these preconditions are specified based on rough analysis / assumptions to achieve the highest turbine efficiency.

An optimization of the design variables of the cross-flow turbine is decided to minimize the stress distributions without affecting the overall turbine efficiency. There are many elements of turbine manufactured from different materials and it is proven that the lower stress distribution does not always mean that the component is safe statically.

2.2 Formulae Related

The formula that can be used in order to determine the power of the turbine is stated as below:

$$P = \frac{1}{2} \times \eta \times \rho \times A \times V^3$$

Where;

P= electrical or mechanical power produced, W

η = turbine efficiency,%

ρ= density of water, kg/m^3

A=area of the rotor blades, m^2

V= water velocity, ms^{-1}

There is also another formula to find the power of the turbine:

$$P = \frac{1}{2} \times Q \times \rho \times V^2$$

Where;

P= electrical or mechanical power produced, W

Q= volume flow rate, m^3/s

ρ= density of water, kg/m^3

V= water velocity, ms^{-1}

The volume flow rate of water, Q can be determined from the formula;

$$Q = A \times L \times C_p / T$$

Where;

A= area of water, m^2

L= length of the river, m

C_p= power coefficient

T= time (ping pong ball from position 1 to position 2)

Or

$$Q = A \times V$$

Where A is the area of blade attacked by the water and V is velocity of the water.

Other things we need to consider are the torque requirement, T and also angular velocity, ω based on the formula;

$$P = T \times \omega$$

$$P = (F \times A_b) \times (TSR \times V_w/r)$$

Where;

P= power (kW)

T= torque (Nm)

ω= angular velocity (rad/s)

F= force attacking the blade (N)

A_b= area of blade that attacked by the water (m^2)

TSR= tip speed ratio

V_w= velocity of water

r= radius of the blade (m)

The main focus of the design is stressed on the design of the blade and also the shaft selection. Shape of blade should be made as a semi-circular blade so that maximum flow rate may enter from the free stream and its thickness was based on strength to thickness ratio. Use of semicircular blade was expected to provide the following properties:-

a. The velocity profile of water stream is normally high at the top surface and decreases downwards as shown;

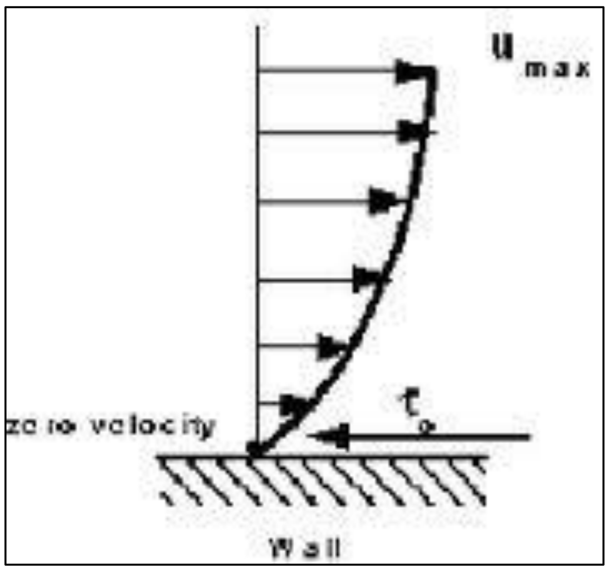


Figure 2.1: Velocity profile of river

b. A semi-circular shape was expected to allow more flow of water to enter the blade as compared to one that could be striking a flat plate. This property was also established by past research.

2.3 Design of Blade

For exact calculations of the geometry of a blade one has to consider the velocity V of water and angle α which force applied by water profile makes with the center line of the blade. Therefore the component of velocity acting on the blade perpendicular could be represented as is $V\cos\alpha$. So when the blade is at center line where $\alpha = 0$, the relationship of applied force of water could be given as:

$$Fi = DVA(V-u)$$

Where u is blade speed, D is density of water, V is free stream velocity, u being blade tangential velocity and A was the blade area expected to be designed. The next important parameter was the angle between two blades for finding the exact number of blades for providing optimum value of torque for a stabilized power output. This angle was calculated by assuming that the blade directly facing water is not rotating and is perpendicular to free stream of water initially.

From the size of the disc, total number of blades positioning circumference of the complete cycle is 8. So, each of them are spaced 45 degree (complete cycle is 360 degree).

Figure 2.2: Angle between the blades

2.4 Design of Shaft

Other important things need to be considered is the shaft selection. It is very crucial part of the design as meant to transmit torque and balance the bending moment. It is the component of a mechanical device that transmits rotational motion and power and integral to any mechanical system in which power is transmitted from a prime mover, such as an electric motor or an engine, to other rotating parts of the system (turbine). The forces, torques, and bending moments that are created in the shaft during operation are being visualized. In the process of transmitting power at a given rotational speed, the shaft is inherently subjected to a torsional moment, or torque. Thus, torsional shear stress is developed in the shaft.

In addition, most shafts must be analyzed for combined stress and because of the simultaneous occurrence of torsional shear stresses and normal stresses due to bending; the stress analysis of a shaft virtually always involves the use of a combined stress approach. The recommended approach for shaft design and analysis is the distortion energy theory of failure. Vertical shear stresses and direct normal stresses due to axial loads also occur at times, but they typically have such a small effect that they can be neglected. On very short shafts or on portions of shafts where no bending or torsion occurs, such stresses may be dominant.

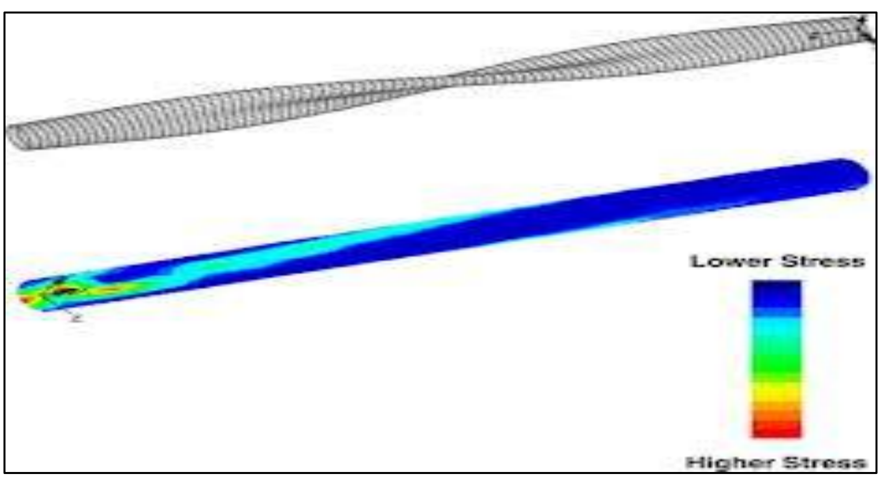


Figure 2.3: Stress analysis by FEA

2.5 Material

The material that we decide to build the turbine prototype is either made from aluminum 6061-T6 which have these properties;

-Density, 2.7g/cc

-Ultimate Tensile Strength, 310 MPa

-Tensile Yield strength, 276 MPa

-Modulus of elasticity, 68.9 GPa

-Poisson Ratio, 0.33

- **Ultimate Tensile Strength** = Maximum stress that a material can withstand while being stretched or pulled before necking which is when the specimen's cross section starts to significantly contract
- **Tensile Yield Strength** = Stress a material can withstand before permanent deformation
- **Modulus of elasticity** = Slope of stress & strain on elastic curve
- **Poisson Ratio** = Measure of Poisson effect. Ratio of the fraction/percentage of expansion divided by fraction/percentage of compression

All of these definition can be explained more by the picture shown, figure 2.4

Why Aluminum 6061?

