PROTOTYPE OF AN EFFICIENT HYDROPOWER PLANT

ONG CHIAN SHEN

A project report submitted in partial fulfilment of the requirements for the award of the degree of Bachelor (Hons.) of Mechatronics Engineering

Faculty of Engineering and Science
Universiti Tunku Abdul Rahman

April 2011

DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that it has not been previously and concurrently submitted for any other degree or award at UTAR or other institutions.

Signature : ___________________________

Name : ____ONG CHIAN SHEN____

ID No. : _______07UEB03227_______

Date : ______15 APRIL 2011 ______

APPROVAL FOR SUBMISSION

I certify that this project report entitled **"Prototype of an Efficient Hydropower Plant"** was prepared by **Ong Chian Shen** has met the required standard for submission in partial fulfilment of the requirements for the award of Bachelor (Hons.) of Mechatronics Engineering at Universiti Tunku Abdul Rahman.

Approved by,

Signature : ____________________________

Supervisor : Dr. Stella Morris

Date : ____________________________

Specially dedicated to

my beloved grandmother, mother and father

ACKNOWLEDGEMENTS

With earnest gratitude and appreciation, I would like to take this opportunity to acknowledge and extend my thanks to those whom have contributed in this project. First and foremost, I offer my outmost gratitude to Universiti Tunku Abdul Rahman (UTAR) for providing me opportunity to take this final year project as a partial fulfilment of the requirement for Degree of Bachelor of Mechatronics Engineering.

Moving on, I would like to express my deepest gratitude to my research supervisor, Dr. Stella Morris for her invaluable advice, commitment, guidance and her enormous patience throughout the development of the research. It has been a great adventure and experience during the undertaking of this project.

Next, I would like to thank my project partner, Chai Wei Chuan for patiently working together on built up the prototype and performed experiments. He gave precious ideals and group work on this project that saves up a lot of works for me.

In addition, I would also like to express my gratitude to my loving parent and friends who had helped and given me encouragement in this project.

PROTOTYPE OF AN EFFICIENT HYDROPOWER PLANT

ABSTRACT

This title of the project is designing a prototype of an efficient hydropower plant. The project scopes were design, construct model, analyze, and implement to real world of an efficient hydropower plant. The design objective is to build out a useful, effective, convenience, reliable, environment friendly and safe to use hydropower plant. Research has been done to fulfil the requirement. Different kinds of hydropower plant have been going through to aid in gathering information and hence implemented a new ideal of hydropower plant. The new hydropower plant from this project was an efficient, portable and able to function in many different kind of flow to generate electricity. The testing for this new design was carried out to meet the objective of the design.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS / ABBREVIATIONS

F	tangential force, N
g	the acceleration due to gravity (9.81 m/s^2)
h	the available head of the water source , cm
I	current, A
l	moment arm length, m
P	power, W
P_s	mechanical power available in the turbine shaft, W
P_w	extractable power of a water jet, W
Q	volumetric flow rate, m^3/s
R	resistance, Ω (or ohms)
r	rotational speed of the shaft, rpm
V	voltage, V
η_m	mechanical efficiency (dimensionless)
π	pi (3.142)
ρ	density of the water, kg/m^3
CAD	computer –aided design
DC	direct current
HEB	hydro-electric barrel
MHPS	micro hydro power system
POM	polyoxymethylene
RPM	revolution per minute

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

Hydropower is produced by converting the potential energy of river water to kinetic energy via a turbine, and then to an electrical energy via a generator. The quantity of electricity generated is determined by the volume of water flow and the amount of head (the height from turbines in the power plant to the water surface) created by the water reservoir.

A typical hydropower plant includes a dam or a mountain reservoir, penstocks, a powerhouse and an electrical power substation. The reservoir stores water and creates the head; penstocks carry water from the reservoir to turbines inside the powerhouse; the water rotates the turbines, which drive generators that produce electricity (Hydroelectric Power , July 2005).

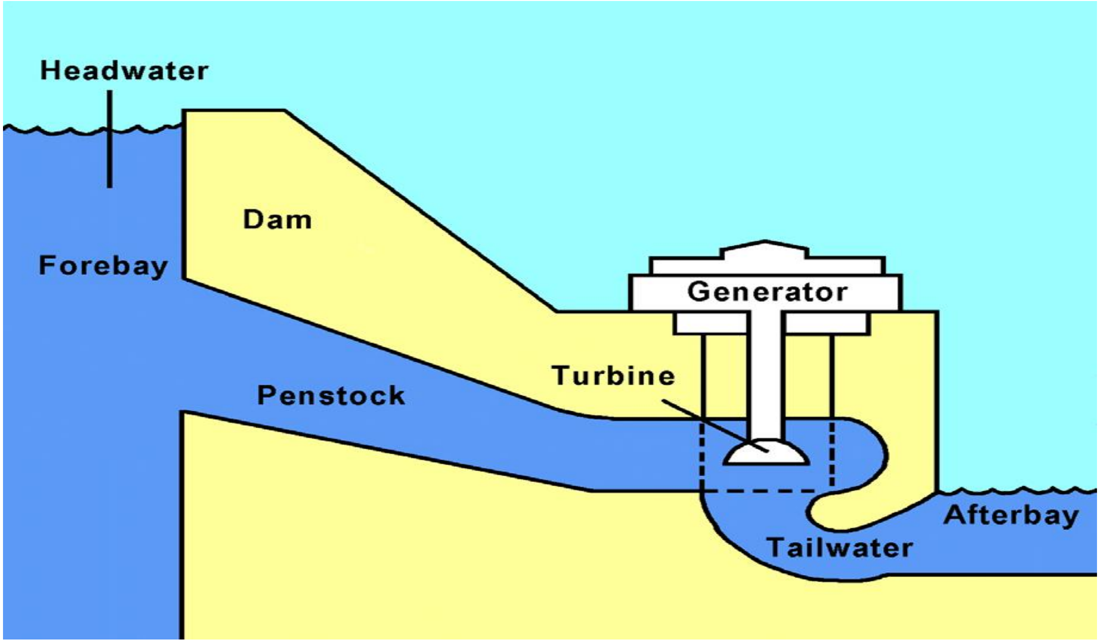


Figure 1.1: Hydro Power Plant

Because the water cycle is an endless, constantly recharging system, hydropower is considered a renewable energy(Hydroelectric Power , July 2005). In the late 19th century, hydropower was first used to generate electricity. The first hydroelectric plant was built at Niagara Falls in 1879. In the years that followed, many more hydropower dams were built. By the 1940s, most of the best sites in the United States for large dams had been developed. (Baumann et al., 2010)

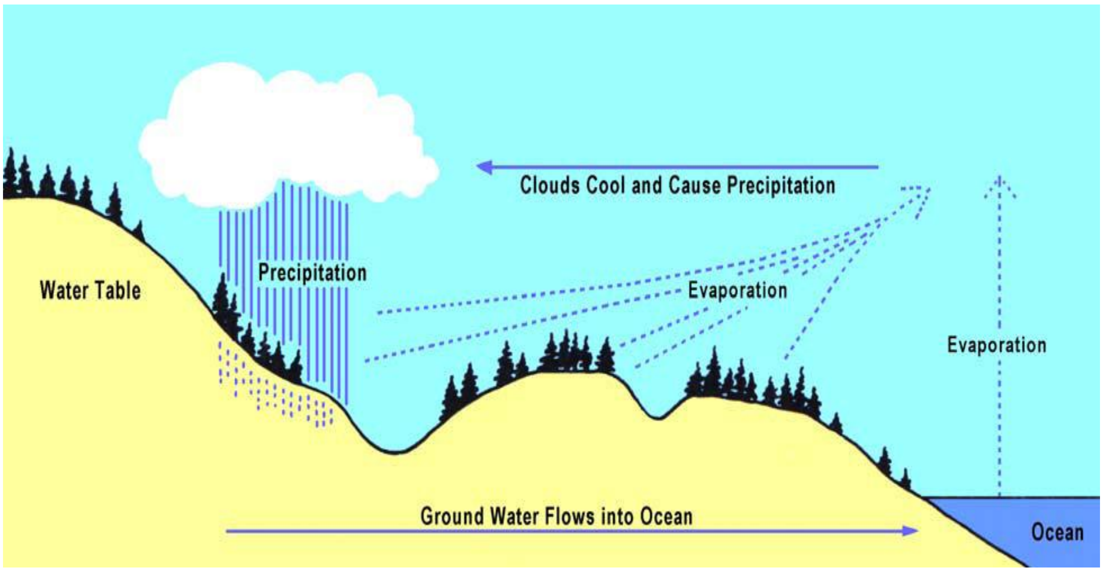


Figure 1.2: Water Cycle

Figure 1.3: Niagara Fall Hydro Power Plant

Hydro power is a very clean source of energy and only uses the water, the water after generating electrical power, is available for other purposes. Due to this reason, hydropower plants become more and more importance. There are few type of hydropower plant which depends on the size which is the large, small, mini, micro, and Pico (Hydropower Energy Technologies Worldwide, 2009) :-

1. Large Hydro (10 MW or more of generating capacity)
2. Small Hydro (1 to 10 MW of generating capacity)
3. Mini Hydro (100 KW to 1 MW of generating capacity)
4. Micro Hydro (5 KW to 100 KW of generating capacity)
5. Pico Hydro (less than 5 KW of generating capacity)

1.1.1 Research and Background of Hydropower

Hydropower is one of the most important renewable energy in the world. Hence development of hydropower has growth widely in the world and issue like environment, cost and efficiency has take into consideration in the research.

Until about 1980, hydropower research and development (R&D) efforts focused mainly on improving turbine efficiency and reducing noise and vibration that can cause damage to turbine blades. These early R&D efforts led to a 30% increase in turbine efficiencies. In 1993, the U.S. Department of Energy (DOE) initiated an effort to develop advanced hydropower turbine systems (AHTS) to improve the overall performance and acceptability of hydropower projects. Turbine, safe pass way for fish, improving mitigation practice are few issue that taken by DOE in hydropower research (Sale et al., 2008).

On the outskirts of Accra, Ghana, business plans are only as final as the next electricity outage permits. In July, food tins at the Prime Pak canning factory were positioned on the assembly line, ready to be sealed before export. Without warning, the machines came to a screeching halt, leaving entrepreneur Cyril Francis standing helplessly in the dark. Thirty per cent of the consignment spoiled. All this has stimulated Ghana government to build an additional hydroelectric project on the Black Volta River. The $700 mn Bui project would have a generation capacity of 400 mw to the country (Madamombe, 2005).

Lately, Universiti Tunku Abdul Rahman (UTAR) study carry out by UTAR's doctoral student Koh Siong Lee and supervisor Dr Lim Yun Seng has found that hydropower and biomass are feasible alternatives to a coal-fired power plant in Sabah. These options meet key objectives of the National Energy Policy, which include promoting the use of clean energy and minimising negative impact of power production to the environment. Results also show these renewable and green options are not only environment friendly but also cost-effective and technologically proven. (Hydropower more cost-effective than coal-fired plant, says Utar study, june 4, 2010).

1.1.2 Micro hydro power system (MHPS) overview

Micro hydropower system is an efficient and reliable form of energy in nowadays. This system is popular in third world country (developing country), especially those rural areas that are not well connected with electricity. Most of the MHPS are operate in isolated form, because of the population in the rural area are small and sparsely distributed and the extension of grid system is not financially feasible because of high cost investment required for transmission line. Micro hydro power system (MHPS) is relatively small sources that are appropriate in many cases for individual users or groups of users who are independent of the electricity supply grid. Although this technology is not new, its wide application to small waterfalls and other potential sites are new. It is best suited to high falls with low volume, such as occur in high valleys in the mountains. A micro hydro power system (MHPS) is the application of hydroelectric power on a commercial scale serving a small community and is classified by power and size of waterfall; MHPS normally which has less than 100kW capacity (Saket, 2008).

1.1.3 Environment Issue and Development of Micro Hydro Power System

A micro hydro system is a more environment friendly renewable energy. This is because the hydraulic works can be made simple and large constructions such as dams are usually not required. This MHPS is simple to be installed due to the parts like pipes, generators and others are usually cheap and easy to find (Saket, 2008).

In recent decade, the environment impact for a large hydro power plant has take into consideration by the local government. This is because, due to the opposition from local resident who living on the land nearby to be flooded, it is difficult for the new dam to be developed. Hence, people start to realize the important of the smaller hydro system like MHPS (Mohibullah et al., 2004).

This hydro power system has become more and more important due to few reasons. The first is the system is this system is close to the demander place, hence building cost is way much cheaper and the money is saved up. Besides, micro hydro power system has become more demandable due to the increasing of energy price worldwide (Bockman et al, 2007).

1.2 Aims and Objectives

The main objective of doing this project is to focus on the designation of an efficient and cost effective micro hydropower prototype which able to generate electricity for basic use and citizen in rural area. Besides the main objective, this project also aims to bring awareness to world about the good of a renewable energy over pollution.

The study of micro hydropower which includes some engineering skill will be carrying out to meet the main objective of this project.

1.3 Motivation

Due to the greenhouse effect gas emission and also the global warming problem that face by the world nowadays, renewable energy become more and more important. Besides, the technology has also increase the world energy consumption and this will more or less inspires the world look over the free renewable energy like hydropower that might be a solution for the above two problem that faced.

This project will be carrying out throughout the whole year, knowledge will be adopted to produce the most effective and suitable outcome.

1.4 Outline of Report

Chapter 2 - Literature Review describes different kind of turbine and waterwheel for hydropower plant which will help in designing the micro hydropower plant.

Chapter 3 - Research Methodology describes the overall process, steps and calculation in designing the micro hydropower plant.

Chapter 4 - Result and Discussion describes the different approaches that adopted like experiment test on different kind of designed to meet the objective of the project.

Chapter 5 - Conclusion and Recommendation describe how well the final implementation meets the design specification and provide further suggestion for improvement that can be made.

CHAPTER 2

LITERATURE REVIEW

2.1 Micro Hydro Power Plant

Micro Hydro Power Plant today is connected either directly to the generator or is connected by means of gear or belts and pulleys, depending on the speed required for the generator. Micro Power Plant depends mainly on the head and the design flow for the generator. Other deciding factors include how deep the turbine must be set, efficiency, and cost. Turbine that used in hydro power system can be classified in to 2 groups. First is the impulse and follow by the reaction turbine.(Saket, july 21, 2008).

2.2 Impulse Turbine

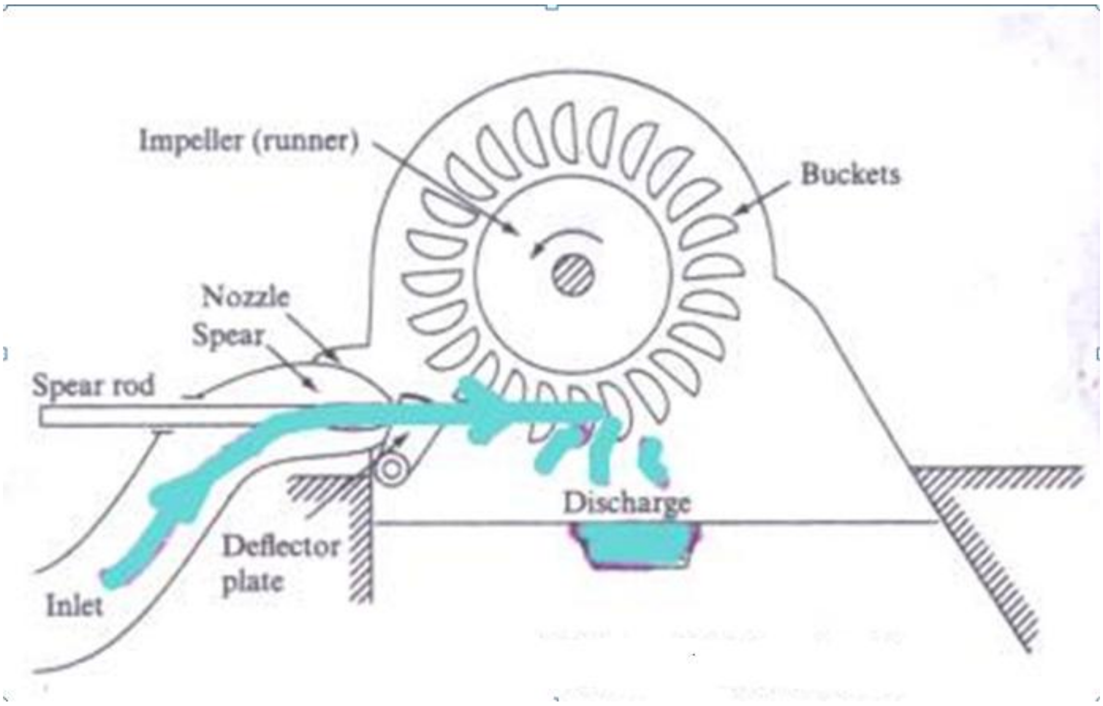


Figure 2.1: Impulse Turbine

The impulse turbine generally uses the velocity of the water to move the runner and discharges to atmospheric pressure. Water stream will hits each bucket on the runner. There is no suction on the down side of the turbine, and the water will flows out the bottom of the turbine housing after hitting the runner. Impulse turbine is generally suitable when high head, low flow applications.(Types of Hydropower Turbines, 2005). There are few example of impulse turbine. For example like the Pelton, Turgo and Cross Flow. (Saket, july 21, 2008). The main different of these turbine is design of the turbine blade of each turbine is unique. Besides, the way of discharging water away from each of the turbines blades are also unique. For example like the Pelton and Closs Flow will discharge water through the upper position of the blade and the Turgo will discharge through the side position. All this is fully depend on their unique design of the blade which can be observed a in the following figures. This design normally is more suitable for water fall area. (Norman, 2003)

2.2.1 Pelton Wheel Turbine Design

Figure 2.2: Pelton Turbine

2.2.1.1 Description of the Design

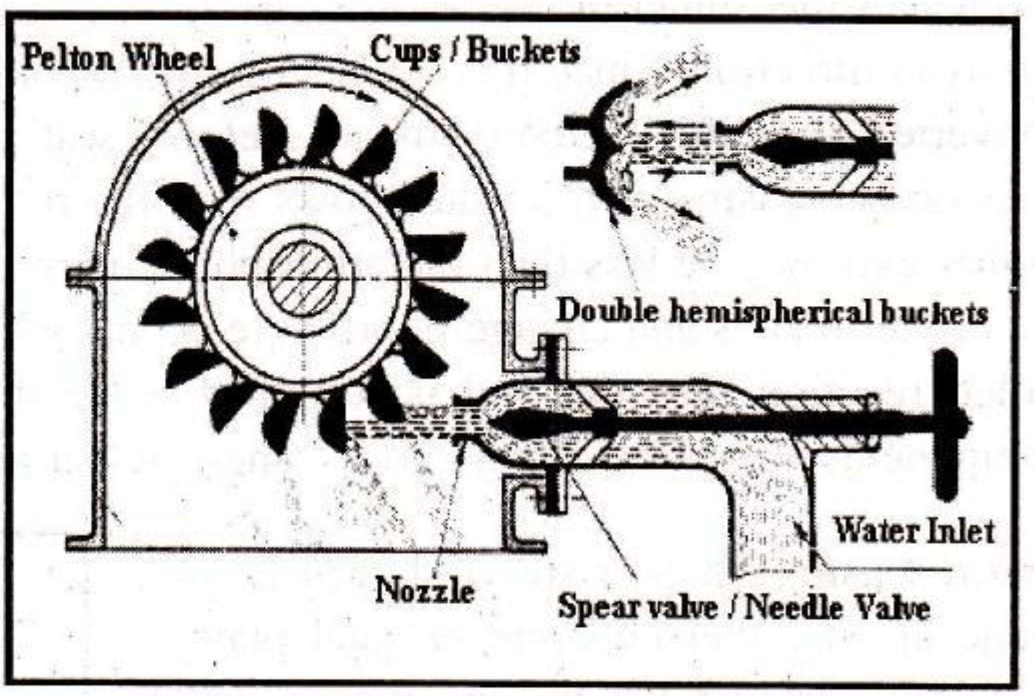


Figure 2.3: Pelton Turbine Working Principle

Pelton turbine is an impulse turbine. This is designed by a man call Lester Allan Pelton in the 1880's. The wheel is fitted with vanes evenly spaced about its circumference. Unlike old wheel designs, each vane is actually composed of two cups joined by a sharp ridge. Water flow is directed by one or more nozzles to strike the ridge of each vane tangentially in succession and in turn delivers the water's kinetic energy in impulses. Hence, the turbine is classified as an impulse turbine. In principle, the ridge acts to divide the water jet in order to achieve better mechanical efficiency. With an optimised jet and cup geometry, more than 90% of the power of the water jet can be transformed into mechanical power by the turbine shaft.(Rasi, 7, July 2008)