-Because it is containing Magnesium (Mg) and Silicon (Si) as its major alloying elements, have good mechanical properties and exhibits good weld ability. The minimum thickness for this material to be able for welding is 0.2cm/2mm.

The material selection is one of foremost functions of effective engineering design as it determines the reliability of the design in terms of industrial and economical aspects. A great design may fail to be a profitable product if unable to find the most appropriate material combinations. So it is vital to know what the best materials for a particular design are. There are some of the properties of the material that need to be considering in the design analysis;

- Mechanical properties (strength and stiffness)
- Wear of materials (sufficient wear resistance)

- Corrosion (increase service life)
- Ability to manufacture (able/ease to be machine)
- Cost (profitable)

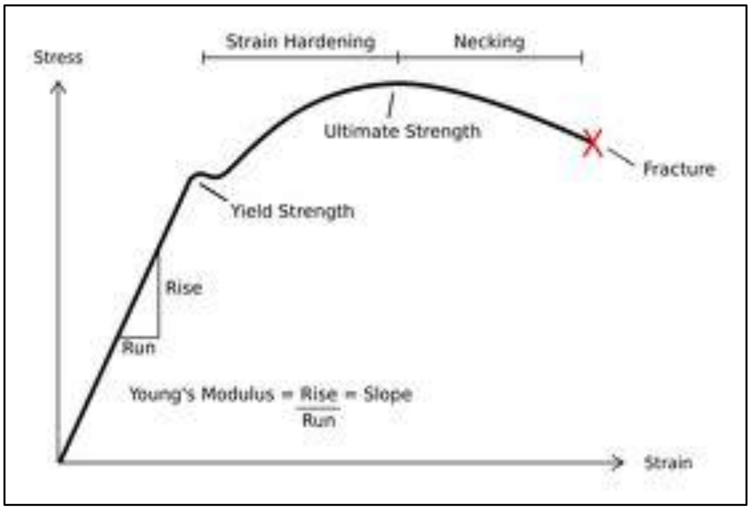


Figure 2.4: Stress vs Strain diagram

2.6 Generator

The other crucial part in this project is generator calculation as we have to consider the type of magnet that we going to use and also the number of coil (type of windings). For magnet, we choose to use N48 (neodymium magnet) which is made of a combination of neodymium, iron and boron. For winding part, there are two types which can be done and their properties are shown below:

Lap Winding	**Wave Winding**
1. As many parallel path as the no of poles	1. Only two parallel paths irrespective of no of poles
2. Full current is distributed between these paths	2. Full current is distributed between two paths only
3. As many brush sets as the paths	3. Only two brush sets are required
4. It is used in the machines which are for **low voltage and high current**	4. It is used in the machines used **for low current and high voltage**

The number of windings can be calculated by using this formula;

$$N= -1 \times [-V / (Tesla \times A)/t)]$$

Where;

N= number of windings

V= amount of voltage (12V-50V)

A= area of magnet

t= number of turns in 1sec

Assumption;

V= 12V or 14V

1 tesla= 10000 gauss

N48= 13800 gauss-14200 gauss

2.7 Turbine's components

The basic system components that should be included are;

- Turbine or waterwheel (transforms the energy flowing water into rotational energy)
- Alternator/ DC generator (transform the rotational energy into electricity)
- DC Regulator (to control the generator)
- Transmission line/ wiring(to deliver the electricity)
- Bearing
- Digital multi-meter

Turbine

As already explained above, turbine is the main important device here which is transforming the water flow energy into rotational/mechanical energy. For the turbine, we need to determine the number of blade, size of blade, suitable shaft and bearing. In addition from that, we have to determine the power output available from that turbine.

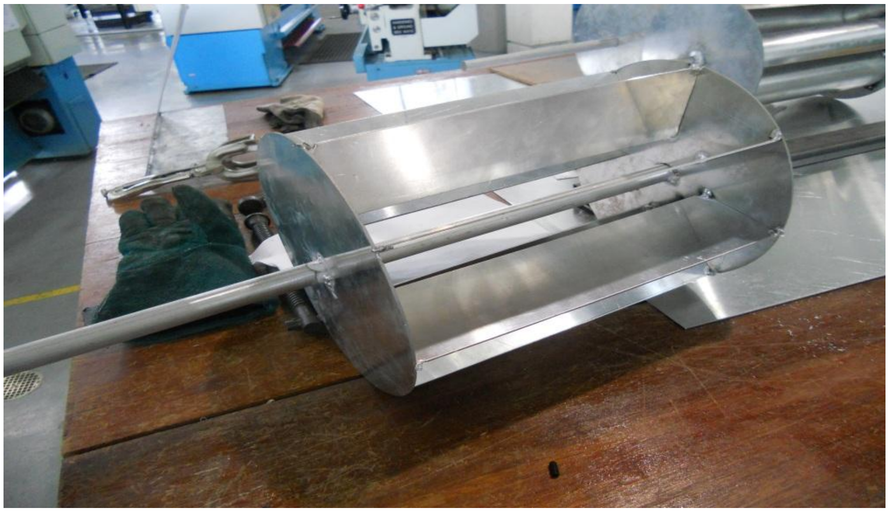


Figure 2.5: Prototype of Cross-flow Turbine

DC generator

The principle of working is just same like the alternator, the different only the output from the alternator is in alternating current (AC) whereas for generator is in direct current (DC). The theory behind its working principle is based on the principle of production of dynamically (or motionally) induced e.m.f electromotive force. Whenever a conductor cuts a magnetic flux, dynamically induced e.m.f is produced in it according to Faraday’s Law of Electromagnetic Induction.