2.2.1.2 Testing of the Design

A laboratory-scale Pelton turbine for hydroelectric generation has been constructed and used in the educational curriculum of The Renewable Energy Programme at the University of Jyväskylä, Finland to test out the turbine efficiency. (Rasi, 7, July 2008)

The apparatus is simple to make and the author uses inexpensive components to construct the turbine as shown in figure 2.2. The turbine vane is made out of Polyoxymethylene (POM) plastics and one end of the turbine shaft extends through the wall of the housing and is fitted with a pulley wheel, which drives a small DC electric generator by use of a rubber belt. The generator itself is a salvaged motor from a DC cooling fan. (Rasi, 7, July 2008)

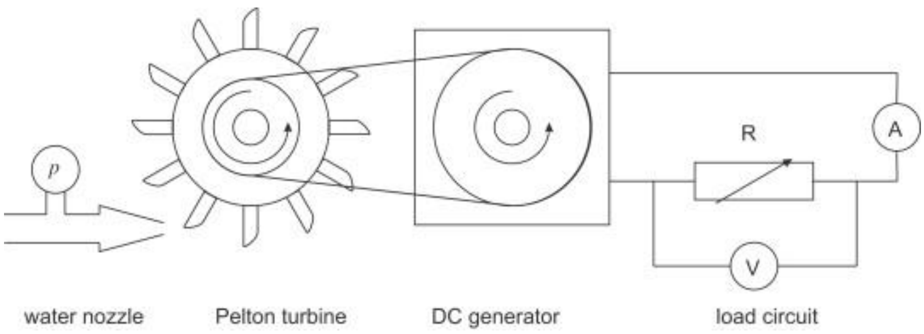


Figure 2.4: Pelton Turbine Testing

The testing build up is as indicate in figure 2.4 and the testing was test out with different flow and different load of resistors. The author has use equation 2.1 to calculate the efficiency of the turbine. (Rasi, 7, July 2008)

$$\eta_m = \frac{P_s}{P_w} = \frac{2\Pi r l F}{\rho g h Q} \qquad (2.1)$$

Where

η_m = mechanical efficiency

P_s = mechanical power available in the turbine shaft

P_w = extractable power of a water jet

ρ = density of the water

g = the acceleration due to gravity (9.81 m/s^2)

h = the available head of the water source

Q = volumetric flow rate

Π = pi (3.142)

r = rotational speed of the shaft

l = moment arm length

F = tangential force

The author has conclude that the design have an efficiency of 0.47±0.02 for a water flow rate of 0.171/s as listed in the table 2.1 and shown in figure below.(Rasi, 7, July 2008). Hence, this design efficiency will be around 80-90%.

Table 2.1: Efficiency with different flow rate

Water Flow Rate, Q (L/s)	Mechanical Efficiency, η_m
0.14	0.45
0.17	0.47
0.20	0.46

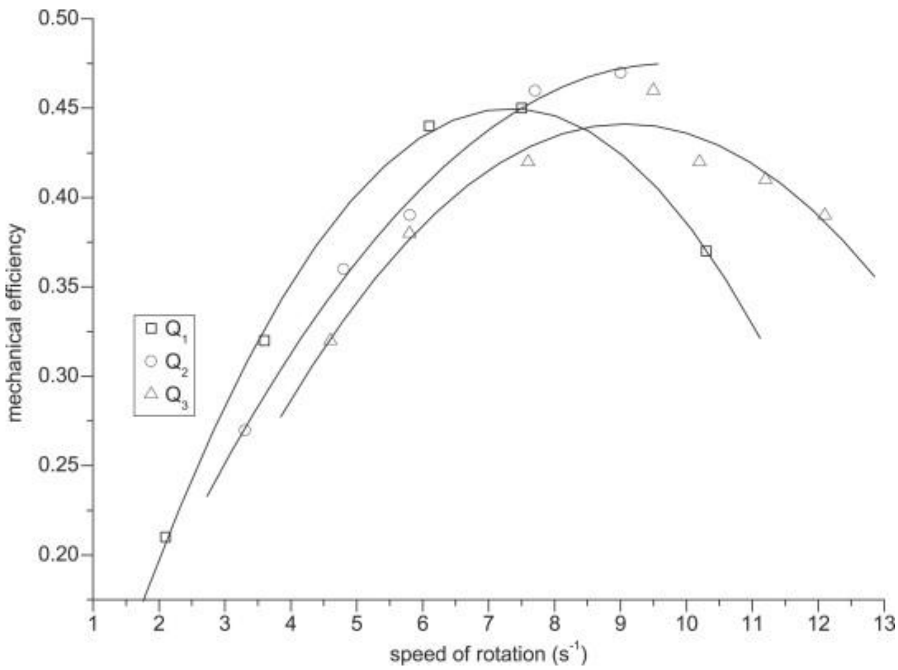


Figure 2.5: The relationships between tangential force on the brake lever and rotational speed of the turbine at the three water volume flow rates.

2.2.2 Turgo Wheel Turbine Design

Figure 2.6: Turgo Turbine

2.2.2.1 Description of Design

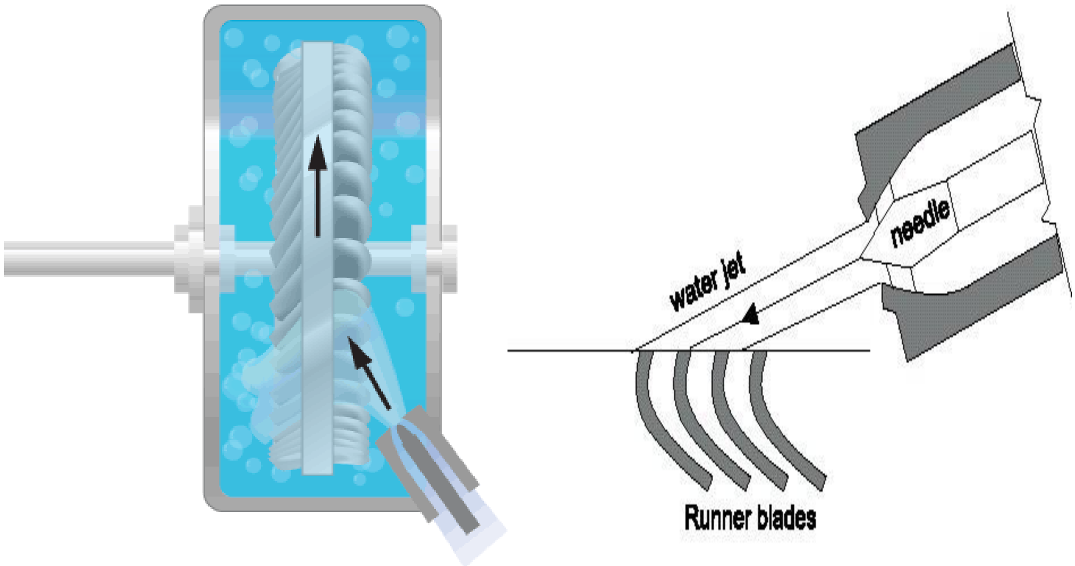


Figure 2.7: Turgo Turbine Working Principle

A Turgo Wheel is a variation on the Pelton and is made exclusively by Gilkes in England. The Turgo runner is a cast wheel whose shape generally resembles a fan blade that is closed on the outer edges. The water stream is applied on one side, goes across the blades and exits on the other side.

2.2.2.2 Testing of the Design

Turgo turbine testing is just same like testing a Pelton turbine. This turgo design can be test out exactly same like tested for Pelton design turbine. The testing build up is as indicate in figure 2.8 and the testing was test out with different flow and different load of resistors. The efficiency of this turbine is just the same like the Pelton turbine. (John S. Anagnostopoulos, 2007). This turbine design efficiency will be around 80-95%. (Micro-Hydropower System; A Buyer's Guide, 2004)

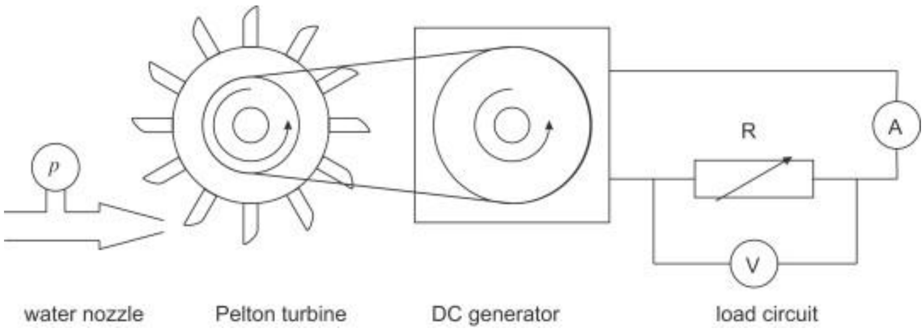


Figure 2.8: Turgo Turbine Testing

2.2.3 Cross-flow Turbine

Figure 2.9: Cross-Flow Turbine

2.2.3.1 Description of the Design

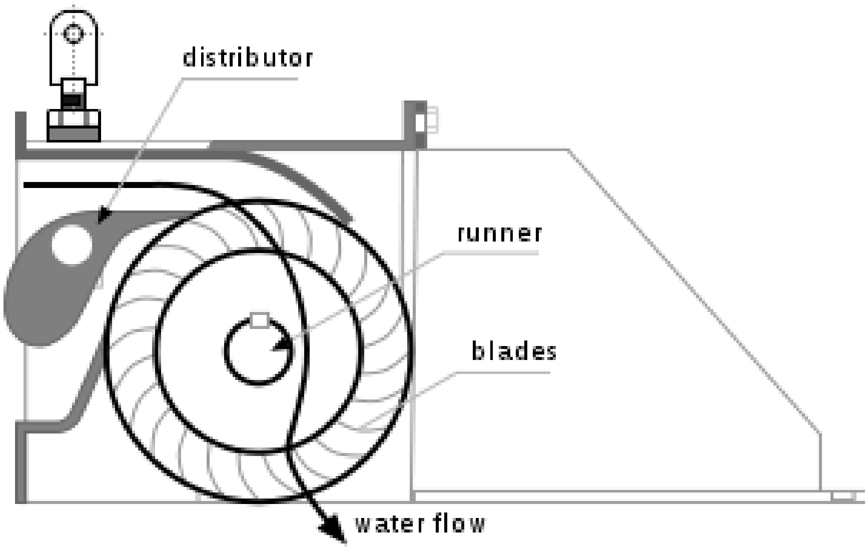


Figure 2.10: Cross-Flow Turbine working Principle

Cross-Flow turbine is a water turbine developed by the Australian Anthony Michell, the Hungarian Donát Bánki and the german Fritz Ossberger. Michell obtained patents for his turbine design in 1903.

A cross-flow turbine is drum-shaped and uses an elongated, rectangular-section nozzle directed against curved vanes on a cylindrically shaped runner. It resembles a "squirrel cage" blower. The cross-flow turbine allows the water to flow through the blades twice. The first pass is when the water flows from the outside of the blades to the inside; the second pass is from the inside back out. A guide vane at the entrance to the turbine directs the flow to a limited portion of the runner. The cross-flow was developed to accommodate larger water flows and lower heads than the Pelton.

2.2.3.2 Testing of the Design

Testing for this design is also the same like all impulse turbines. We can connect the turbine with load and using a nozzle to create water flow into it. However the result from this turbine was not that good if compare to other two, this design can only produce around 65% to 85% of efficiency if compare with the other with the high efficiency of 80% to 95% for Turgo turbine and 80% to 90% for Pelton design.

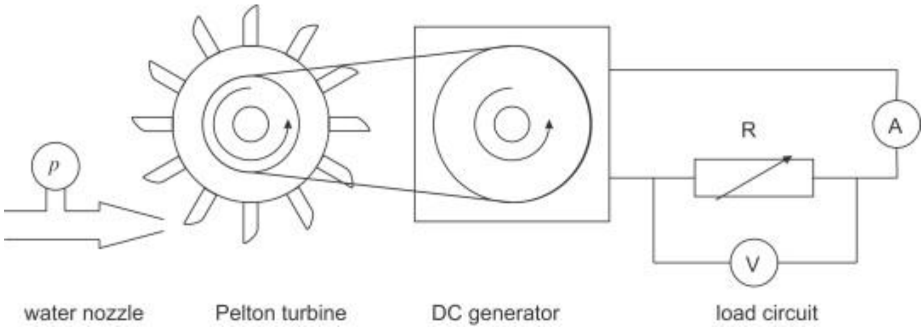


Figure 2.11: Cross-Flow Turbine Testing

2.2.4 Hydro-electric barrel generator (HEB)-Lowery and Price's design

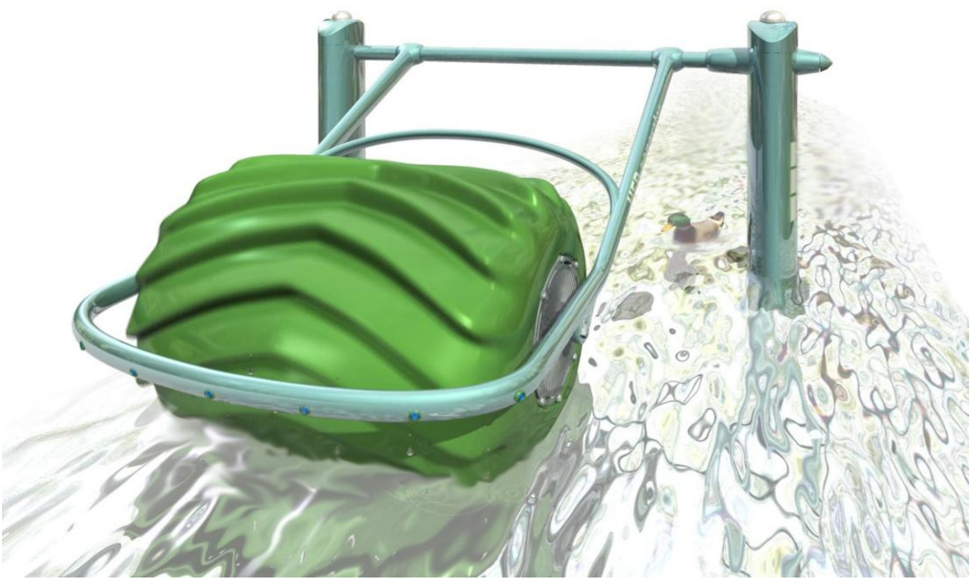


Figure 2.12: Hydro-electric Barrel Generator (HEB)-Lowery and Price's Design

2.2.4.1 Description of the design

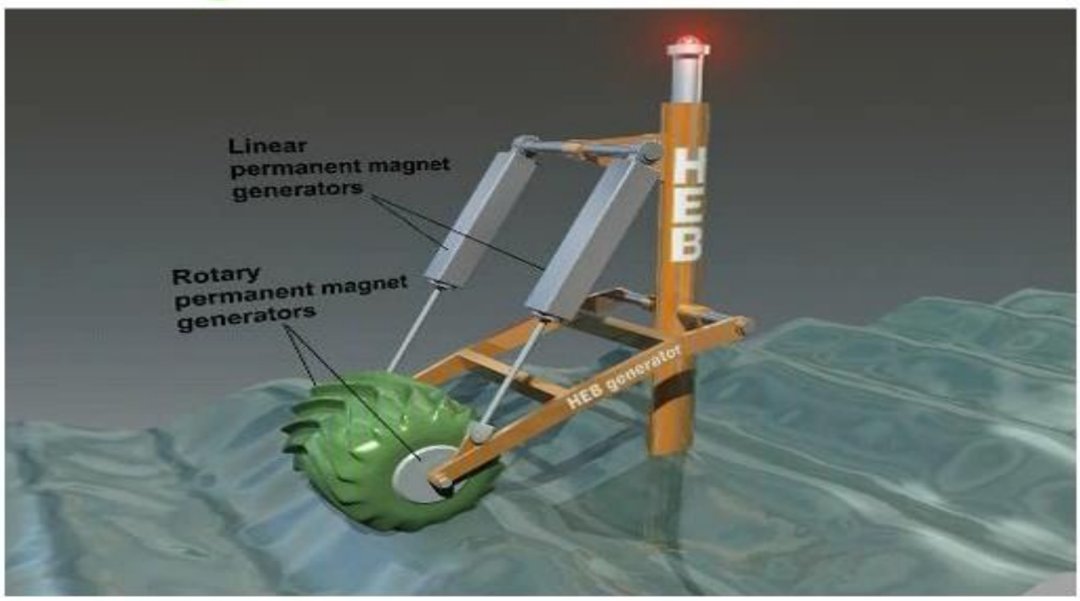


Figure 2.13: Hydro-electric Barrel Generator (HEB) Working Principle

This Hydro-electric barrel generator is design by Lowery and Price's and the designers have got the patent on the 8th September of 2008. The whole structure is on the flowing water. This is a floating waterwheel that can generate electricity when suspended over a river or other flowing water regardless of the depth and speed of flow (the designers stated that the depth will only take into consideration when installation and set up where the user have to place the generator stand at the bottom of the river).

The barrel was one-piece moulded plastic with paddle treads and two integral planet gear driven permanent magnet generators installed making this a relatively light assembly for transportation and installation. The rotating barrel turns the generator case which drives the planet gears which in turn spin the discs which holds the permanent magnets. The movement of the magnets induces electrical current in the coils which are held stationary. The unique chevron shaped paddle treads give the barrel the ability to rotate about its horizontal axis in fast flowing water, entering the water smoothly and re-surfacing without lifting water.

The merit of this design is the significant reduction of any down force and the elimination of the bow wave in front of the barrel as it rotates at the same speed as the flow of water, thus increasing the efficiency of the machine.