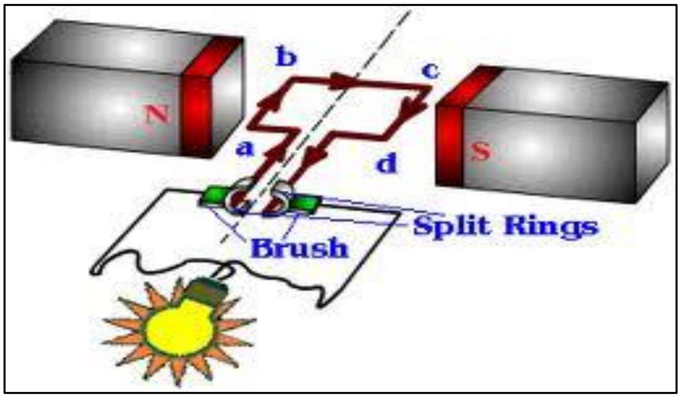


Figure 2.6: Simple Circuit of Generator

Regulator

Strictly speaking, the function of the regulator is to control the generator. It keeps the voltage in a circuit relatively close to a desired value. There are two types of generator;

- **Passive voltage regulation**
  If power supply consistently produce a voltage greater than what the components on the circuit require, it will reduces the incoming voltage to the desired output level and dumps the excess energy as heat.
- **Active voltage regulation**
  The circuits that require the voltage to increase will require an active voltage regulator.

Figure 2.7: Regulator

<u>Bearing</u>

Rolling-element bearings are either ball bearings or roller bearings. Frankly speaking, we choose to use ball bearing as it has lower cost compare to the roller bearing. In others, the ball bearing also capable of higher speeds. The purpose of this bearing is to reduce rotational friction (rotating shaft) and also support radial and axial loads. It is important to specify the location of bearings to support the shaft. The reactions on bearings supporting radial loads are assumed to act at the midpoint of the bearings.

Another important concept is that normally two and only two bearings are used to support a shaft. They should be placed on either side of the power-transmitting elements if possible to provide stable support for the shaft and to produce reasonably well-balanced loading of the bearings. The bearings should be placed close to the power-transmitting elements to minimize bending moments. Also, the overall length of the shaft should be kept small to keep deflections at reasonable levels.

Figure 2.8: Ball Bearing

Transmission line/wiring

The main function is as a main passage to deliver the electricity.

Digital multi-meter

A multi-meter or a multi-tester, also known as a VOM (Volt-Ohm meter), is an electronic measuring instrument that combines several measurement functions in one unit. A typical multi-meter may include features such as the ability to measure voltage, current and resistance.

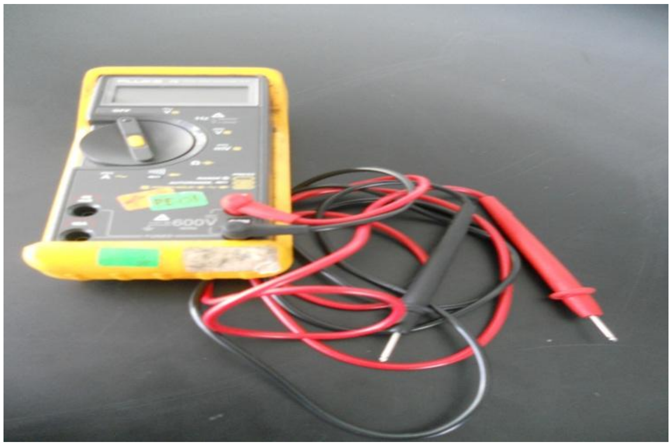
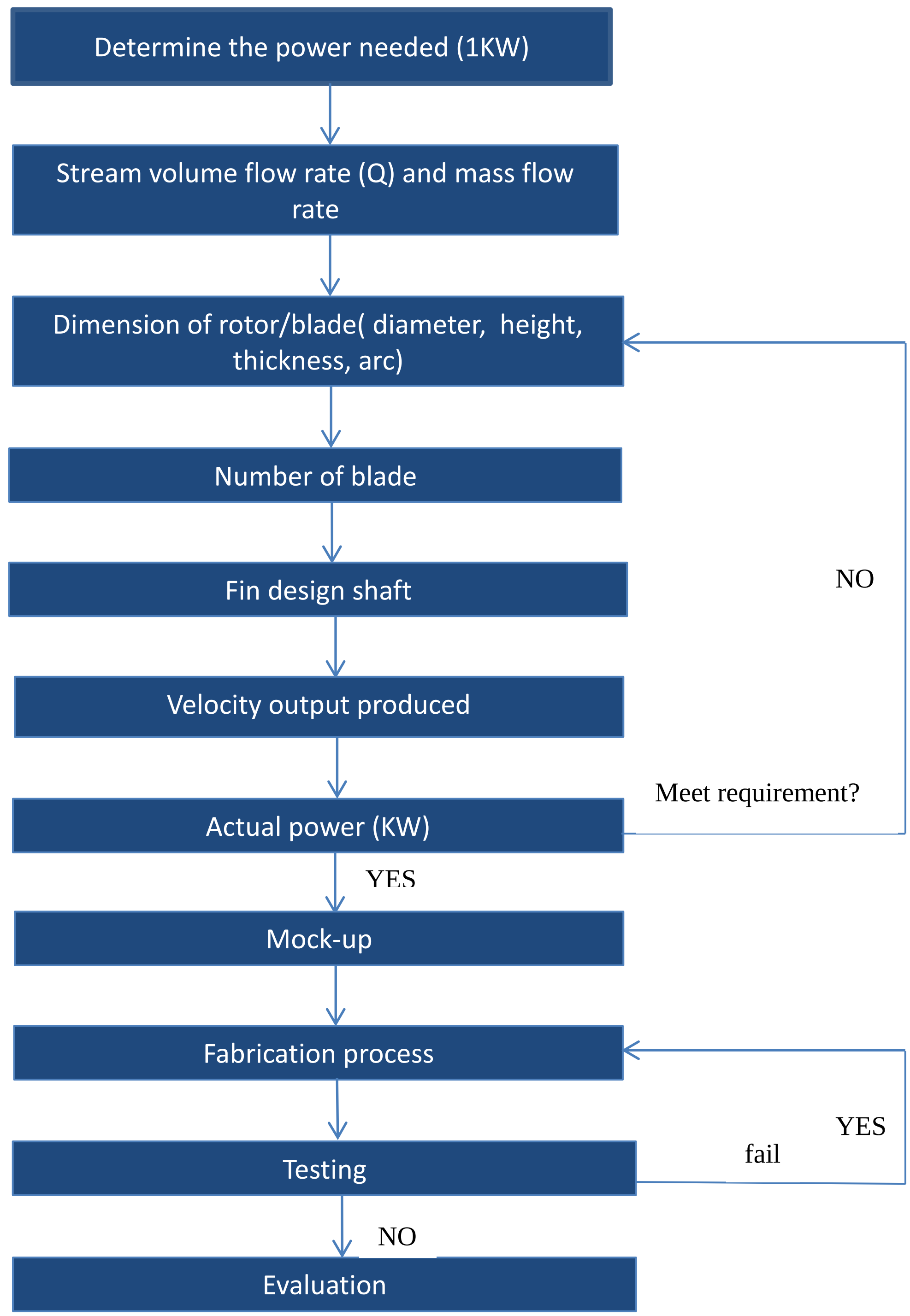


Figure 2.9: Digital Multi-meter

CHAPTER 3

METHODOLOGY

3.1 Working Flow



3.2 Sample Preparation

Figure 3.1: Turbine parts before welding

All of these materials are provided at block 21, mechanical department. The pieces are cut by the shearing machine and cutter machine. Driller is also used to make the hole. The design calculation is made at first before the fabrication.

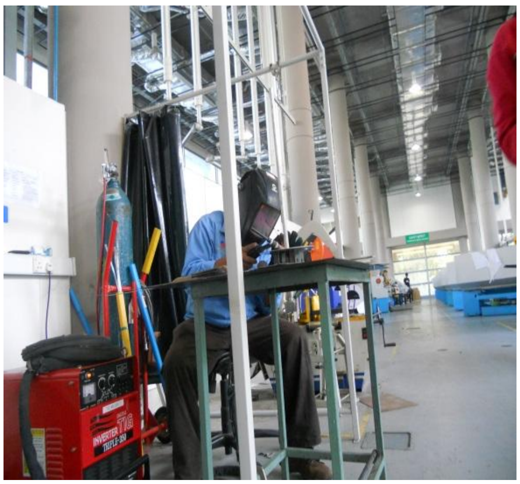


Figure 3.2: Welding process

One of the technicians does the welding process. This is one of the fabrication processes to join the materials (disc to the shaft and blades to the disc) by melting the workpieces and adding a filler material to form a pool of molten material.

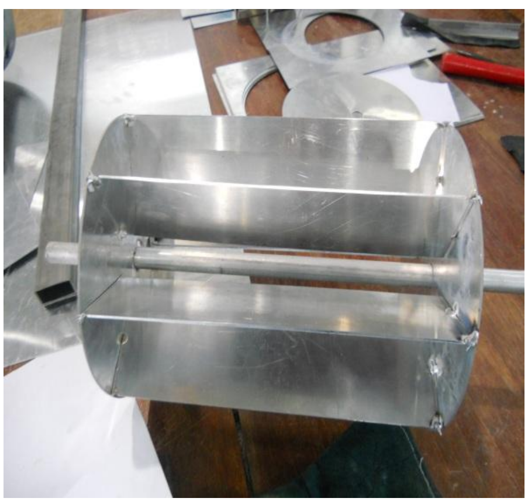


Figure 3.3: Finishing prototype

The completed turbine after the welding process. There is little deficiency with the shape of the disc as it experience very high temperature during the process of welding. The minimum/allowable thickness of aluminum to be welded is 0.2cm/2mm.

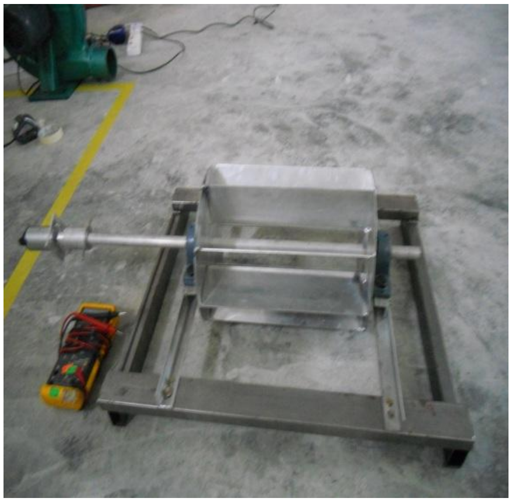


Figure 3.4: Fully assembly prototype

The base is designed to give structural support to the turbine during placement onto the surface of the river. Bearing is also attached together to support the radial and axial load.