This design has many advantages over other methods of hydroelectric power production. The advantages will be stated as below:

- Quiet operation compared to conventional waterwheel
- Easy to transport and install
- Environmentally friendly due to shallow draft
- Cost effective to manufacture, low capital outlay per kilowatt
- Does not significantly interrupt river flow and can roll over debris
- Adjusts to water level
- Tidal estuary variant
- Massive potential for grants

2.2.4.1.1 The HEB Generator

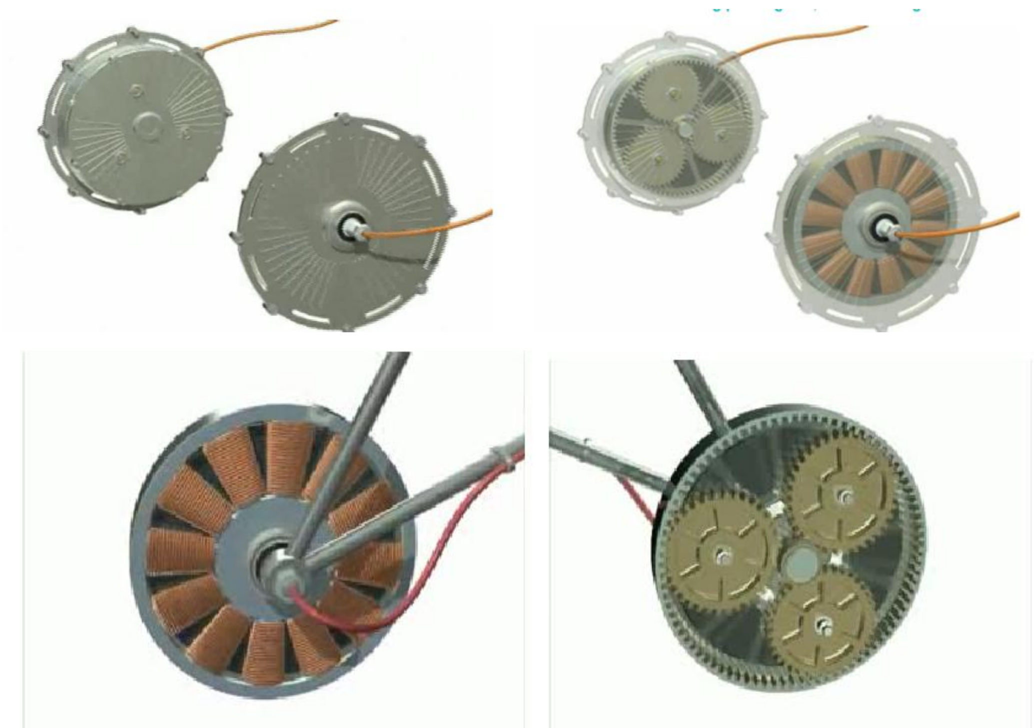


Figure 2.14: HEB Generator View

This would be a brush-less permanent magnet type as this type can produce high currents at low revolutions and its "pancake" format is ideal for this device as indicate in the figure 2.14. The illustration shows the concept involved. Harnessing a large force at low speed may require some form of gearing as illustrated. However a small diameter HEB on a fast stream could perhaps drive the armature directly and benefit from the energy saving lost through gearing. A brush-less generator will of course require less maintenance and the vented "pancake" design facilitates cooling. There is a planet gear for more stability and the coil and magnet to generate electricity.

2.2.4.1.2 The HEB barrel

This design is like a balloon that float on the river. As the HEB is completely sealed it could be an option to install a valve to maintain slight internal pressure improving rigidity. This valve would vent during periods of hot weather to protect the barrel. A more clearer picture about the barrel will be shown at the figures below.

Figure 2.15: HEB Barrel Body View

Figure 2.16: HEB Barrel Body View (without generator)

Figure 2.17: HEB Barrel Internal View (without generator)

2.2.4.1.3 Sling (support frame)

This would be left to the developer but a common component is that the Swing tube is mounted above the height of the barrel. Shown in the figure below are 3 of the designs as examples, depending on location, suitable river bank, average water speed or size of barrel. The single stanchion design could possibly have the capability to swing the barrel round on to the bank for cleaning and maintenance. The frames could incorporate navigation lights.

Figure 2.18: HEB Sling

2.2.4.1.4 A possible sling design for the purpose of prototyping

This consists mainly of common scaffolding parts but could be fabricated out of whatever is available. The structure is held anchored by the two baskets filled with rocks, bricks, sandbags or hardcore. As a temporary structure it may be useful in situations where planning permission is an issue. Anchoring to one bank avoids other problems such as requiring access to the other bank or problems anchoring to the riverbed. It is fairly unobtrusive as it would straddle a riverbank path.

Figure 2.19: HEB Possible Sling

2.2.4.2 Testing of the Design

The output power can be estimate using 2 different method by the designers.
Calculation using simple formula for Power
Horsepower = Torque (foot pounds) x 2 pi x rpm / 33000 which simplifies to:
Horsepower = Torque x rpm / 5252.
Finding Torque by calculating the water pressure on the paddle area using:
Paddle Area x Length x density of water x (Velocity of current2 / 2 x gravitational constant) and multiplying this by Radius

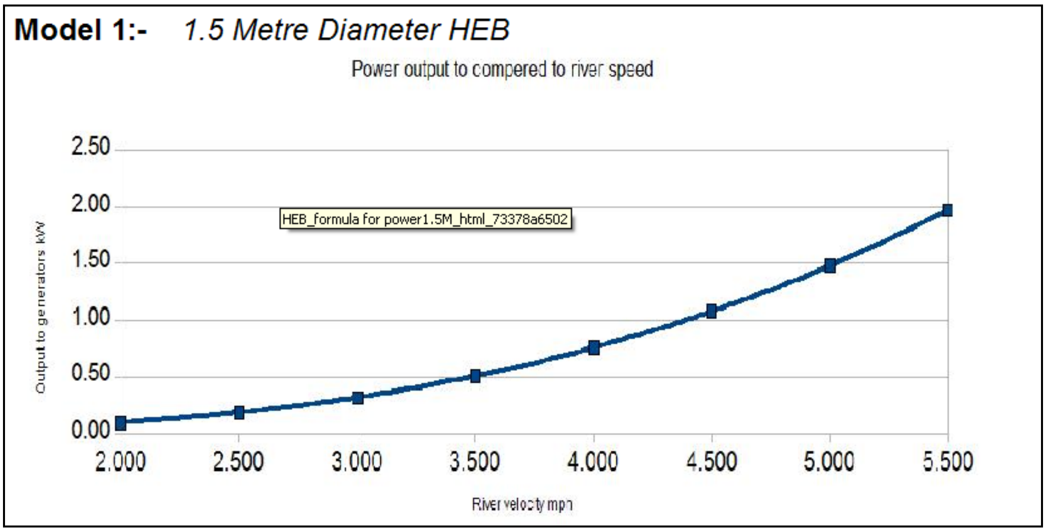


Figure 2.20: HEB Output Power Model 1

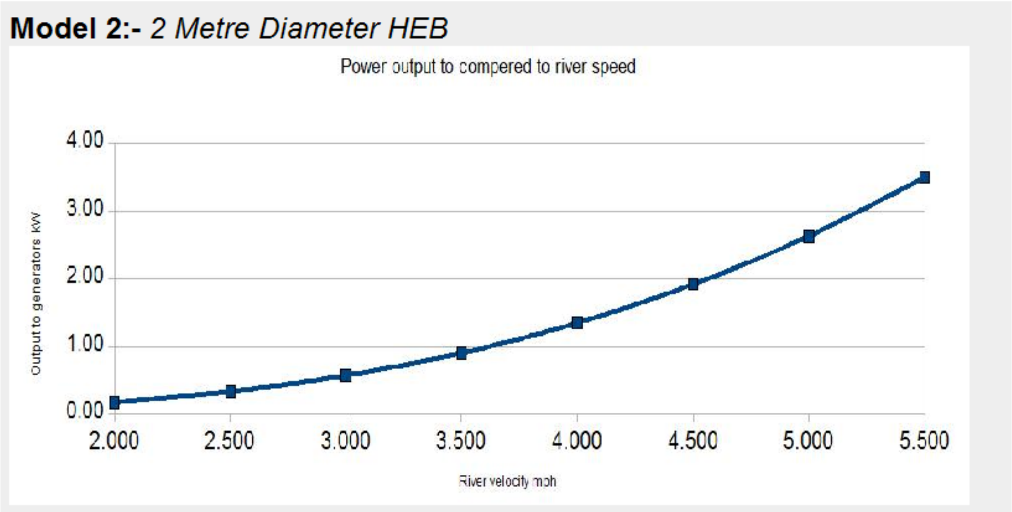


Figure 2.21: HEB Output Power Model 2

2.2.5 Waterwheel

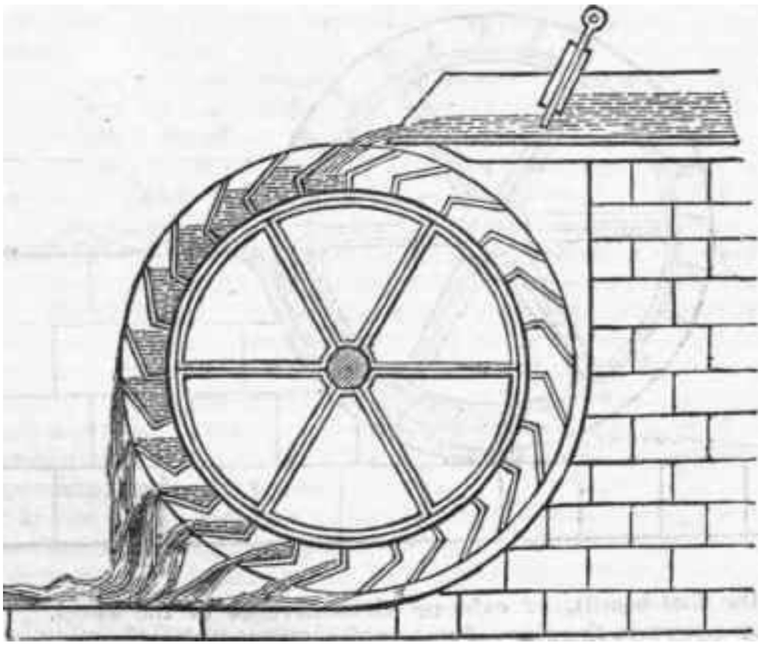


Figure 2.22: Waterwheel

As the water flow from the higher level to the lower level of the water wheel, this will cause the turning of the wheel. From the angle of energy, the potential energy will be converted into the kinetic energy when the wheel turns. Then this will create a mechanical energy and turn the generator that is attached to this. Hence, it will create electricity when the generator turned. There are 3 type of waterwheel in hyfro electricity which is the overshot, undershot and the breadshot. All have their own function. (Jones, 2005). This design normally is suitable for a water fall.(Norman, 2003)

2.2.5.1 Overshot waterwheel

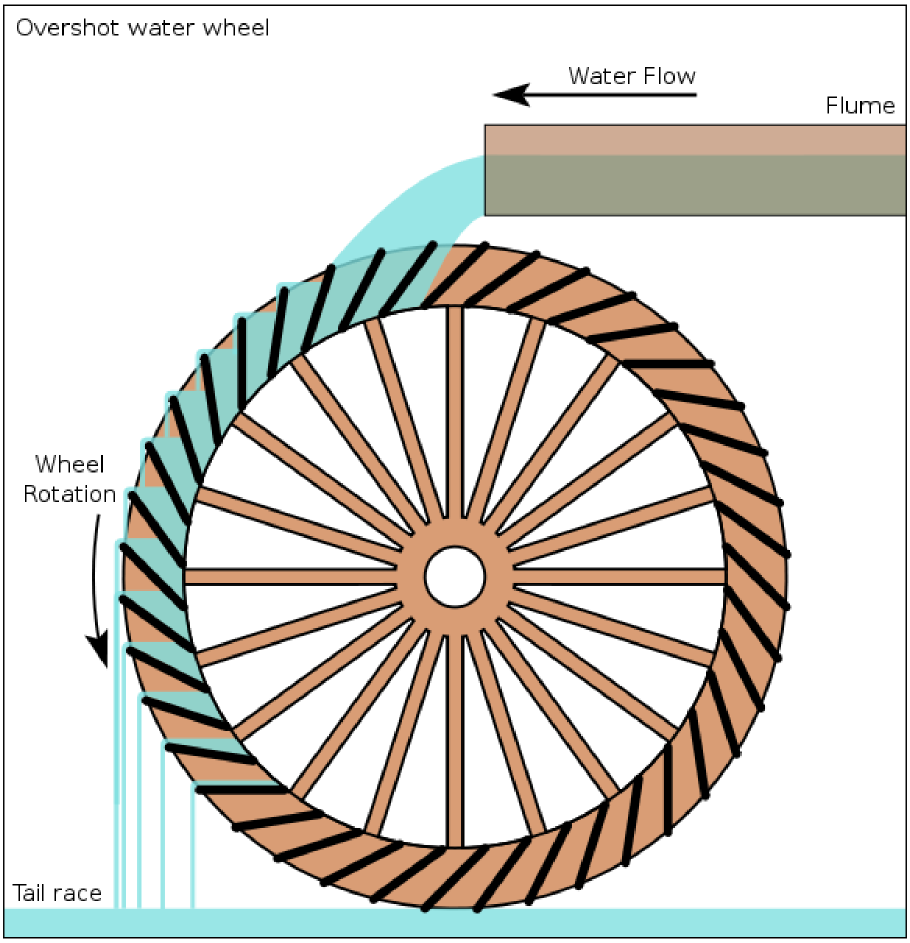


Figure 2.23: Overshot Waterwheel

This type of waterwheel will let the water enter from the above of the wheel and falls into the buckets turning the wheel with efficiency of about 85%. the head diameter for this is normally between 2.5m to 10m and the flow rate will be lesser than 0.2 m^3/s per m width.

2.2.5.2 Breadshot waterwheel

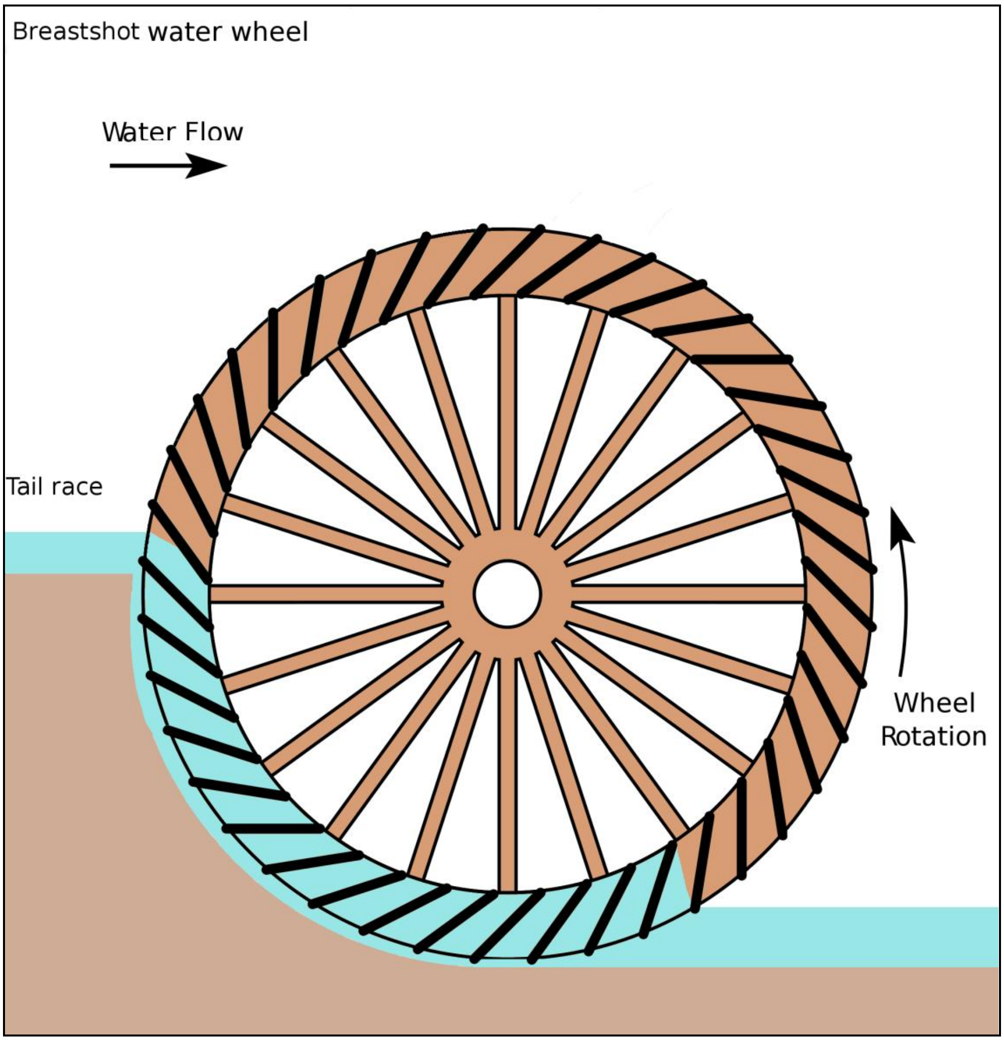


Figure 2.24: Breadshot Waterwheel

This type of waterwheel will let water enters half way up the diameter of the wheel, falling into buckets turning the wheel. The efficiency is up to 87%. The head diameter is normally between 1.5m to 3m. The flow rate will be between 0.3 to 0.65 m^3/s per m width.

2.2.5.3 Undershot waterwheel

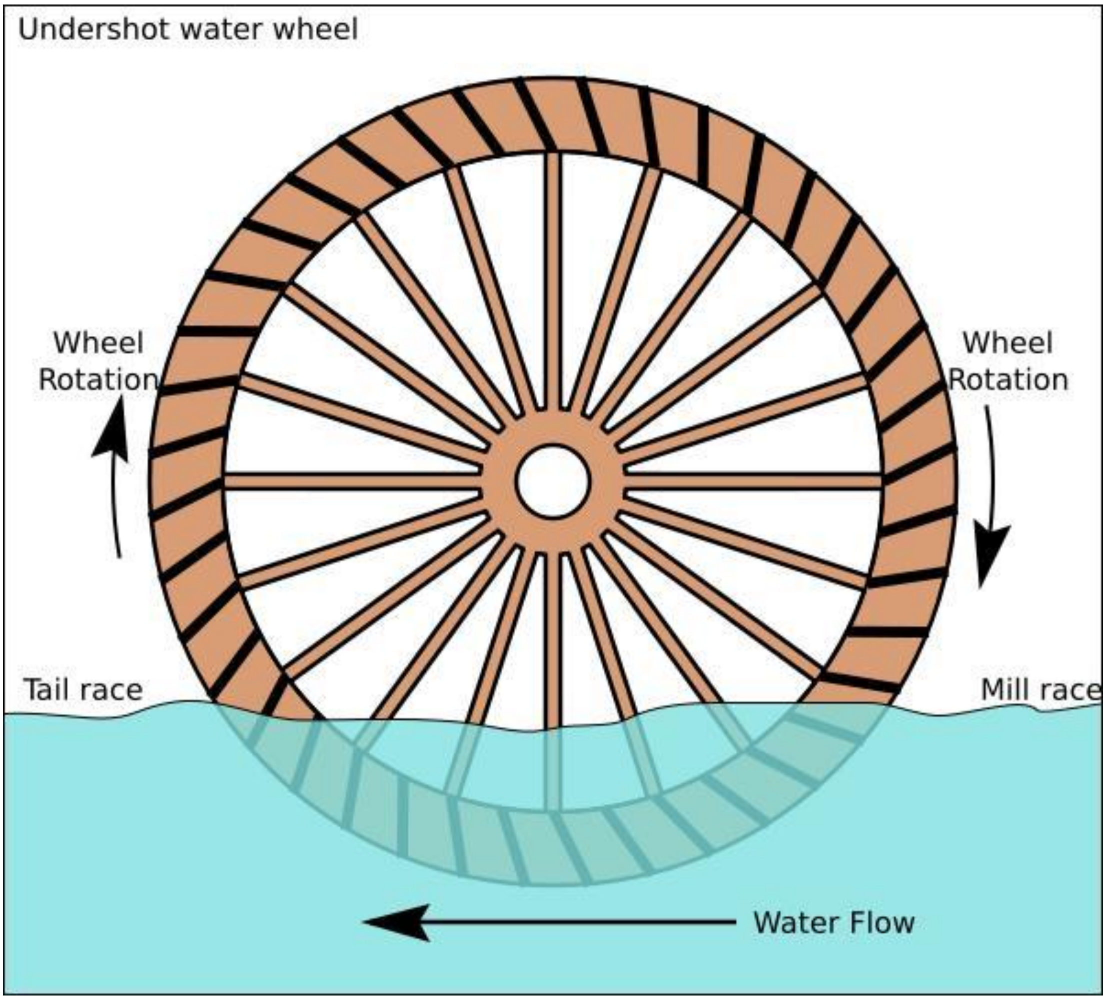


Figure 2.25: Undershot Waterwheel

This type of wheel can be defined into 2 types. The first is where some modules use a very small head drop and curved blades to take potential energy from the river and this will give around 60 to 77 % of efficiency. While other will use the kinetics energy of the river on the blades but this will give only 33% of efficiency. The head diameter is normally between 0.3m to 2.0m. The flow rate will be between 0.45 to 1 m^3/s per m width.