3.3 Sample testing

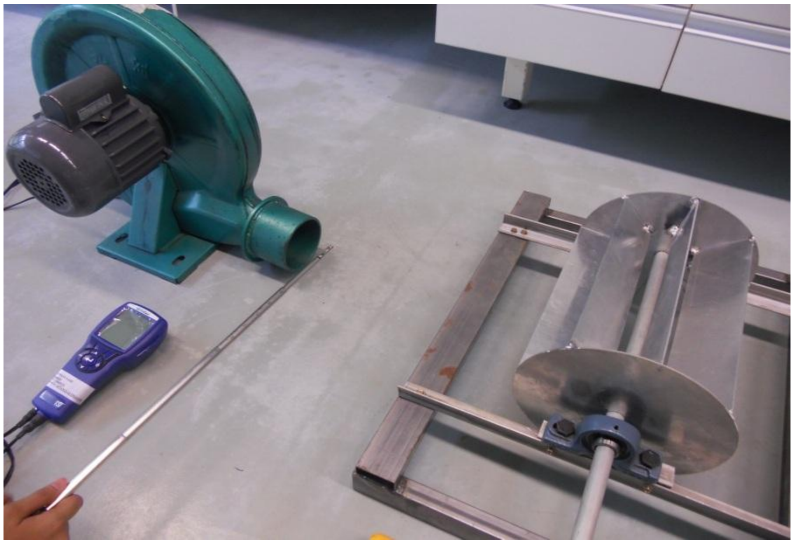


Figure 3.5: Measure air velocities by using anemometer

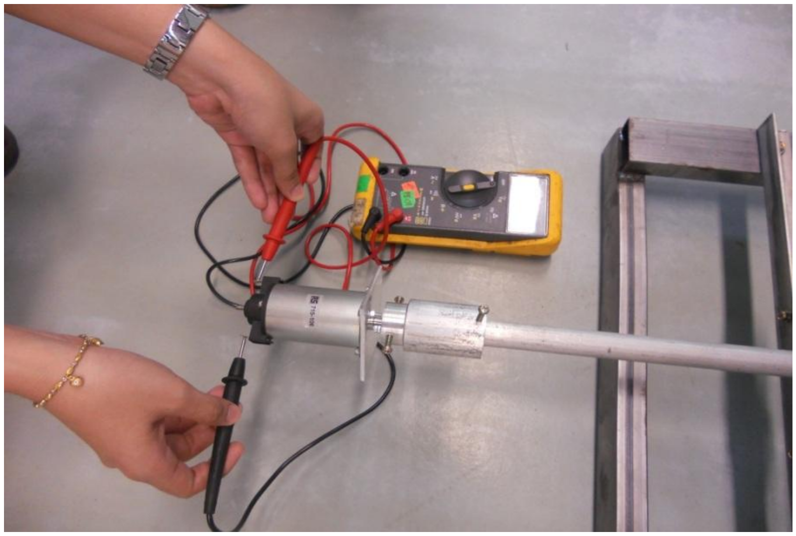


Figure 3.6: Measure voltage output by using digital multi-meter

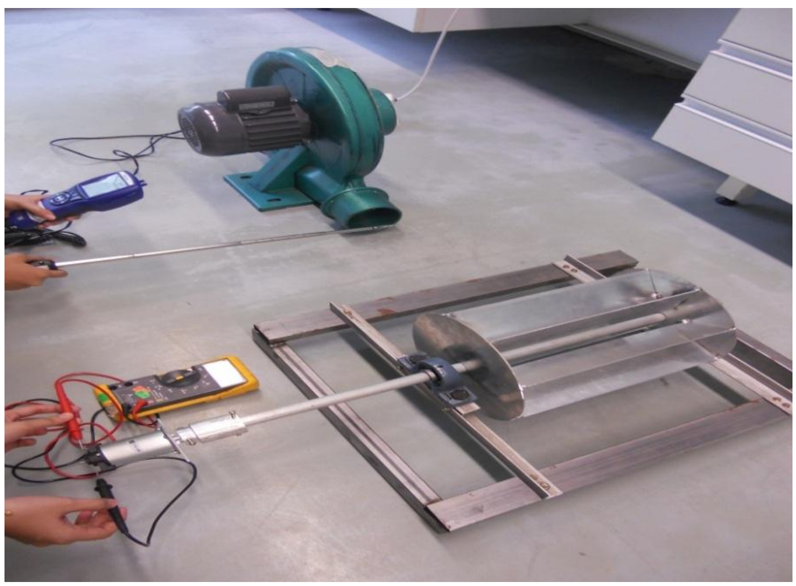


Figure 3.7: Overall testing

The turbine was tested at block 17 by using an air blower as a medium instead of using water. The velocities of the air are measured by the anemometer (blue color in the picture above) and the output voltage is measured by the digital multi-meter.

CHAPTER 4

RESULT & DISCUSSION

4.1 Data gathering & analysis

4.1.1 Theoretical value

From the formulae, $P = \frac{1}{2} \times \eta \times \rho \times A \times V^3$

For the worst case, we assume the turbine efficiency is 50%.

$$\text{So, } P = \tfrac{1}{2} \times 0.5 \times 1000 \times 0.015 \times 3^3$$

$$= 101.25\text{W (this value is for one blade)}$$

$$101.25\text{W} \times 8 = \mathbf{810W}$$

Next, we determine the volumetric flow rate of the water (Q) and also the mass flow rate ($\dot{m}$) by using the formulae;

$$Q = A \times V$$

$$= 0.015 \times 3$$

$$= \mathbf{0.045m^3/s}$$

$\dot{m} = Q \times \rho \times SG$ where SG is specific gravity, assume SG = 0.85

$$= 0.045 \times 1000 \times 0.85$$

$$= \mathbf{38.25kg/s}$$

Determine the angular speed, ω;

$$\omega = TSR \times V_w / r$$

Where;

TSR = Vtip blade linear velocity / V_{river} take V_{tip} = 3m/s, same as V_{river}

= 3/3

=1

ω = 1 x 3 / 0.11 r = radius of the disc excluding the shaft

= **27.27rad/s**

27.27 rad/s x 1rev/2π rad x 60s/1min

= **260.41rpm**

From equation P = T x ω, we can get the value of torque;

810 = T x 27.27

T = **29.7Nm**

After consider the worst case, we assume the turbine efficiency is 80% and usually it is the maximum efficiency that cross flow turbine can achieved.

$P = \frac{1}{2} \times 0.8 \times 1000 \times 0.015 \times 3^3$

= 162W (this value is for one blade)

162W x 8 = **1296W @ 1.3KW**

P = T x ω

1296 = T x 27.27

T = **47.52Nm**

From the above calculation, we can see that the increase value of water velocity will increase the value of angular speed (rad/s), angular velocity (rpm) and the value of torque (Nm). In this case, we keep tip speed ratio constant. If the tip speed ratio increase, the torque value is decrease proportionally and vice versa.

Now, we determine the mass each of the components and force exerted by them;

For shaft (Aluminum);

$\rho = 2700\ kg/m^3$, h = 0.7m, d = 0.02m

$V = \pi \times r^2 \times h$

$= \pi \times 0.01^2 \times 0.7$

$= 2.199 \times 10^{-4} m^3$

$\rho = m/V \longrightarrow 2700 = m / 2.199 \times 10^{-4}$

m = **0.6kg**

$F = ma \longrightarrow F = 600 \times 9.81$

= **5886N**

For disc (Aluminum);

$\rho = 2700 kg/m^3$, h = 0.002m, d = 0.24m

$V = \pi \times r^2 \times h$

$= \pi \times 0.12^2 \times 0.002$

$= 9.048 \times 10^{-5} m^3$

$\rho = m/V \longrightarrow 2700 = m / 9.048 \times 10^{-5}$

m= 0.24kg x 2 = **0.48kg** (for two disc)

$F = 480 \times 9.81$

= **4709N**

For blade (Aluminum);

$\rho = 2700 kg/m^3$, length (l) = 0.3m, width (w) = 0.07m, thickness (t) = 0.002m

$V = l \times w \times t$

$= 0.3 \times 0.07 \times 0.002$

$= 4.2 \times 10^{-5} m^3$

$m = 2700 \times 4.2 \times 10^{-5}$

$= 0.1134kg \times 8 =$ **0.91kg**

$F = 910 \times 9.81$

$=$ **8927N**

For bearing (chrome steel), we assume it has the density of **7190kg/m^3** and the mass is about **1kg**. So,

$F = 1000 \times 9.81$

$=$ **9810N**

The last part need to be calculated is the requirement for motor/generator. We need to determine the type of magnet that we use and number of coils for the winding purpose.

Type of magnet = N48 (Neodymium magnet)

Length (l) = 0.029m, width (w) = 0.012m, thickness /depth (h) = 0.006m

To find the number of winding, find the coil resistance (ohm per unit length) by using Faraday's law of voltage generator;

$N = -1 [-V / ((Tesla \times A) / t))]$

Assumptions; V = 14V

N48 = 13800 gauss- 14200gauss

1 Tesla = 10000 gauss

So for 13800 gauss = 1.38 Tesla

$N = -1\ [-14 / ((1.38 \times 0.029 \times 0.012) / 0.2)]$

$= 5830.42$ windings $\div 12$ (since we have 12 magnets)

$= 485.87$ windings, we took approximately **400** windings per coil.

4.1.2 Experimental value

For the experiment, we use air blower instead of water. The distance of air blower from the turbine determine the amount of velocity attacked at the blade and next will determine the value of voltage from digital multi-meter.