2.3 Reaction Turbine

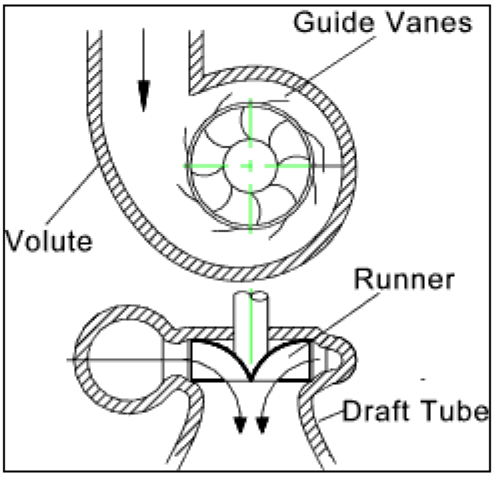


Figure 2.26: Reaction Turbine

A reaction turbine develops power from the combined action of pressure and moving water. The runner is placed directly in the water stream flowing over the blades rather than striking each individually. Reaction turbines are generally used for sites with lower head and higher flows than compared with the impulse turbines. This design will more suitable for a flowing river or a quiet river.(Norman, 2003)

2.3.1 Propeller Type Reaction Turbine

Figure 2.27: Bulb Turbine

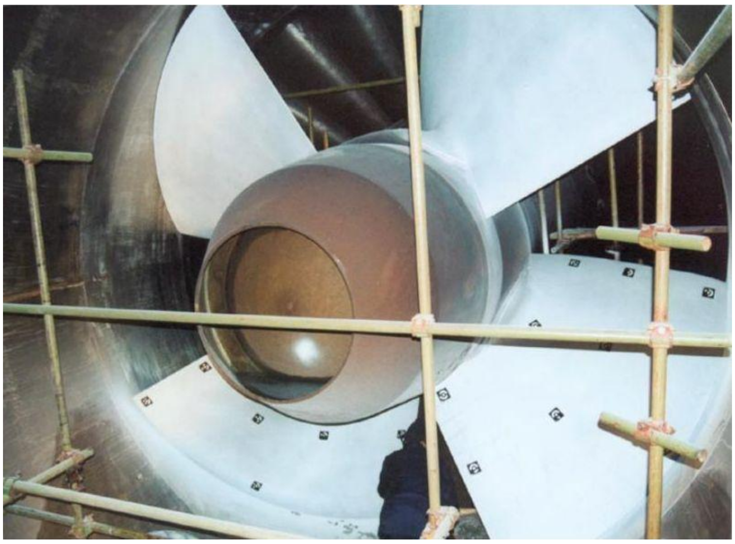


Figure 2.28: Kaplan Turbine

2.3.1.1 Propeller Type Reaction Turbine Working Principle

A propeller turbine generally has a runner with three to six blades in which the water contacts all of the blades constantly. Picture a boat propeller running in a pipe.

Through the pipe, the pressure is constant; if it isn't, the runner would be out of balance. The pitch of the blades may be fixed or adjustable. The major components besides the runner are a scroll case, wicket gates, and a draft tube. There are several different types of propeller turbines. The first is the bulb turbine where the turbine and generator is a sealed unit placed directly in the water stream. The second is the straflo where the generator is attached directly to the perimeter of the turbine. The third is the tube turbine where The penstock bends just before or after the runner, allowing a straight line connection to the generator. The last is the Kaplan turbine where both the blades and the wicket gates are adjustable, allowing for a wider range of operation.

2.3.1.2 Testing of the Design

This type of turbine will only work well when the water pressure is constant, the runner will be out of balance if the pressure is too high. According to the Micro Hydro Plant Buyer’s Guide book stated that this turbine will give around 80% to 95% of efficiency. (Micro-Hydropower System; A Buyer's Guide, 2004)

2.3.2 Francis Type Reaction Turbine

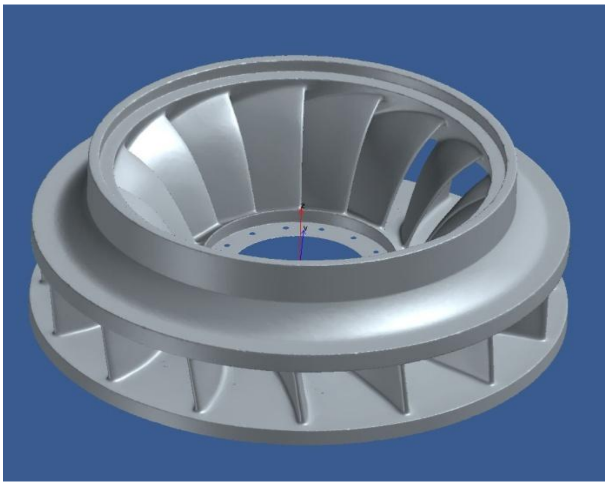


Figure 2.29: Francis Turbine

2.3.2.1 Francis Type Reaction Turbine Working Principle

A Francis turbine has a runner with fixed buckets (vanes), usually nine or more. Water is introduced just above the runner and all around it and then falls through, causing it to spin. Besides the runner, the other major components are the scroll case, wicket gates, and draft tube.

2.3.2.2 Testing of the Design

This design will be more stable compare to the propeller type design. According to the Micro-Hydropower system buyer guide's book, this type of design has an efficiency of 80% to 90%. (Micro-Hydropower System; A Buyer's Guide, 2004)

2.4 Comparison of the Micro Hydro Power Plant Design

The table below is the some group of Micro Hydro Power Plant and the needed head for all kind of turbines.(Micro-Hydropower System; A Buyer's Guide, 2004)

Table 2.2: Head of Water turbine

Turbine Runner	High Head (more than 100m / 325ft.)	Medium Head (20 to 100m / 60 to 325 ft.)	Low Head (5 to 20m / 16 to 60 ft.)	Ultra-Low Head (less than 5m/ 16 ft.)
Impulse	Pelton , Turgo	Cross-flow, Turgo	Cross-flow	Water Wheel
Reaction	-	Francis	Propeller	Propeller

The table below will be the efficiency of all kind of the Micro Hydro Power Plant design. (Micro-Hydropower System; A Buyer's Guide, 2004)

Table 2.3: Typical Efficiency of Turbines

Micro Hydro Power Plant Design	Efficiency Range
Impulse turbine :	
Pelton	80 – 90%
Turgo	80 – 95%
Cross-flow	65 – 85%
Water wheel undershot	25 – 45%
Water wheel breadshot	35 – 65%
Water wheel overshot	60 – 75%
Reaction turbine :	
Francis	80 – 90%
Propeller	80 – 95%
Kaplan	80 – 90%

CHAPTER 3

METHODOLOGY

3.1 Phase of design (Planning of the project)

A phase of design is like drawing a map for the project. This is to guide the author through out the project. A flow chart can be map in this project. A good flow chart is to formulate the satisfaction of a project manager need. The outline of the flow chart that used in this project will be as indicate in figure 3.1. Besides, a Gantt chart (appendix a) will be drawn to describe and monitor about the planning process for the prototype in which have to perform on specific period.

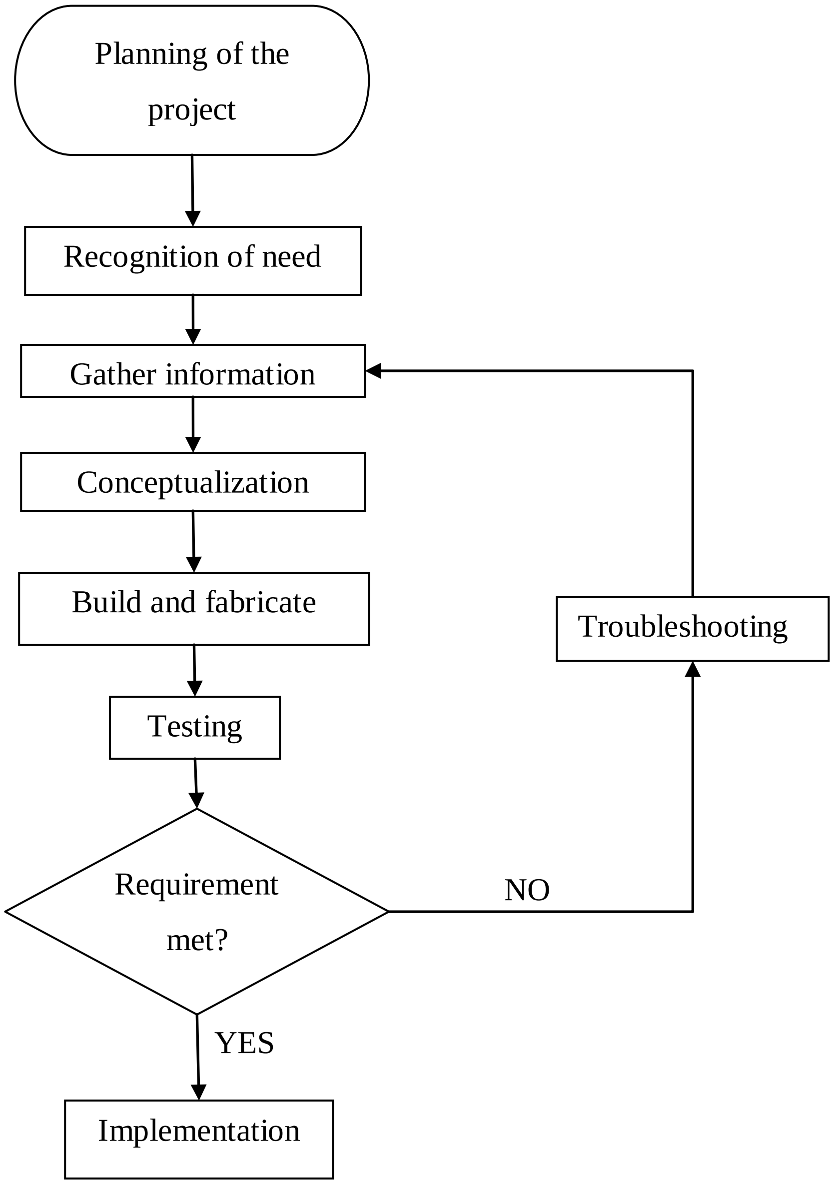


Figure 3.1: Phase of Design

3.2 Recognition of Need

Normally design of a Micro Hydro Plant is site-specific but there are still things that are in common for all Micro Hydro Plants. This step will tell the author the basic need and common thing of all the micro hydro power plant. For example, a water supply is needed for all the plants- this can be water flow down from the water fall from the mountain or a water flow from the river. Relying on a minimal flow of water year-round for some of the countries, an artificial reservoir might solve the problem. Of cause all of the Micro Hydro Plants, they do not need a damn to function. If the Micro Hydro Plant is apart from the water supply, a penstock pipe might be needed to carry the supplied water to generate power.

A common Micro Hydro Plant will need a turbine and generator to function. As for the turbine, different Micro Hydro Plant might have different turbine design. In this project, a specific design of turbine might be needed to increase the efficiency of the existing Micro Hydro Plant concept. A turbine turn the generator, which then connected to the electric loads. The connection can be just a simple bulb to the complicated housing areas. These are the basic need to create a Micro Hydro Plant that the author has to know at the first step of designing a new micro hydro power plant.

3.3 Gather Information

Case study through out the world via different sources. For example, Pelton turbine; one of the most popular and great design of Micro Hydro Plant today. Research is made on this concept and many others to aid in designing a more efficient and new Micro Hydro Plant.

With the limited budget, the author has to be extra careful when come to collecting information for the few basic need of the new Micro Hydro Plant. For example like the generator, material selection, the environment, and so on. Consideration has to be taken into their characteristic that mostly from different angle kind of view related. For example like their ability and properties. Besides, reliability for long term use and commercial are importance. Hence, indirectly cost has become the importance issue to consider.

3.4 Conceptualization

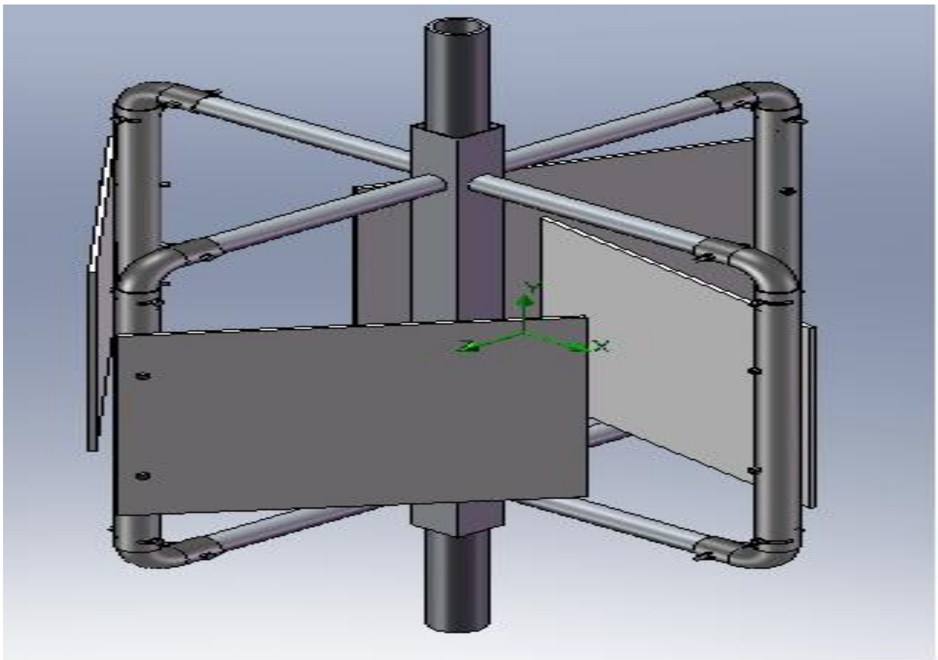


Figure 3.2: New Design Micro Hydro Power Plant Turbine

By obtaining sufficient information for each part of the prototype design, it has provides a better solution when constructing the prototyping. This step is to generate a wide range of design option and this is where the author use creativity and imagination to develop approaches to achieve the design objective while satisfying the constraints. Hence, with few considerations, the author has come out with a new design ideal of micro hydro power plant as indicate in the figure 3.3.

This concept will be draw out using a 3D mechanical computer-aided design (CAD) program; Solidwork. This mechanical design automation software is a featured based, parametric solid modelling design tool. The author was able to create fully associate 3D solid models with or without constraints while utilizing automatic or the author can defined relations to capture design intent. Using this 3D mechanical computer-aided design (CAD) program in creating the author concept micro hydro power plant turbine, it allow the author to work easily, intelligently in understanding the author new concept of micro hydro power plant geometric features. This software is giving better services to the author in designing the new concept of micro hydro power plant turbine. This program not only reduce the errors and provide an easy way in achieving a prefect model, but also carries with important information and data to the author such as dimension of the turbine, material selection, hardness and strength of the material. Besides, with the Solidwork program the author are allow capturing their own design intent and also make changes or modification to the model easily and quickly. With the aid of computer, simulation has been done by the author to get the optimize dimension before constructing the real prototype. Besides the simulation, this software also shows the author the working principle and reliability of the new ideal. Material for this prototype also has been considered by the author. With the hardness and strength analysis, plastic and aluminium will be consider so that it will give a lighter weight and prevent the prototype from deteriorate and rust.

3.5 Build and Fabricating

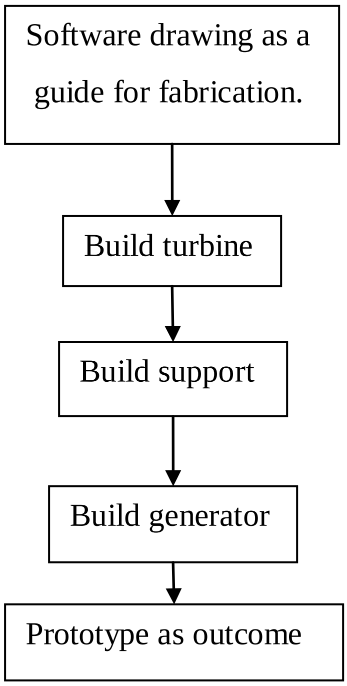


Figure 3.3: Fabrication Flow Chart

The fabrication process was carried out to build author's micro hydro power plant new idea design as like the flow chart above. The dimension of the material was selected in the software used with some analysis. With the basic design that has drawn out with the software. The author can fabricate easily with the drawing prepared earlier.

3.5.1 Turbine

3.5.1.1 Drive Shaft

The drive shaft is the main support and carries the blades of the new design turbine. Hence, this is an importance part. A stainless steel hollow shaft was chosen by the author. Besides, a square aluminium hollow shaft was added to hold all the 4 blade of the turbine. Bolts, nuts, and washer will be joining both of this part together.

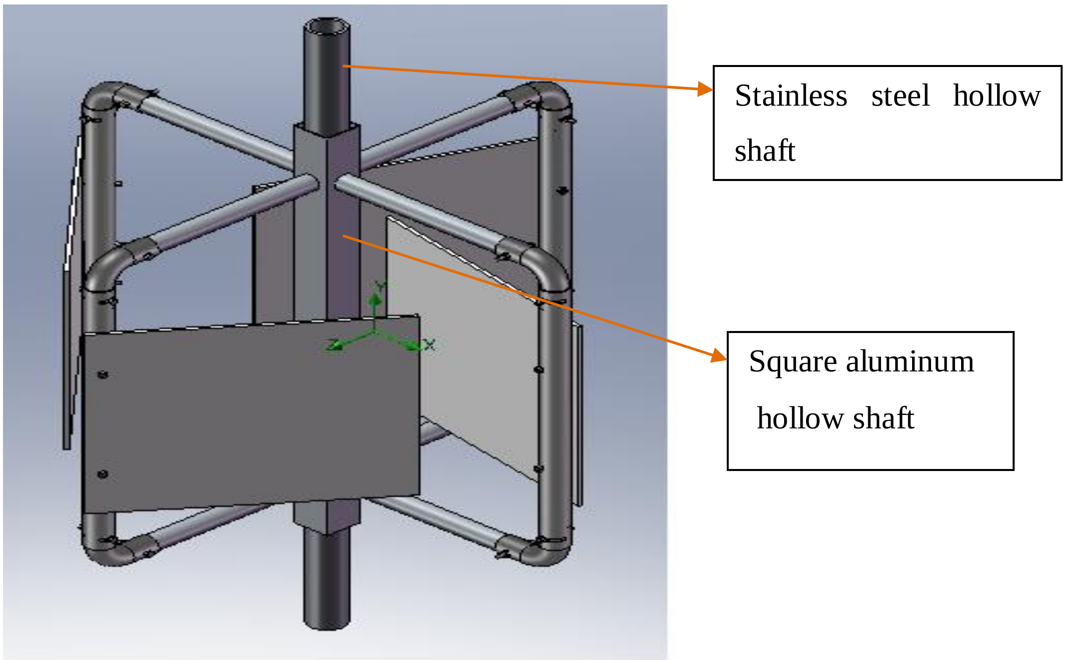


Figure 3.4: Turbine Drive Shaft

3.5.1.2 Turbine blade

The turbine blades will be the part that contacts the most with the water so that it can provide a reaction to generate electricity. All this part will be join together with bolt, nuts and also washers. Besides, there are extra butterfly hinges added to the blade for the ideal of portable. This will be shown in the figure 3.5.

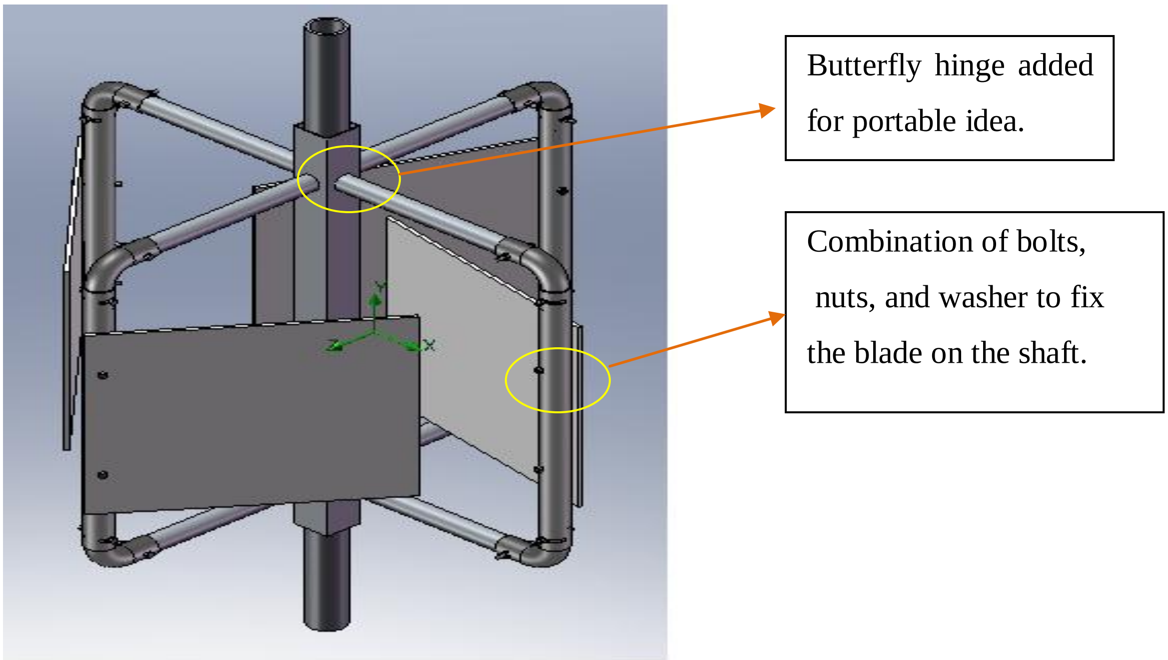


Figure 3.5: Turbine Connector

3.5.2 Supporting

3.5.2.1 Supporting framework

This part was fully depended on the turbine and the environment itself. The dimension will be obtain from there and hence the author has chosen an L shape steel to build up the supporting frame as indicated in the figure 3.5 after the turbine and the drive shaft is built.

Figure 3.6: Supporting Framework

3.5.2.2 Supporting bearing

A bearing will be added to hold the turbine and the supporting framework. So that the design turbine will be able to rotate on the supporting frame. The bearing will be select according to the size of the design shaft and UCF 205 bearing was chosen for the prototype. The author has only chosen one bearing to hold the prototype, so that this will not be a burden for the turbine.

Figure 3.7: Supporting Bearing

3.5.3 Generator

3.5.3.1 Generator selection

Generator is another importance part of the design turbine. From the information gather, an induction generator will be select. Hence, the author has chosen a 12V ac generator.

Figure 3.8: Generator

3.5.3.2 Speed increasing mechanism

For a low speed generator (normally less than 1000 RPM), a speed increasing mechanism such as belt and or gear box is required to increase the turning speed of the generator, hence provide a higher RPM. According to the author, 2 gears have been select to increase the RPM of the generator to give a clearer picture when running the test. One of the gears will have 160 teeth and the smaller one will have 106 of teeth as indicate in the figure 3.6.

Figure 3.9: Gears

3.6 First Prototype

The first prototype is assembly and build as like the drawing prepare earlier. The figure 3.10 shows the ready first prototype.

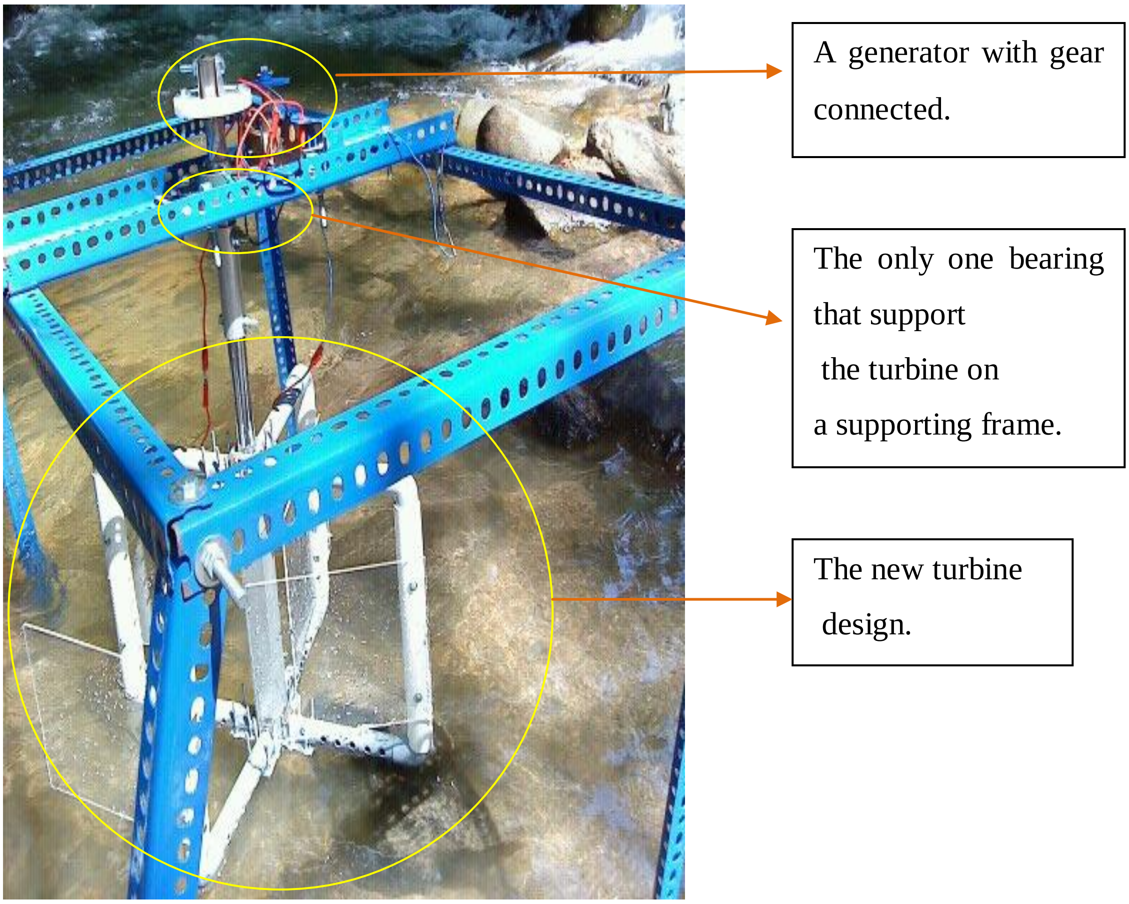


Figure 3.10: First Prototype

3.7 Testing

The author of the new turbine design has tested the design in several places and ways when the prototype is ready. There will be load added like a resistor. Besides, a multi meter, oscilloscope, tachometer and so on can be use to obtain the result. There are few ways to test the prototype:

- Test with high pressure water jet spray water flow inside a water tank with turbine place inside the tank and turbine blade depth inside the water of 10cm.
- Test with high pressure water jet spray water flow inside a water tank with turbine place inside the tank and turbine blade depth inside the water of 3cm.
- Test in a river flow with turbine blade depth inside the water of 3cm.

- Test with at horizontal position of the turbine with water pressure pump spray on the turbine blade.
- Test with vertical position of the turbine with water pressure pump spray on the turbine blade.

The testing was carrying out for few tests with different depth of blade sock inside the water as indicate in the figure 3.11. The tank that is used to test is a square tank that has 3ft on each of the dimension as indicated in figure 3.12, turbine will be place inside this tank with full of water. Besides, Sungai Pisang water fall at old genting road will be the river that test by the author, the environment of the river as indicated figure 3.13. Besides, the high pressure water jet used is the Bosch Aquatak 100 as indicate in the figure 3.14.

With the result gain, the author will do analysis on the result gain like plotting graph for a better view on the result.

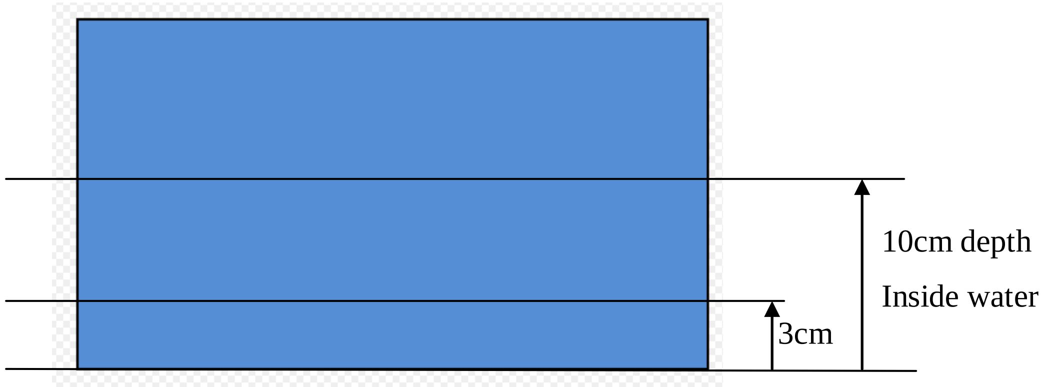


Figure 3.11: Depth of Blade

Figure 3.12: Testing Water Tank

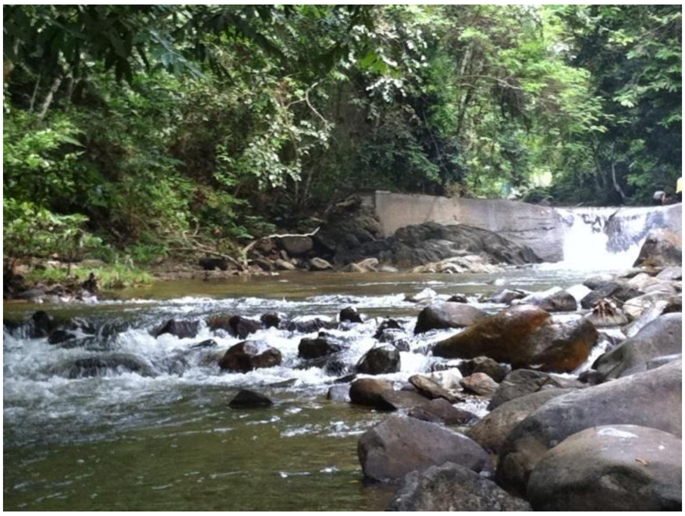


Figure 3.13: Testing River

- Motor Power : 1400 watt
- Pressure : 100bar max press;
  90bar work press
- Max flow rate :340 l/h
- Max water temp : $40^{0}C$; h2o
- Weight : 7.7kg

Figure 3.14: High Pressure Water Jet (Bosch Aquatak 100)

3.8 Prototype improvement

The efficiency of the first test was not good due to some problem occur on the turbine and this will need to be solved to obtain a better efficiency generation. By knowing the problems occurred from the first prototype, some improvements and features are added to the second prototype to improve it.

- Hole is made on the turbine blade holder on each blade as indicated in the figure 3.15.

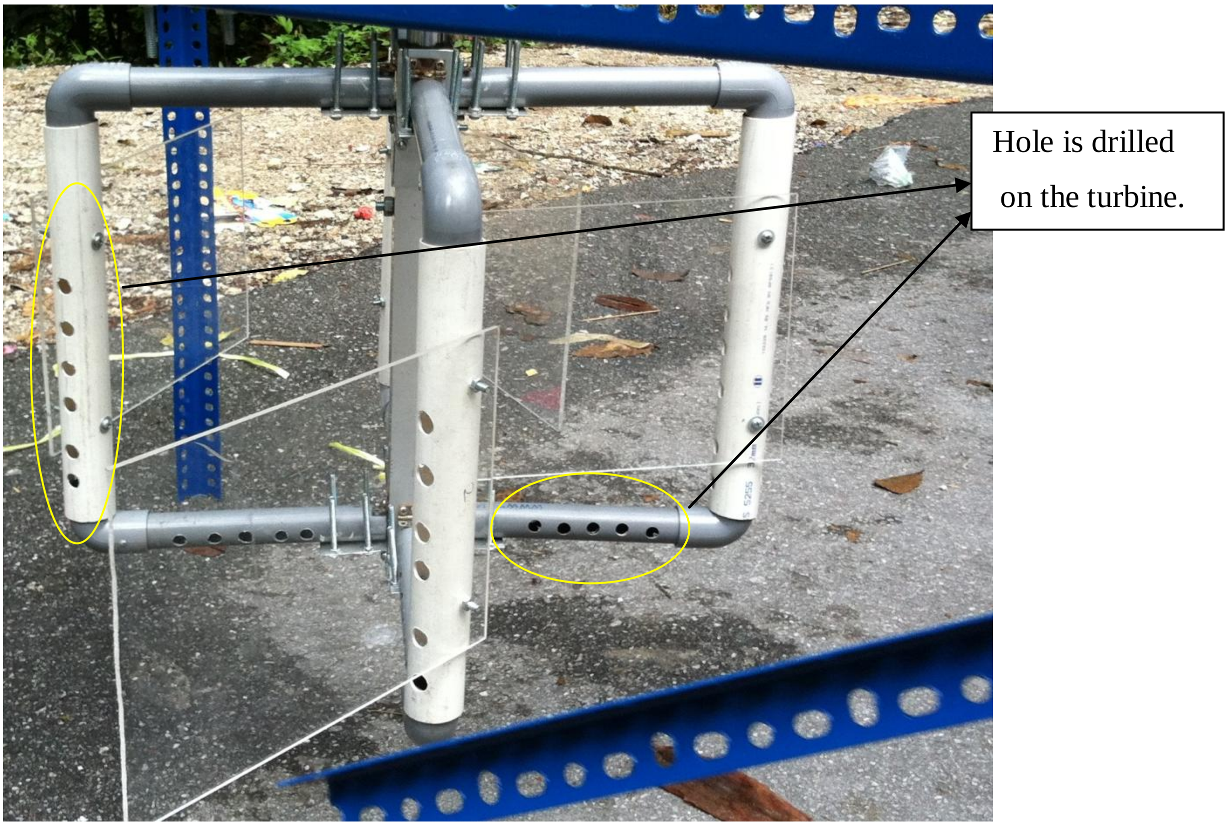


Figure 3.15: Hole Drilled on the Turbine Blade Holder

- Besides, a better generator has replaced the old generator as indicated in figure 3.16. The specification of the motor will show in the appendix b.

Figure 3.16: Better Generator (Cytron Motor)

- A second bearing is added to stabilize the turbine on the supporting frame and a direct coupling concept is applied on the turbine as indicate in the figure 3.17.

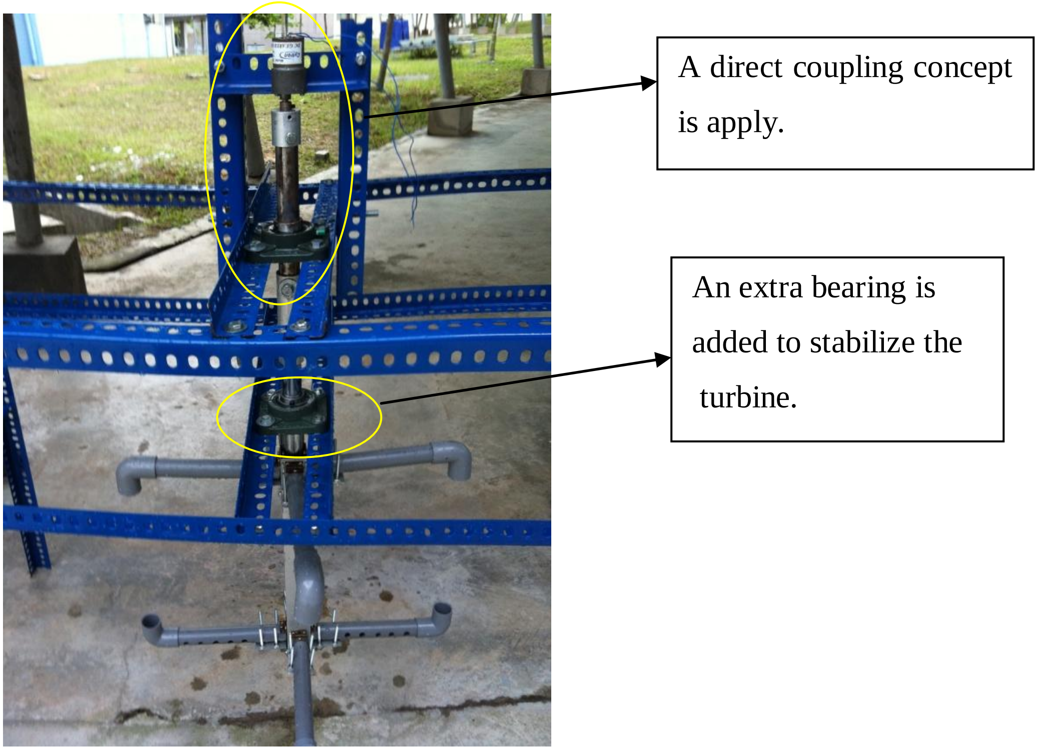


Figure 3.17: Improvement of the Second Prototype

3.9 Implementation

3.9.1 Second Prototype

The improvement has been made with drilling hole and a direct coupling concept and extra bearing is added. The second prototype is shown in figure 3.16 and this improved prototype undergoes the testing as same like the first prototype and got a better result. Hence, the new turbine design idea is implementing to others.