Assume density of air, $\rho = 1.225 kg/m^3$ and the turbine efficiency is 50%.

$$P = \tfrac{1}{2} \times 0.5 \times 1.225 \times 0.015 \times 7.53^3$$

$$= 1.96W \times 8 = \mathbf{15.7W}$$

if turbine efficiency is 80%,

$$P = \tfrac{1}{2} \times 0.8 \times 1.225 \times 0.015 \times 7.53^3$$

$$= 3.14W \times 8 = \mathbf{25.11W}$$

Both values are much smaller compare to water as a medium for mechanical energy in generating the electricity.

$$\omega = TSR \times V_{air} / r \qquad \text{Assume } TSR = 1$$

$$= 1 \times 7.53 / 0.11$$

$$= \mathbf{68.45 rad/s \text{ or } 654 rpm}$$

$$P = T \times \omega$$

$$25.11 = T \times 68.45$$

$$T = \mathbf{0.37Nm}$$

4.2 Result & Discussion

4.2.1 Theoretical value

Constant ρ, η , A variable V

power (w)	power(Kw)	eff of turbine (%	density(kg/m3)	area (m2)	velocity(m/s)of water	velocity(m/s)tip of blade	tsr	angular speed(rad/s)	torque(Nm)
0.75	0.00075	0.8	1000	0.015	0.5	3	6	27.27272727	0.0275
6	0.006	0.8	1000	0.015	1	3.5	3.5	31.81818182	0.18857143
20.25	0.02025	0.8	1000	0.015	1.5	4	2.66667	36.36363636	0.556875
48	0.048	0.8	1000	0.015	2	4.5	2.25	40.90909091	1.17333333
93.75	0.09375	0.8	1000	0.015	2.5	5	2	45.45454545	2.0625
162	0.162	0.8	1000	0.015	3	5.5	1.83333	50	3.24

Table 4.1 Variable velocity with constant value of density, turbine efficiency and area

*tip speed ratio(tsr)= velocity tip of blade linear velocity/river velocity

*angular velocity= (tsr x river velocity)/radius

ρ = density of water, η = efficiency of turbine, A = area of blade attacked by water, V= velocity of water

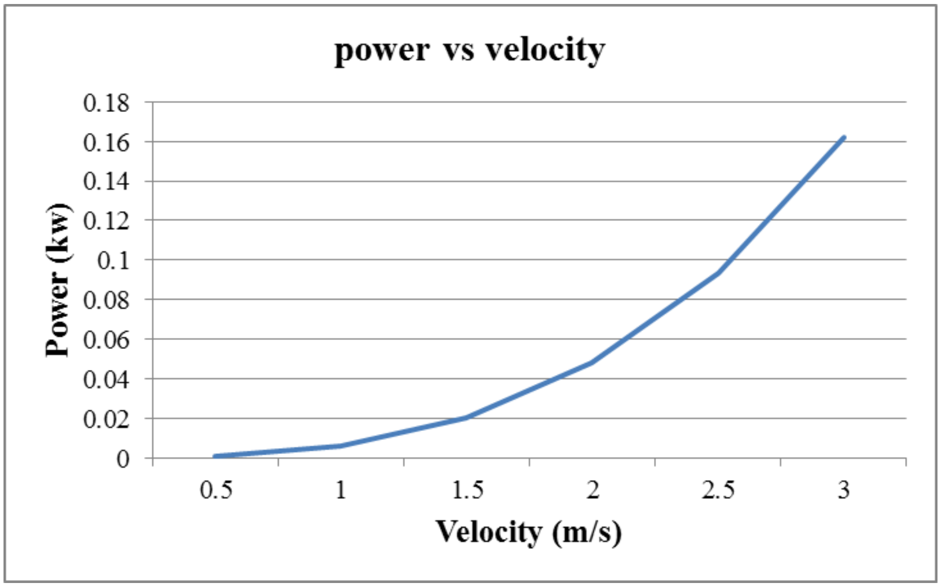


Figure 4.1: Graph power vs velocity

Constant ρ, η , V variable A

power(Kw)	eff of turbine (%)	density(kg/m3)	area (m2)	velocity(m/s)of water
0.0162	0.8	1000	0.0015	3
0.0324	0.8	1000	0.003	3
0.0486	0.8	1000	0.0045	3
0.0648	0.8	1000	0.006	3
0.081	0.8	1000	0.0075	3
0.0972	0.8	1000	0.009	3
0.1134	0.8	1000	0.0105	3
0.1296	0.8	1000	0.012	3
0.1458	0.8	1000	0.0135	3
0.162	0.8	1000	0.015	3

Table 4.2: Variable area with constant value of density, turbine efficiency and velocity

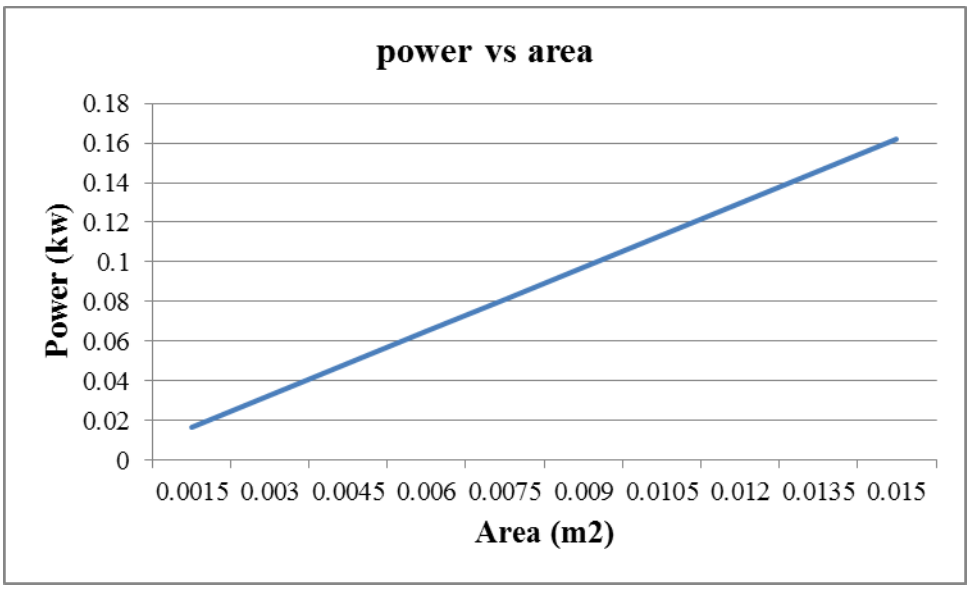


Figure 4.2: Graph power vs area

Constant ρ, A, V variable η

power(w)	power(Kw)	eff of turbine (%)	density(kg/m3)	area (m2)	velocity(m/s)of water	velocity(m/s)tip of blade	tsr	angular speed(rad/s)	torque(Nm)
101.25	0.10125	0.5	1000	0.015	3	3	1	27.27272727	3.7125
111.375	0.111375	0.55	1000	0.015	3	3.5	1.167	31.81818182	3.50035714
121.5	0.1215	0.6	1000	0.015	3	4	1.333	36.36363636	3.34125
131.625	0.131625	0.65	1000	0.015	3	4.5	1.5	40.90909091	3.2175
141.75	0.14175	0.7	1000	0.015	3	5	1.667	45.45454545	3.1185
151.875	0.151875	0.75	1000	0.015	3	5.5	1.833	50	3.0375
162	0.162	0.8	1000	0.015	3	6	2	54.54545455	2.97
172.125	0.172125	0.85	1000	0.015	3	6.5	2.167	59.09090909	2.91288462
182.25	0.18225	0.9	1000	0.015	3	7	2.333	63.63636364	2.86392857

Table 4.3: Variable turbine efficiency with constant value of density, area and velocity

Note: 162W is power produce from one blade. So, 8 blades will produce **1296W.** The value of angular speed and torque also will be multiplied by 8.