Figure 3.18: Second Improved Prototype

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 The New Design Analysis

4.1.1 Description of The New Design

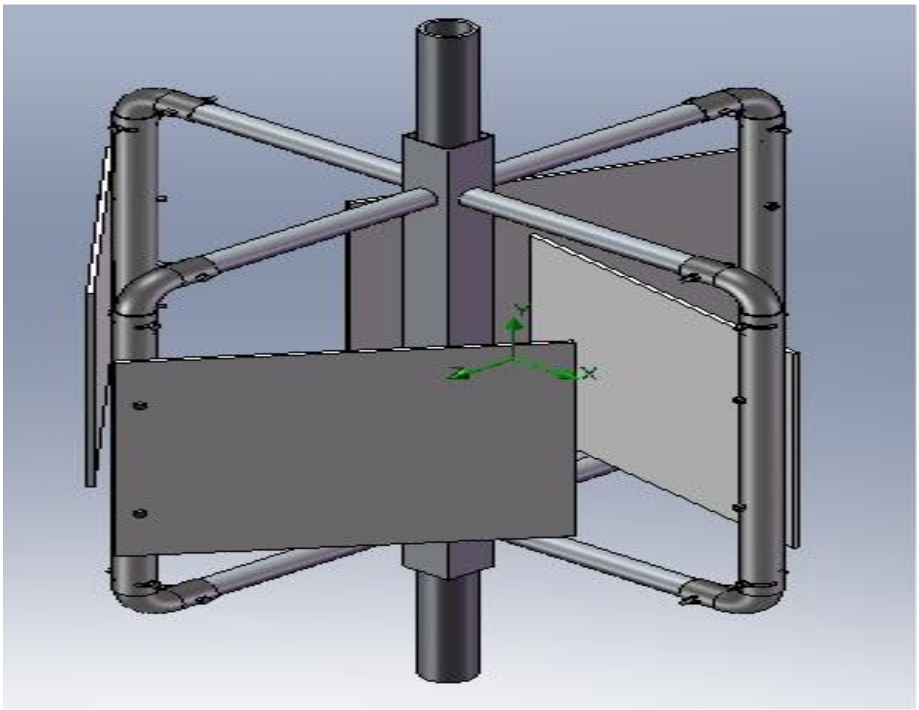


Figure 4.1: New Turbine Design of Micro Hydro Power Plant

The new idea of the design uses water flow to generate electricity as shown in Figure 4.1. The whole structure is on the flowing water. With a certain depth of the turbine blade goes under water, this new design is able to generate electricity as indicated in

Figure 4.2. Hence this design were not take into consideration about the depth of the flowing water like other design (only certain depth like around 15cm will needed to plan the turbine inside the water).

Not like many other micro hydro turbine, this design is unique. As many other turbines, they have a fix and stationary turbine blade. However, this new design will have a flexible and mobile able blade. When the water flow through the turbine, only one of the blades will close up to turn the turbine. While the others follow the water flow as indicated in the Figures 4.3 and 4.4. Hence, the water will not trap between the turbine blades. This will dramatically reduce the friction of water onto the other non-functioning blade.

The merit of this design is the flexible blade as the non-functioning blades will follow the flow of the water, thus increasing the efficiency of the machine. Besides, this machine is also a portable type of micro-hydro plant. When finish using, the blade can be depart from the turbine as the perpendicular to the drive shaft blade holder can be bend up to the same direction with the drive shaft. This will reduce the area space when travel. Hence, this design is convenience to mobile.

This design has many advantages over other methods of hydroelectric power production. For example, it is quiet when operating compared to conventional waterwheel. Besides, the portable idea of this machine has leaded it to be easy to transport and install. Moreover, this design was environmentally friendly. This design was also cost effective while it uses all inexpensive material and also this design does not significantly interrupt the river flow.

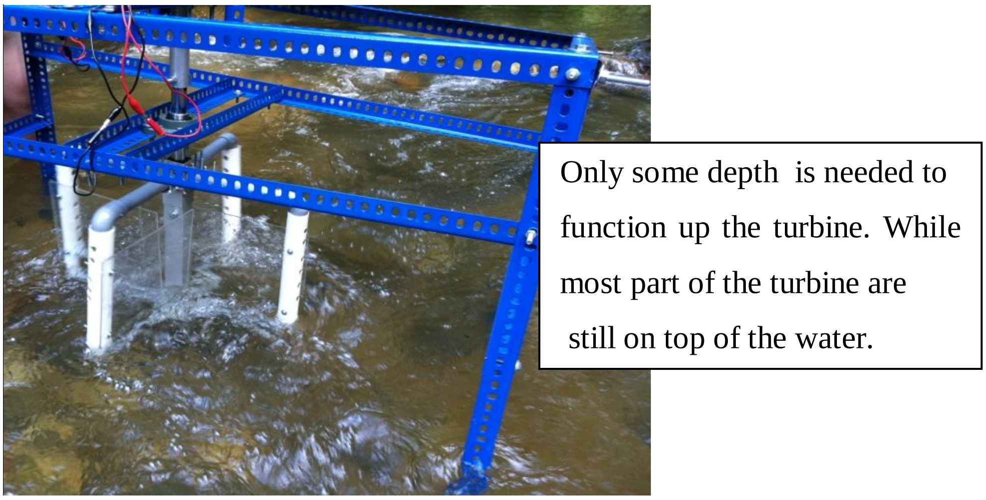


Figure 4.2: New Design on Flowing Water

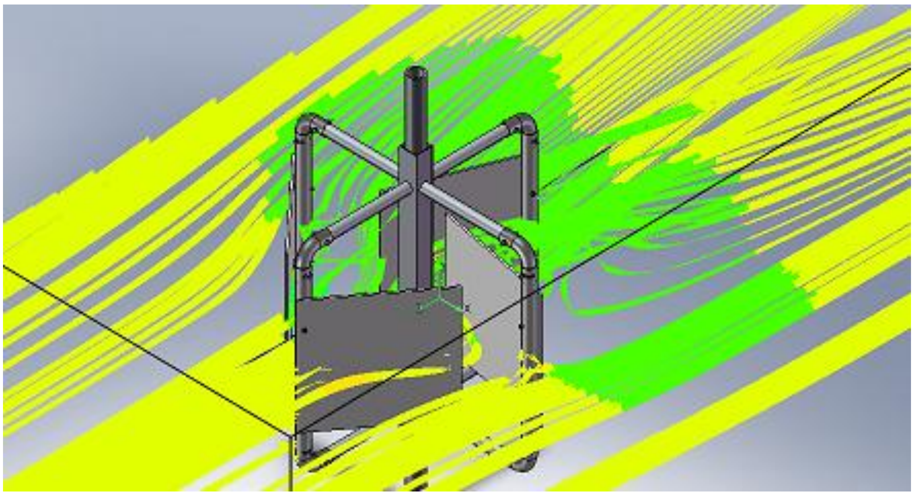


Figure 4.3: Side View of Flexible Blade on The New Design

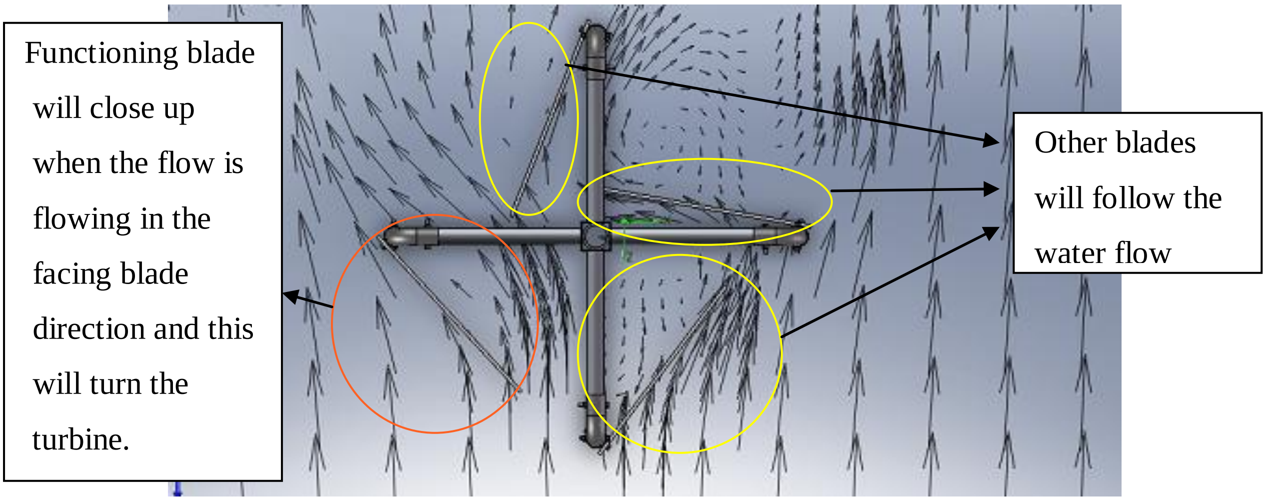


Figure 4.4: Top View of Flexible Blade on The New Design

4.1.2 Equipment and Material Selection for the Design

This section describes the ways author make decision on the materials and equipments. The decision of dimension of the material was make from the pressure simulation analysis. In Figure 4.5 stated some of the material selected by the author and Figure 4.6 shows the pressure simulation analysis.

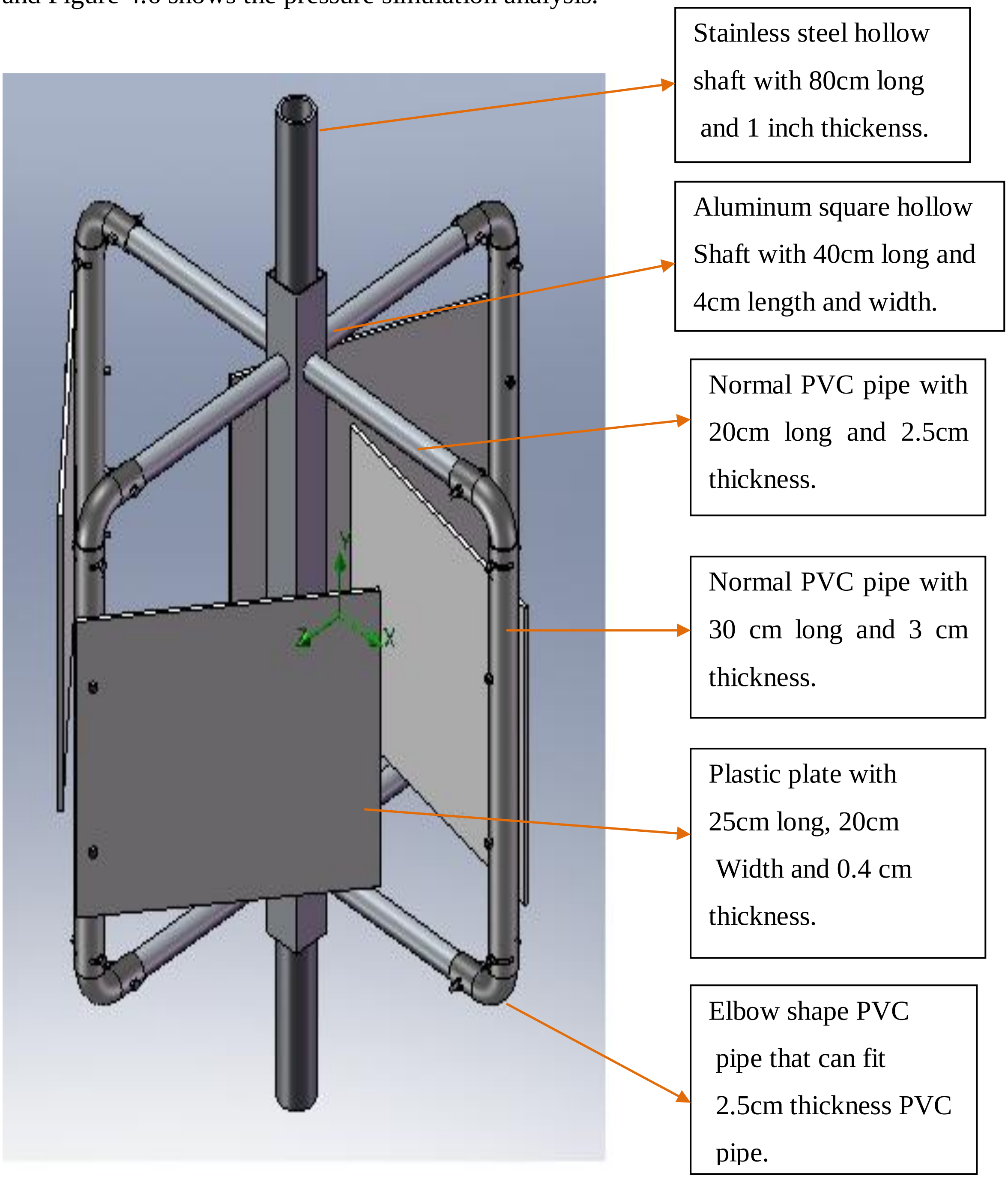


Figure 4.5: New Design Micro Hydro Power Plant Turbine with Selected Material

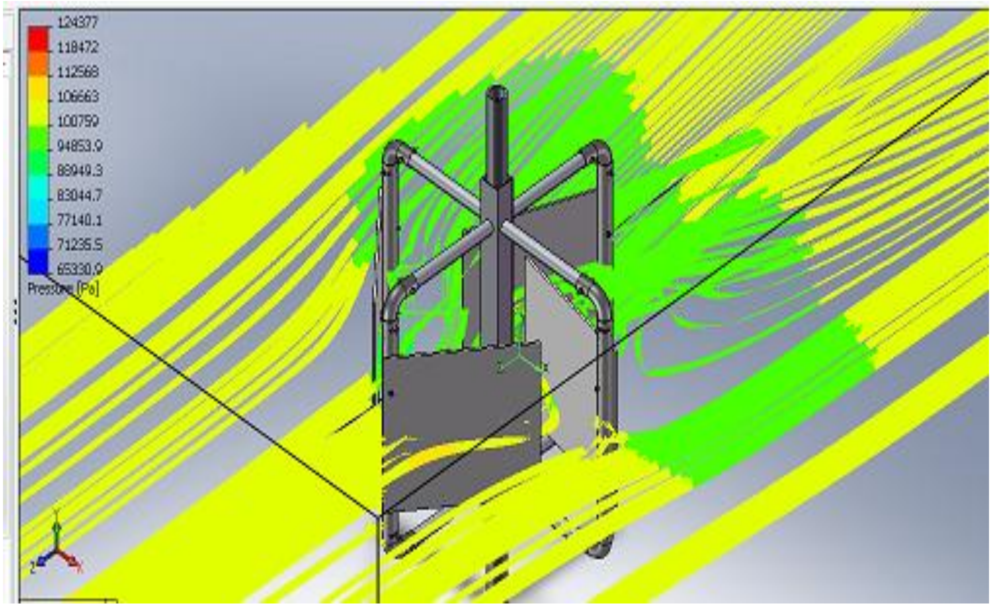


Figure 4.6: Software Pressure Flow Analysis

The software pressure flow analysis shows that the flow rate was reduced when it crossed the turbine as indicate in green colour. However, the flow rate was higher when the flow does not touch the turbine as indicate in the Figure 4.6. According to the energy conservation law, the energy can neither be created nor destroyed: it can only be transformed from one state to another. Hence from the analysis in Figure 4.6, the energy of the water flow reduce when cross over the turbine and this caused a pressure impact on the turbine increase. Consequently, the turbine can turn. Hence, the material that selected for this part has to suit the equipment, so that the turbine can sustain the flow and work well.

Firstly, the drive shaft is the main support and carries the blades of the new design turbine. Hence, it is an importance part. A stainless steel hollow shaft was chosen by the author because this material is lighter in weight as it is hollow if compare with a non-hollow shaft. Besides, a stainless steel material was chosen by the author because this material will not out of shape and can sustain a high pressure head flow. Moreover, this kind of material will not rust if compare with a steel material that will rust very fast if contact with water and this will cause the failure for the micro hydro power plant to generate electricity. Besides, a square aluminium hollow shaft was added to hold all the 4 blade of the turbine. This material was chosen because it is light in weight and prevents rust when contact with water, but this material was not able to sustain a high head flow like the stainless steel. However, when this material is joining together with the stainless steel, it will be able to sustain a high head flow.

Second, the turbine blades will be the part that contacts the most with the water so that it can provide a reaction to generate electricity. All plastic material was chosen so that avoiding too much additional weight as they would in turn increase their inertia. All these parts were joined together with bolt, nuts and also washer. The screw pick will be according to the hardness and strength analysis that apply when water flow head hit on it. The bigger force the turbine sustains the bigger screw the area will need. But for other places, the author will pick the screws to as small as possible to reduce the weight.

Third is the supporting framework, this part will fully depend on the turbine and the environment itself. A wider river will need a longer and bigger support to carry the turbine.. During the building process, a bigger bolt, nut and washer will be preferred to provide a better and stronger support.

4.1.3 Troubleshooting on the Design

When first the author implements the new design into the water and the author found that the turbine is hardly move due to few problems.

The first was the material selection that causes a heavy weight, the blade holder down PVC pipe which is submarine in the water has trap a lot of water inside it and this indirectly has increase the weight of the turbine where it has to bring along the water to go round with the turbine. This has increase the inertia force. This is different from the simulation; the water will not go into the pipe in the software simulation. Hence the author drill holes at the water submarine pipe to reduce the weight of the turbine. This has indicated in the previous Figure 3.15. Besides, the generator of the new design is giving a non-constant output voltage. This has influence the output reading. To solve this problem, the author has change the generator to a more stable generator as in Figure 3.16.

The second problem arises on the alignment problem as indicate in the Figure 4.7. This problem arises when the head of the flow is too high where only one bearing design was unable to sustain the high head flow. Hence this problem has been solved by the author with adding an extra bearing into the design to support the structure. Besides, the gear system has been removed and replace with the direct coupling system to solve this problem as well like indicate in the Figure 3.17. Hence, all these improvement has result in the new prototype as indicated in Figure 3.18. The new prototype will have a lighter weight and small inertia. Besides, it also has a better alignment that can run smoother in the testing.

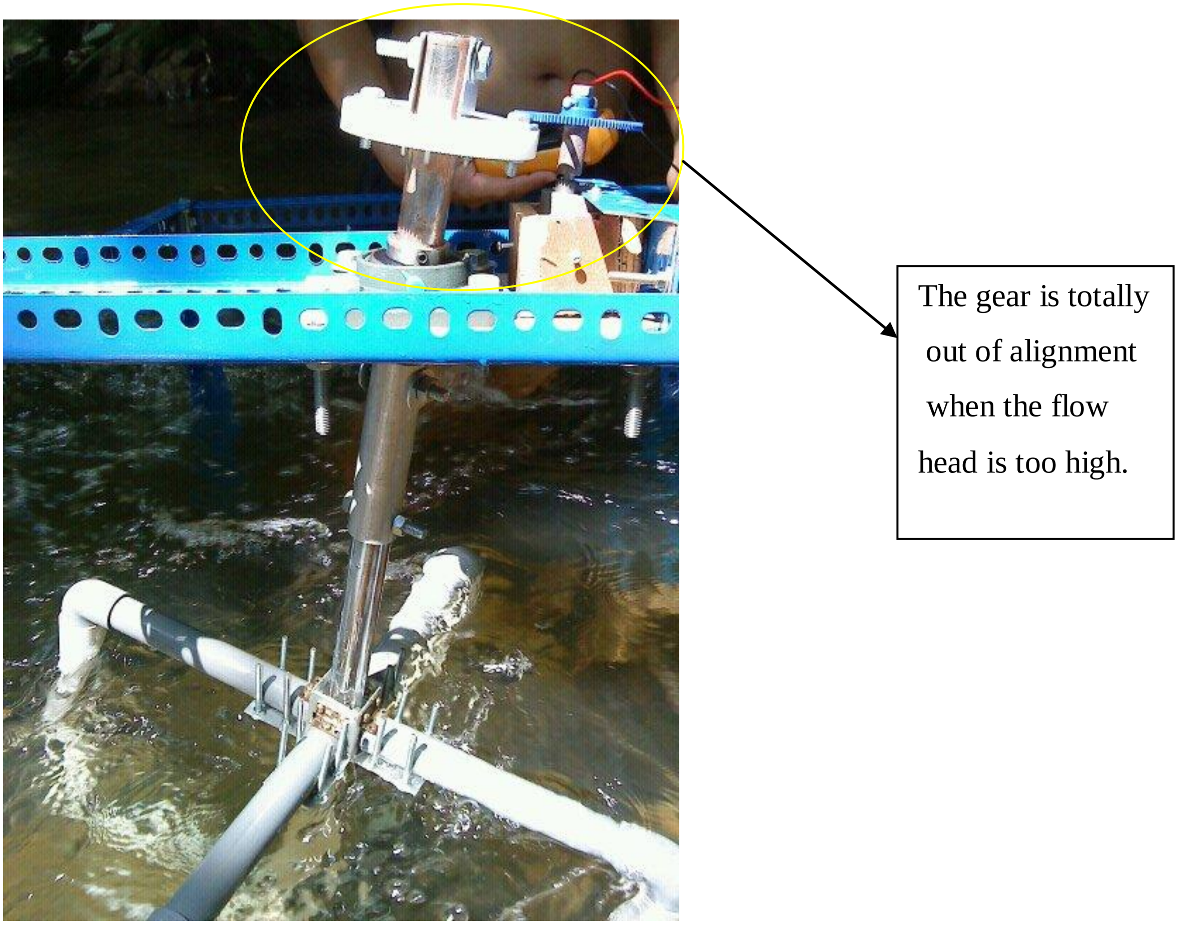


Figure 4.7: Bad Alignment of The First Prototype

4.1.4 Improved Design

The improvement of the prototype was highly increased the efficiency of the first prototype. The first prototype always faces the alignment problem very seriously where the turbine was only able to turn for a few rounds in a simple testing with water jet spray on it. After that, the turbine was out off its alignment. This problem is solved in the improved prototype. Besides, the weight of the first prototype was heavier and holes drilling had solved the problem. Hence, the second prototype had highly improved the first prototype.

4.2 Experiment 1 on the New Design: Depth Testing

The new design was put inside a water tank with different dept on the turbine blade for testing as indicated in Figure 3.11, a high pressure water jet is use to test the turbine. The testing method is shows in Figure 4.8. Table 4.1 will show the data from 10cm depth of the blade in the water, and table 4.2 will shows the data from 3cm depth of the blade in the water.

Table 4.1: Data of 10cm dept of the blade in the water

Number	Voltage obtained (V)
1.	1.26
2.	1.35
3.	1.29
Average	1.30

Table 4.2: Data of 3cm dept of the blade in the water

Number	Voltage obtained (V)
1	2.04
2	1.99
3	1.98
Average	2.00

Figure 4.8: Water Tank Testing

4.2.1 Discussion on the experiment 1

By comparing the 2 different depths that use for the testing, the author found that the 3cm blade depth in water generate more voltage than the 10cm blade depth. This is because there is more force that the turbine needs to over come on pushing the water when a larger part of turbine blade is inside the water. Hence the 3cm depth gives a larger average voltage of 2.00V than 10cm depth with 1.30V. Besides, the author has found out that the minimum depth that the turbine can function well is 3cm depth inside the water. If the blade was place higher than 3cm, the turbine was not able to function properly. Besides, the author has notice that some energy had lost during the closing of the functioning blade as indicated in Figure 4.9. This is one of the disadvantages of the design. From this test, the author concluded that the lesser the turbine blade inside the water, the higher the efficiency but the maximum was only 3cm depth into the water.

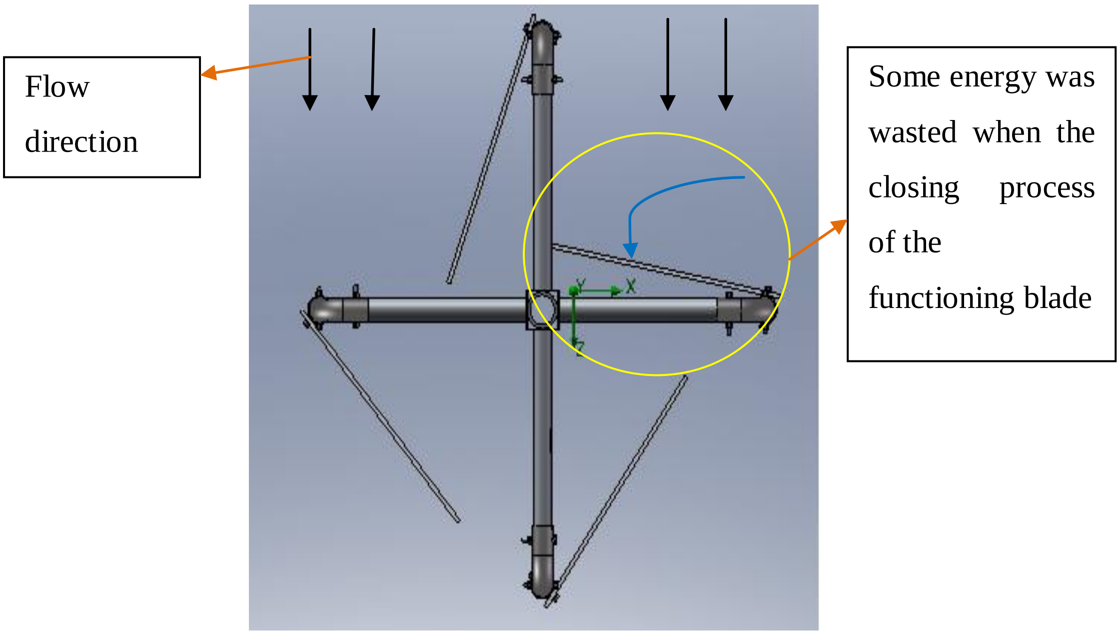


Figure 4.9: Closing Process of the Functioning Blade

4.3 Experiment 2 on the New Turbine: Different Kind of Flow

This test will carried out with different kind of flow on the turbine. Testing was carried out in a river and in a water tank (same procedure with experiment 1 for water tank test). The experiment was carried out with the same depth of blade of 3cm inside the water. The Figure 4.8 will shows the testing method on a tank and Figure 4.11 will shows a testing method in the river. Table 4.3 will showed data from turbine testing in a river and a tank, Figure 4.10 will show the relationship between the two flows.

Table 4.3: Data of testing in a water tank and river

Time (s)	Voltage (V)	
	Tank	River
0	0.00	0.00
0.2	0.02	0.20
0.4	0.20	0.90
0.6	0.50	0.88
0.8	0.70	0.99
1.0	1.20	0.10
1.2	1.50	0.35
1.4	2.04	0.65
1.6	1.99	0.98
1.8	1.98	0.40

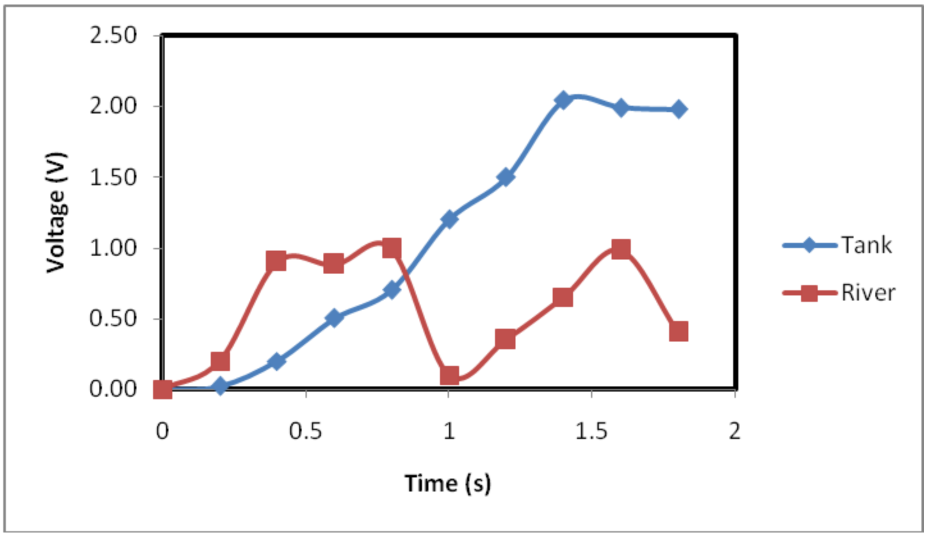


Figure 4.10: Voltage Along Time at Different Flows

Figure 4.11: River Testing

4.3.1 Discussion on the Experiment 2

This experiment shows that the turbine be able to generate electricity in different kind of flows. In a tank, there will be a circular flow as the water will turn insides the tank. However in the river, there will be a horizontal constant flow from the water fall or hill ahead.

There are advantages and disadvantages between these two kinds of flows. The advantage of the turbine in river is that the turbine does not need much inertia force at start to turn the turbine. As indicated in figure 4.10, time taken to reach the maximum voltage gain for horizontal flow is much lesser than the circular flow. While for circular flow, the inertia force is needed to spin the water in the tank. The bigger the force when the tank is bigger hence will result in longer period in reaching the stability state.

Mean while as for the horizontal river flow, the voltage will not be stable. As indicated in figure 4.10, the river flow voltage goes very low due to the unstable turn of the turbine. This was because the area of the non-functioning blade holder when it reached the opposite side of the functioning blade was too big that blocked the flowing water as indicated in figure 4.12. This big area will be an advantage when it is at the functioning blade side that will creating a bigger area to turn the turbine, but it will become a disadvantages when it reached the opposite side of the functioning blade because it will blocked the flowing water and affected the turning of the turbine as indicated in Figure 4.13. On the other hand, this problem did not occur in the circular flow.

Besides, the average voltage had found out with few assumptions. The average voltage has taken from each after constant flow for the tank test. As for the river test, fluctuation was not taken into consideration as only the value from the constant flow taken into consideration. Hence result in Table 4.4 of average voltage for river and tank test.

Table 4.4: Average Voltage in a water tank and river

Number	River	Water Tank
1	0.90	2.04
2	0.88	1.99
3	0.99	1.98
Average	0.92	2.00

Hence form this experiment; the author found out that the new design was able to function in both of the tested flow and they had their advantages and disadvantages and the average voltage for river flow is 0.92V and tank flow is 2.00V with few assumption considered.

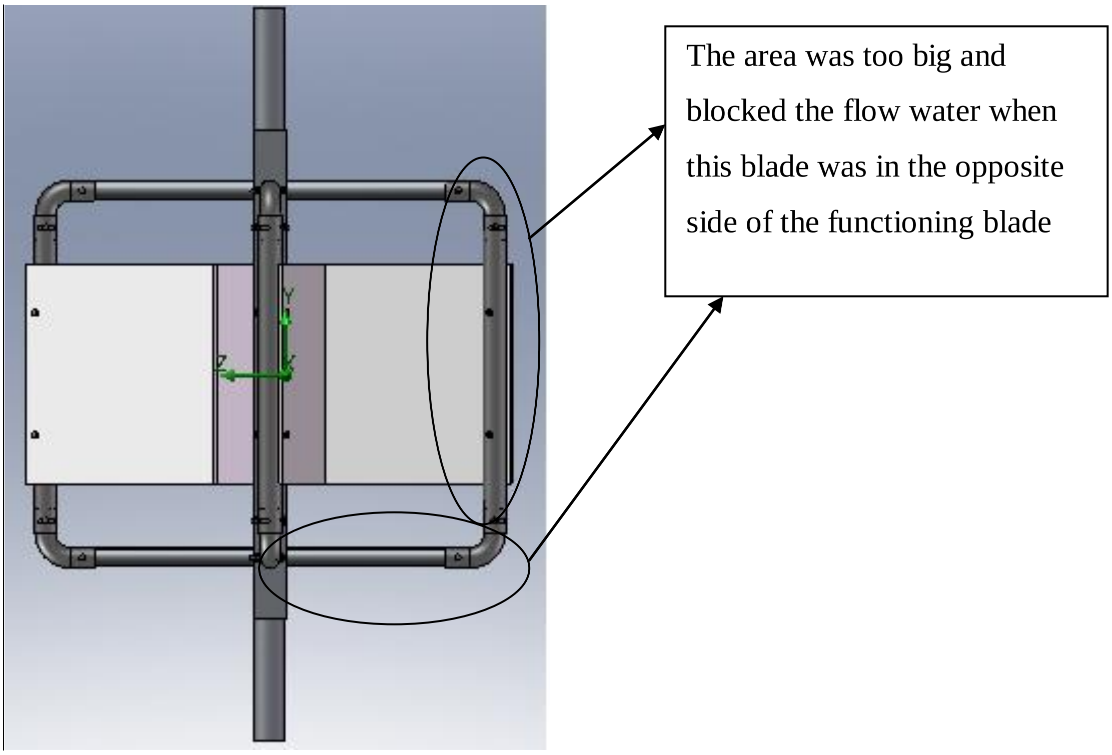


Figure 4.12: Turbine Blade That Block Flow

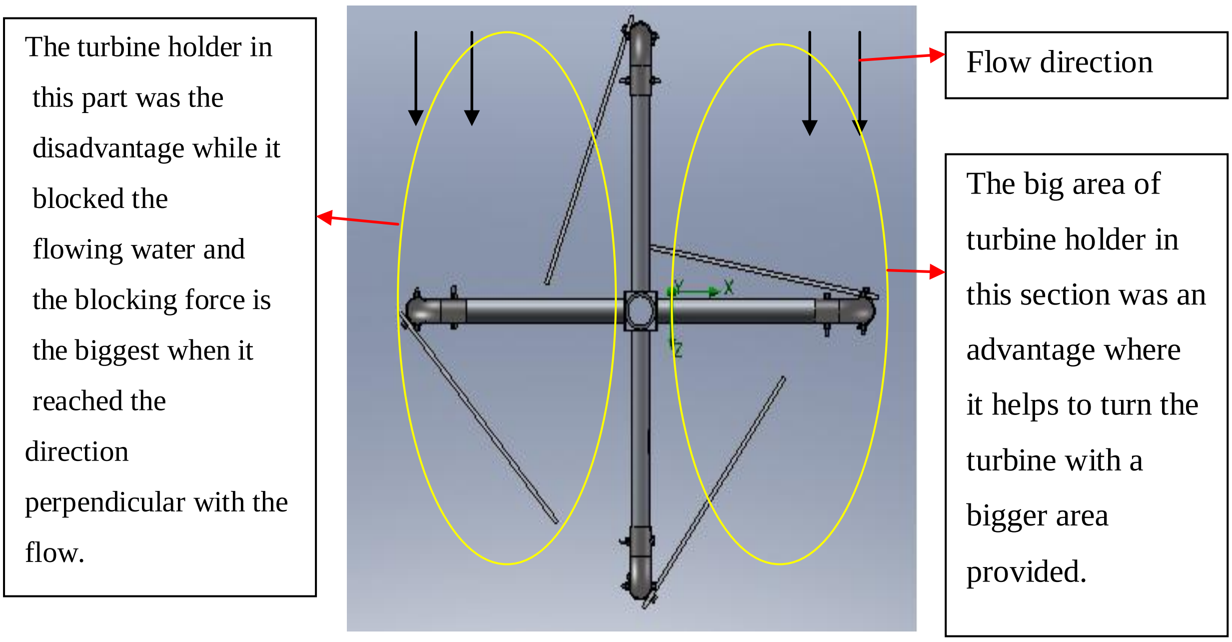


Figure 4.13: Turbine Affection Theory

4.4 Experiment 3 on the New Turbine: Different Medium

This section, the author tested the new design in the different medium. The turbine was tested using with a high pressure water jet spray on the turbine blade which was placed without any contact with water. The experiment was tested with vertical and horizontal placement of turbine as indicated in Figure 4.14 and Figure 4.15 and the result was shown in table 4.5.

Table 4.5: Data of testing in air medium with vertical and horizontal position of turbine,

	Voltage, *V* (V)	
Number	Vertical Test	Horizontal Test
1	5.88	0.08
2	5.79	0.06
3	5.81	0.09
Average	5.83	0.08

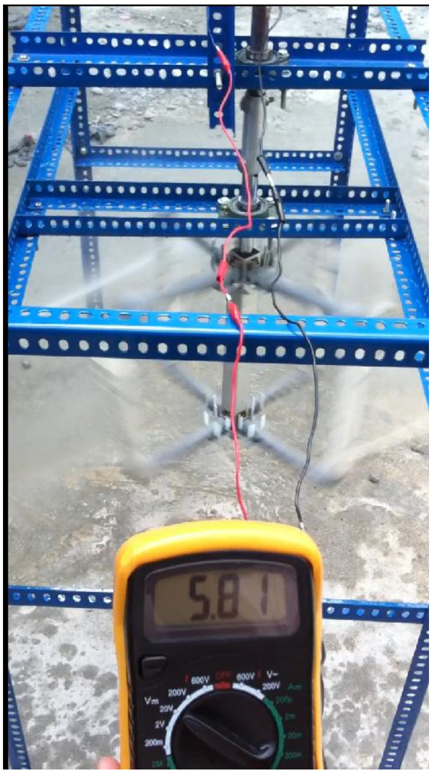


Figure 4.14: Vertical Position Turbine

Figure 4.15: Horizontal Position Turbine

4.4.1 Discussion on the Experiment 3

This test was run out to test the new design in a different medium which is in the air. This test has shows that the new design can function in the air medium vertical position well. There is no force needed to push the water like in the experiment 1. However, the turbine worked not smoothly in the horizontal position.

In the vertical position, the test was carried out with the position of all the blades facing in to the central drive shaft then the water will be spray out to it on the functioning blade. The spraying direction needed to change when the blades swung out. The blades will then all open up facing out of the shaft after few turn. This process has decrease the inertia forces that needed to turn the turbine because with the swinging blade weight had create a swinging force that reduce the inertia turning force of the turbine. Hence, this increased the efficiency.

While in the horizontal position, the test was carried out with the position of all the blades facing down the floor. Then the water will be spray on the function blade. The function blade turned around and face back to the floor after pass through the spraying water. This swinging blade process had benefited the vertical position turbine but not the horizontal position turbine. This swinging force had slow down and interrupts the turbine turning process of the horizontal position turbine. Hence, reduced the efficiency.

Besides, with idea of portable, when running the experiment, the blade has to be fixed tightly to prevent it dropped and disassembled from the turbine.

From this test, the author had found out that the average voltage for the vertical position test was 5.83V and the horizontal test was 0.08V. Hence, vertical position turbine produced higher efficiency than the horizontal position turbine. Besides, this method shows that in different medium, the efficiency of the turbine was different and in air medium the turbine was having the highest efficiency if compare to other medium like water in experiment 2.

4.5 Experiment 4 on the New Turbine: Impedance Matching Test

The impedance matching test was a test that the author applied some loads like resistor to the turbine for testing. This test is to obtain the suitable resistance value that fixed the impedance matching. This test was tested on the most efficiency method (air medium horizontal position of the turbine). Besides, the power was obtain from test in the first section (Table 4.6,4.7,4.8,4.9 and 4.10) as well as the relationship was shown in the graphs in the second section (Table 4.11, 4.12,4.13 and Figure 4.16,4.17,4.18).