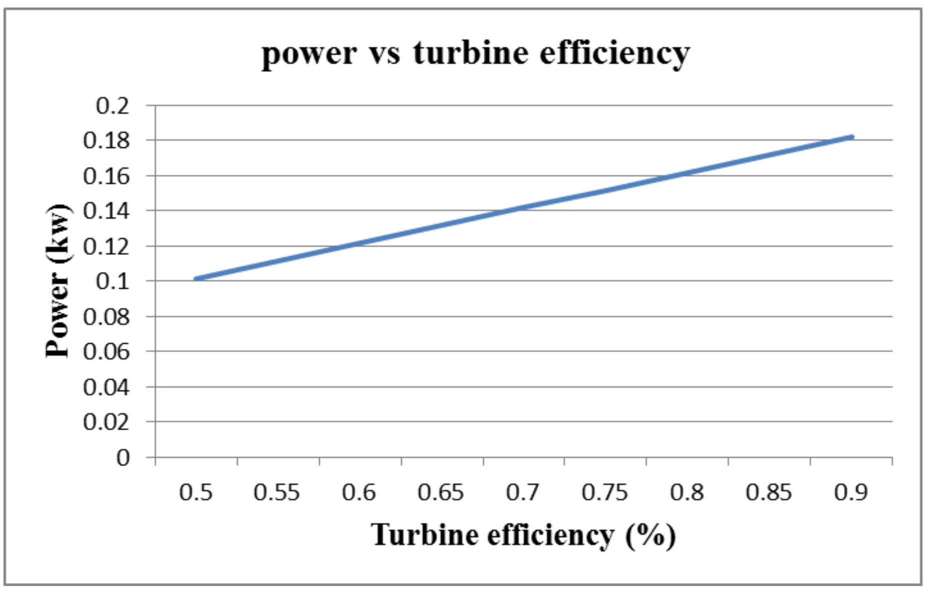


Figure 4.3: Graph power vs turbine efficiency

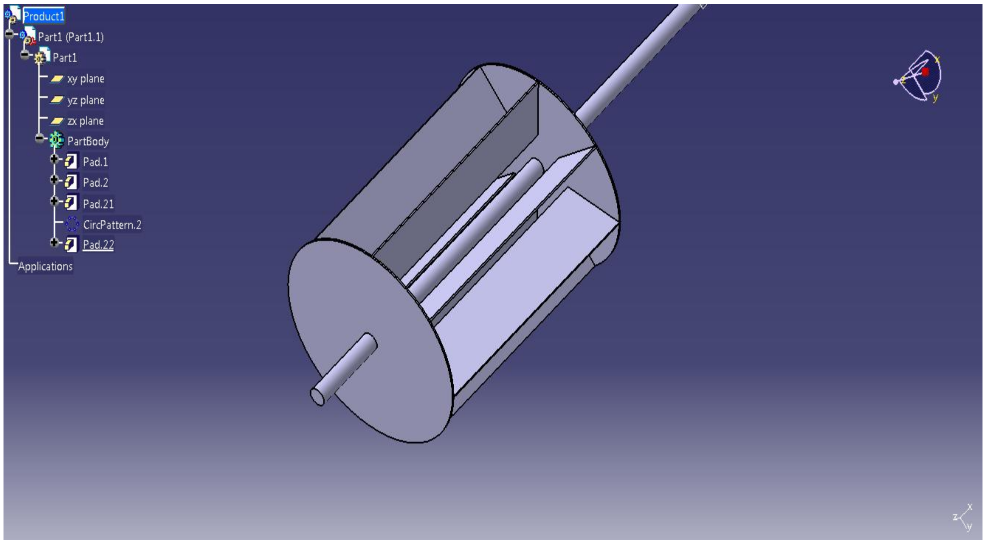


Figure 4.4: Turbine design by using Catia

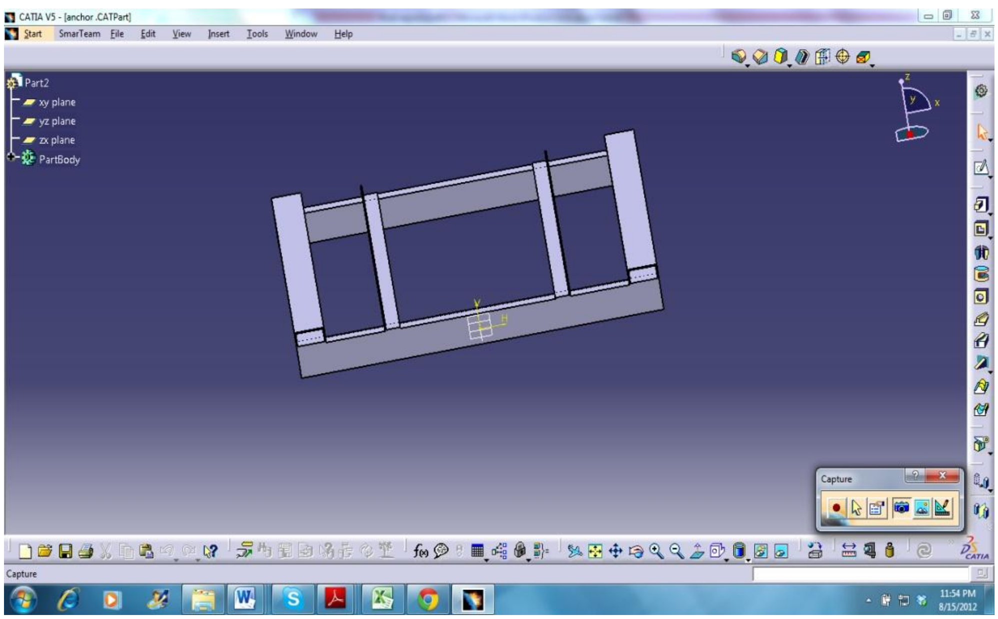


Figure 4.5: Base design by using Catia

4.2.2 Experimental value

Distance(m)	Air velocity(m/s)	Voltage(V)	Power(w)	Current(I)	Angular speed(rad/s)	Torque(Nm)
0.25	7.53	10.3	25.10512	2.43739	68.45454545	0.3667414
0.5	6.86	8.3	18.98234	2.287029	62.36363636	0.3043815
0.75	6.01	7.24	12.76441	1.76304	54.63636364	0.2336248
1	5.71	5.7	10.94676	1.920484	51.90909091	0.2108833
1.25	4.83	4.52	6.625501	1.465819	43.90909091	0.1508913
1.5	4.6	3.5	5.723357	1.635245	41.81818182	0.1368629

Table 4.4: Value measured from the experiment

Distance here means relative measurement from the air blower to the turbine.

Assumptions;

Air density = 1.225kg/m^3

Turbine efficiency = 80%

Area of air attack the blade = area of water attack the blade

4.2.3 Discussion

Designated power by using the formula;

$$P = \frac{1}{2} \times \rho \times \eta \times A \times V^3$$

In this calculation, we have come out with some of the assumptions;

ρ= density of water is fix which is 1000kg/m^3 and for air is 1.225kg/m^3

η =maximum efficiency of turbine is 80%.Usually efficiency of turbine is between 60%-80%

A= maximum area of blade attacked by the water is 0.015m^2 which can be get from this relationship;

0.3m (length of blade (fix)) x 0.05m (maximum width of blade attacked by water)

= 0.015m^2

V= minimum velocity of water stream (flow of river) is 3m/s.

From three different graphs above, it can be conclude that the maximum power output from the turbine (theoretical value) is about 1296W as we set maximum efficiency of turbine; 80%, density of water; 1000kg/m^3 and maximum area of blade attacked by the water; 0.015m^2. The maximum power (experimental value) is 5.72W as we set maximum efficiency of turbine; 80%, density if air; 1.225kg/m^3, area of blade; 0.015m^2 and minimum velocity of air; 4.6m/s which can be seen on the table above.

We use air blower (concept of wind turbine) instead of water to test the turbine as there are already available equipment in the laboratory and it is easy to conduct. Basically we know that the mechanical energy that comes from the water is higher compare to the air. It can be clearly seen in the value of densities for both medium which have significant differences and that will affect the amount of power/energy/force that going to be produced.

On the other hand, we can compare in terms of reliability. The steady flow of rivers means power can be produced around the clock, while wind turbines remain motionless on calm days. The amount of water flowing through a river is nearly always predictable, allowing their gearboxes to keep the speed of the blades at a safe and productive level. The strength of the wind is not constant and it varies from zero to storm force. This means that wind turbines do not produce the same amount of electricity all the time. There will be times when they produce no electricity at all.

Next, the blade design in theoretical part has some angle/curve and most of the references design it as semicircular. The shape should be made like that as the maximum flow rate may enter from the free stream. But as in the fabrication, we faced a lot of problem during making the shape by using the rolling machine at block 21. It’s hard to get the symmetrical shape and even the machine itself has some area/part of deficiency and can be a barrier in getting the right shape. In others, human error also must be put as one of the main hurdle in getting the actual result. In the end, we build the turbine with the flat blades.

After all, the type of motor/generator use in generating the electricity also plays major role in producing the power output. It relies on the strength of the magnet, number of coil use, the thickness of the coil and the rotation speed. There are some magnet properties which affect the performance of the generator: remanence, which measures the strength of the magnetic field; coercivity, the material's resistance to becoming demagnetized; energy product, the density of magnetic energy; and Curie temperature, the temperature at which the material loses its magnetism. On the other hand, the greater number of coil and thickness (area) will results in greater inductance or generate a greater amount of magnetic field force.

One way to increase the total power output of the turbine is to build some of this designated turbine and put them in series. But currently, this amount of power (1296W) should be enough for the villagers to power up some of the bulb or television.

CHAPTER 5

CONCLUSION &RECOMMENDATION

5.1 Conclusion

As a conclusion, the main objectives of the project have successfully achieved. However, the power that generated from this turbine quite low compare to other existing turbine but still produce enough electricity for the villagers/rural area to power up some of electrical appliance. The power output of the turbine closely depends to the velocity of the river and type of generator used to connect with the turbine. Proper selection of the turbine also very important as to produce as much output as possible. Even the turbine is tested by using the water, the actual value usually lower than the theoretical one.

5.2 Recommendation

1. Put the same turbine in series which result in higher production of electricity.
- As one prototype may not enough for the whole villagers, two, three or more turbine with the same size and specifications can be built with the low cost. The power output is sum up from each of them which result high electricity generation

2. Optimization of the blade design.
- As been explained in the previous section, the proper selections of the blade design determine the efficiency for the whole design. The blade length also determines how much water power can be captured, according to the “swept area” of the rotor disc.

3. Good selection of material.
- Consider all properties of material in details such as tensile strength, ultimate tensile strength, stress & strain, density, hardness and etc.

4. Place turbine in steady flow river
- The power output from the turbine is directly proportional to the velocity of the water (river). Velocity of the water may depend on the river cross section and also the curvature.

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APPENDICES

Fig. 1: Aluminum zero head turbine

Fig 2: Practical demonstration

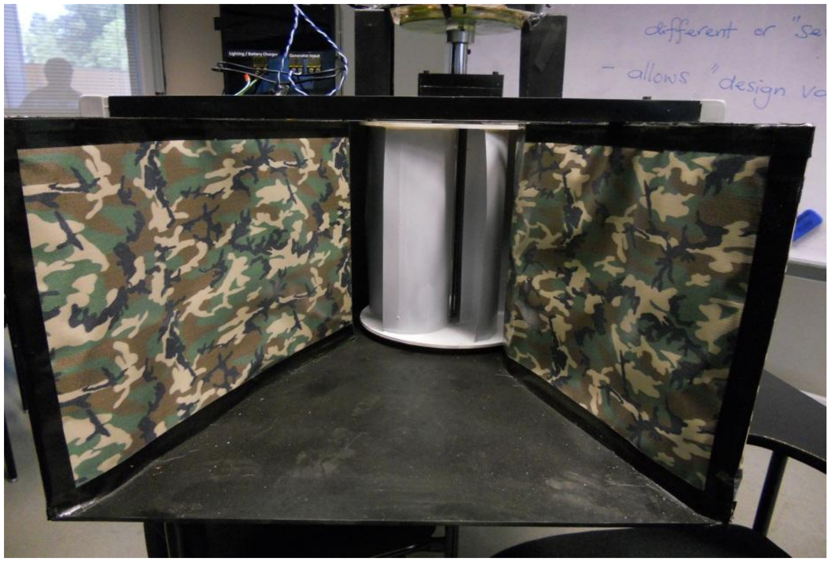

Fig 3&4: Vertical turbine (located at block 14)

Timeline for FYP 1

No.	Detail/ Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14
1	Selection of project topic (given by supervisor,Mr Faizairi)								Mid Sem Break							
2	Preliminary research work (understand the concept, find requirement design)															
3	Submission of extended proposal defence															
4	Proposal defence															
5	Project work continues (start design,use software such as AutoCad and Ansys)															
6	Submission of Interim draft report															
7	Submission of Interim report															

Timeline for FYP 2

No.	Detail/ Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14	15
1	Project work continues (do the mock-up)								Mid Sem Break								
2	Submission of progress report																
3	Project work continues (fabricating, testing)																
4	Pre-EDX																
5	Submission of draft report																
6	Submission of dissertation (soft bound)																
7	Submission of technical paper																
8	Oral presentation																
9	Submission of project dissertation (hard bound)																

Work Progress