4.5.1 Result from load test

- Load = 10 ohms Resistor

Table 4.6: Result computation for 10 ohms Resistor

No.	Voltage, *V* (V)	Current, *I* (mA)
1	0.55	55.00
2	0.60	60.00
3	0.59	59.00
Average	0.58	58.00

Power, P = VI

= (0.58) (58.00m)

= 33.64mW

- Load = 50 ohms Resistor

Table 4.7: Result computation for 50 ohms Resistor

No.	Voltage, *V* (V)	Current, *I* (mA)
1	1.77	35.4
2	1.69	33.8
3	1.73	34.6
Average	1.73	34.6

Power, P = VI

= (1.73)(34.6m)

= 59.85mW

- Load = 100 ohms Resistor

Table 4.8: Result computation for 100 ohms Resistor

No.	Voltage, *V* (V)	Current, *I* (mA)
1	2.31	23.1
2	2.22	22.2
3	2.28	22.8
Average	2.27	22.7

Power, P = VI

= (2.27)(22.7m)

= 51.53mW

- Load = 150 ohms Resistor

Table 4.9: Result computation for 150 ohms Resistor

No.	Voltage, *V* (V)	Current, *I* (mA)
1	2.54	16.9
2	2.59	17.27
3	2.45	16.33
Average	2.53	16.80

Power, P = VI

= (2.53)(16.8m)

= 42.50mW

- Load = 200 ohms Resistor

Table 4.10: Result computation for 200 ohms Resistor

No.	Voltage, *V* (V)	Current, *I* (mA)
1	3.11	15.50
2	2.92	14.60
3	2.82	14.10
Average	2.95	14.80

Power, P=VI

= (2.95)(14.8m)

= 43.66mW

4.5.2 Relationship between the gained results

- Voltage and Resistance Value

Table 4.11: Voltage and Resistance Value

Resistor, *R* (Ohms)	Voltage, *V* (V)
10	0.58
50	1.73
100	2.27
150	2.53
200	2.95

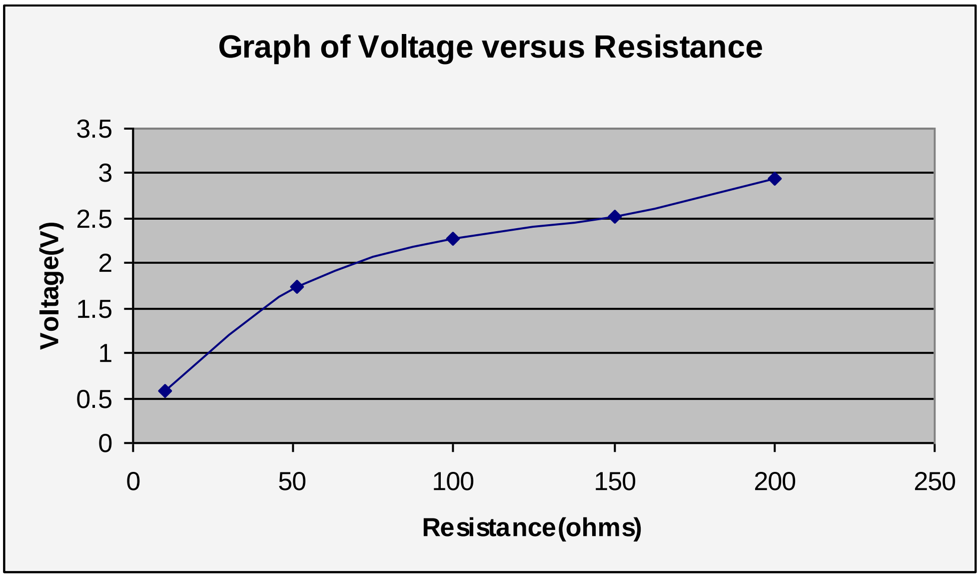


Figure 4.16: Graph of Voltage versus Resistance

- Current and resistance value

Table 4.12: Current and Resistance Value

Resistor, *R* (Ohms)	Current, *I* (mA)
10	58.0
50	24.6
100	22.7
150	16.8
200	14.8

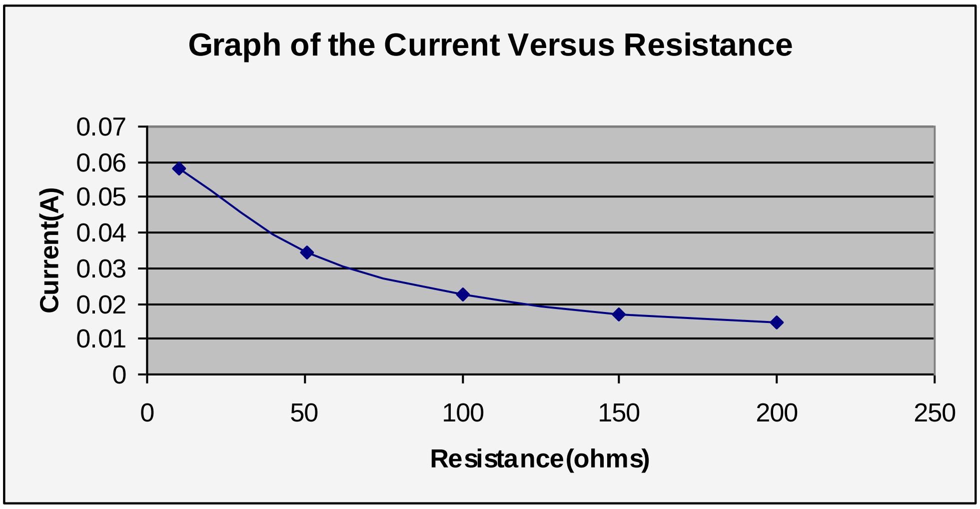


Figure 4.17: Graph of Current versus Resistance

- Power and resistor value

Table 4.13: Power and Resistance Value

Resistor, *R* (Ohms)	Power, *P* (mW)
10	22.64
50	59.85
100	51.53
150	42.50
200	43.66

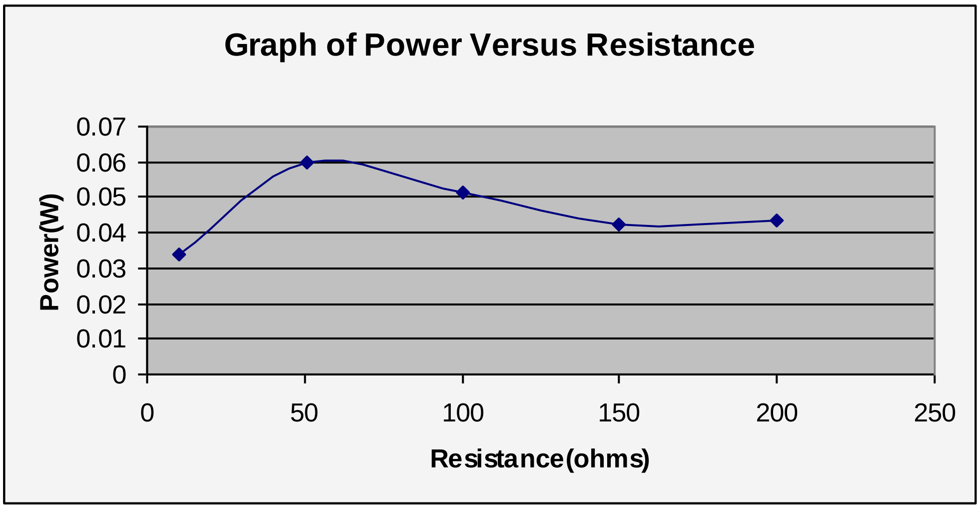


Figure 4.18: Graph of Power versus Resistance

4.5.3 Discussion on experiment 4

From the figure 4.16, the graph Voltage versus Resistance, the author observes that the voltage is increasing when the resistance value is increasing but not with a constant straight line. In theoretical, the graph should be linear according to Ohms law; Equation 4.1. This might cause by the unstable rotating during the test. The author observed that the whole system was vibrating (only little vibration) and this will affect the turning of the turbine and hence resulted in this section. Besides, the friction from the bearing was not the same because the friction became bigger with turning. The lubricant inside the bearing became lesser and different amount was added into it.

Form the Figure 4.17, the graph of the Current versus Resistance; the author observes that the current value decreased with increased resistance value. According to Ohm law the relation between current and resistance was inversed. The shape of the graph was smooth and only small amount of significant change and this was cause by the same problem as discuss about by the voltage versus resistance relationship.

The power has an equation as indicate in equation 4.2. According to the experiment, the highest output was 59.85mW with 50 ohm resistor. The non consistence of the value from this part was caused by the turning vibration effect.

$$V=IR \tag{4.1}$$

where
V= Voltage , V
I= current, A
R= resistance, Ω

$$P = IV \tag{4.2}$$

P= Power, W
I=current, A
V=voltage, V

4.6 Efficiency Calculation

The efficiency can be calculated by the equation 4.3

$$\eta = P_{out} / P_{in} * 100\% \tag{4.3}$$

where
η = efficiency, %
P_{out} = output power; W
P_{in} = input power; W

The input power can calculated from the formula as below:

Power input = Head x Flow x Gravity (4.4)

where

Power input = power input; W

Head = head of water; m

Flow = input flow rate; l/s

Gravity = gravitational force; m/s*s

For this experiment, the author is using a high pressure water jet that has it flow rate stated by the manufacturer. This value was 340 l/h, and this is equal to 0.94444 l/s. the head in this experiment was defined as 0.2m and gravity was 9.81 m/s*s.

With the equation 4.2, power input was calculated as 0.1853 W.

Power input = (0.2) x (0.09444) x (9.81)
= 0.1853 W

For power output is 59.85mW which is the highest power value achieved in the experiment 4

Efficiency = (59.85m/0.1853) x 100%
= 32.30%

Hence, the efficiency for the new turbine is 32.30% as tested in the vertical position of the turbine place in the air medium.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Overall Conclusion

The objective of this project was achieved. A new cost effective micro hydropower prototype which was able to generate electricity for basic use is built. With the unique design of this hydropower turbine, it is able to generate electricity in different kind of places; the most effective generation was the vertical position of the turbine in air medium. The merit of this design is the flexible blade as the non-functioning blades will follow the flow of the water or air, thus increasing the efficiency of the machine.

Beside, with the portable idea of this turbine, it was able to mobile to different places for electricity generation as this point brings convenience to the user. When finish using, the blade can be depart from the turbine as the perpendicular to the drive shaft blade holder can be bend up to the same direction with the drive shaft as shows in figure 5.1. This will reduce the area space when travel. Hence, this design is convenience to mobile.

This design has many advantages over other methods of hydroelectric power production. For example, it is quiet when operating compared to conventional waterwheel. Besides, the portable idea of this machine has leaded it to be easy to transport and install. Moreover, this design is environmentally friendly. This design is also cost effective while it uses all inexpensive material and also this design does not significantly interrupt the river flow.

Figure 5.1: Portable Turbine

Besides this, through the involvement on this project. The author had realized the importance of green energy that deal with the environment impact issues of the world today. Micro hydropower project also able to open new markets related to the marginal hydro potential and improve the rehabilitation on the hydropower research for further development.

5.2 Project Achievement

The new design of the author has efficiency of 32.30% overall. With this new idea, user will be able to mobile to different hydro places to generate electricity. Besides, the most importance point of this idea was eco-friendly usage with no environment harmful item produced.

5.3 Recommendation and Future Work

There are advantages and disadvantages of the author new design that affect the efficiency of the electricity generation. There are few recommendations that can improve to this design:

- A smaller dimension of turbine blade holder that can increase the efficiency. While this will decrease the blocking force from the river flow when this design is apply to river to generate electricity.
- A suitable thickness of aluminium blades can be replace by the plastic blade because it easy to create a more suitable degree of angle blade to increase the efficiency.

Besides, with the improvement, this design will perform better. Recommendation on application like this micro deigns will possibility is able to replace the big dam needed hydropower design after some adjustment of design. With many of this designs place across the flowing river, it will be able to generate electricity and do not need a dam. Hence, it is more eco-friendly to the nature. Besides, it also will be able to help some rural area citizen to generate light in the dark.

REFERENCES

Baumann, S., Beatty, C., Brownell, S., Constant, A., Coons, J., Fisher, D., Lazar, B., & Yonkelowitz. W. (2010). Intermediate Energy Infobook. Rockford, MI: Need, National Energy Education Development.

Bockman, T., Fleten, S. E., Juluissen, E., Langhammer, H. J., & Revdal, I. (2007). Investment Timing and Optimal Capacity Choice for Small Hydropower Project. European Journal of Operational Research 190 , 255-267.

Hydroelectric Power. (July 2005). U.S. Department of the Inrerior Bureau of Reclamation Power Resources Office.

Hydropower Energy Technologies Worldwide. (October 2009). Large, Small, Mini,micro and pico. report linker, SBI. Retrieved August 29, 2010 from http://www.reportlinker.com/p0154015/Hydropower-Energy-Technologies-Worldwide-Large-Small-Mini-Micro-and-Pico.html.

John, S., & Anagnostopoulos, A. D. (2007). Flow Modeling and Runner Design Optimization in turgo Water Turbines. World Academy of Science, Engineering and Technology .

Jones, Z. (2005). Domestic electricity generation using waterwheel on moored barge. Meng in Structural Engineering with International Studies .

Madamombe, I. (2005). Energy key to Africa's prosperity,Challenges in West Africa's quest for electricity. Africa Renewal.

Micro-Hydropower System; A Buyer's Guide. (2004). Canada: Natural Resources Canada.

Mohibullah, Hakim, M. A., & Abdul, M. I. (2004). Basic Design Aspects of Micro Hydro Power Plant. Nationai Power & Energy Conference (PECon) 2004 Proceedings, Kuala Lumpur, Malaysia , 220.

Norman, J. (2003). welcome to the world of hydropower. Retrieved September 6, 2010, from http://www.tande.com.tw/rn-hydro/alaskan.pdf.

Rasi, D. a. (2008). On the use of a laboratory-scale Pelton wheel turbine in renewable energy education. Renewable Energy , 1517-1522.

Saket, D. R. (2008). Design, Development and Reliability Evaluation of Micro Hydro Power Generation System Based on Municipal Waste Water. IEEE Electrical Power & Energy Conference , 1-2.

Sale et al, M. J. (2008). Status of the U.S. Department of Energy's. U.S. Department of Energy (DOE).

Stiesdal, H. (1999). The wind turbine components and operation. IEEE Transactions on Energy Conversion .

The Star. (June 4, 2010). Hydropower more cost-effective than coal-fired plant, says Utar study. Kota kinabalu: The Star.

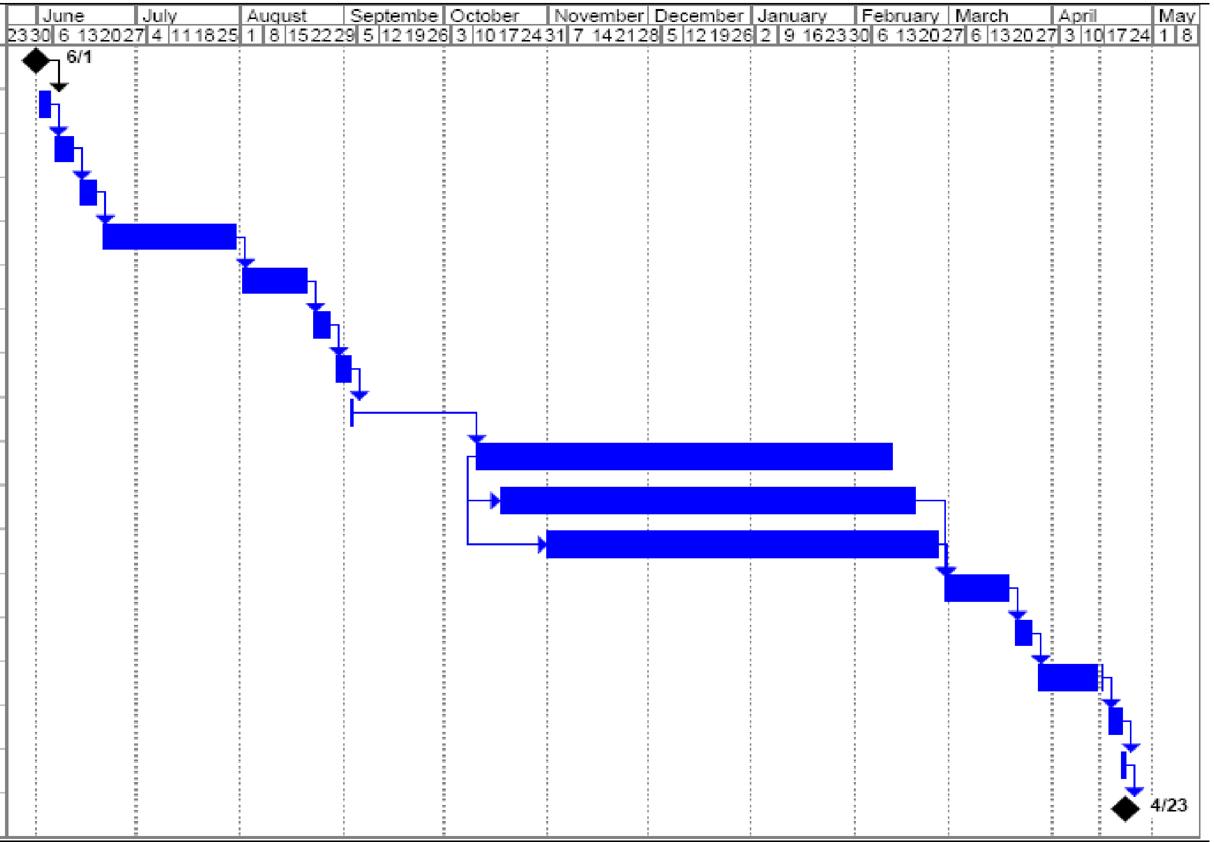
Types of Hydropower Turbines. (2005). Retrieved July 2, 2010, from U.S Department of Energy, Energy Efficiency and Renewable Energy .

APPENDICES

APPENDIX A: Gantt Chart

Universiti Tunku Abdul Rahman
Faculty of Engineering & Science
Department of Mechatronics Engineering
Final Year Project
Project Schedule

ID	Task Name	% Complete
1	Start	100%
2	Understanding of Title	100%
3	Research Related Information	100%
4	Introduction	100%
5	Literature Review	100%
6	Methodology	100%
7	Report 1	100%
8	Power Point Slide 1	100%
9	Presentation 1	100%
10	Design Module	100%
11	Module Build Up	100%
12	Experiment	100%
13	Result & Discussion	100%
14	Conclusion	100%
15	Report 2	100%
16	Power Point 2	100%
17	Prototype Presentation	100%
18	Finish	100%



Date: Sun 04/10/11

Task		Milestone		External Tasks	
Split		Summary		External MileTask	
Progress		Project Summary		Split	

Title: Prototype of an Efficient Hydropower Plant

Reported by:
Ong Chian Shen

Date: 10th April 2011

APPENDIX B: Generator Specification

SPG30 Series

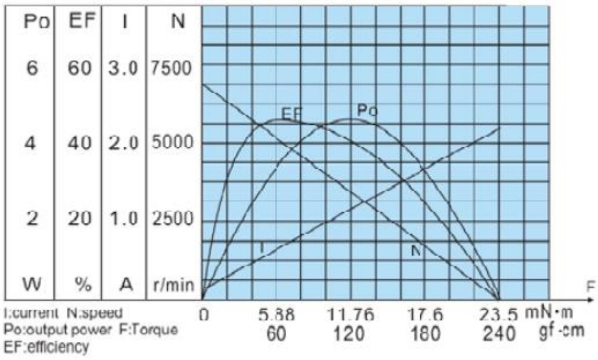
Cytron Technologies

Output Power: 1.1W

Weight: ~160g

Typical applications: Labal printers, auto shutter, welding machines, water meter IC card, grill, oven, cleaning machine, garbage disposers, household appliances, slot machines, money detector, automatic actuator, coffee machine, towel disposal, lighting, coin refund devices, peristaltic pump.

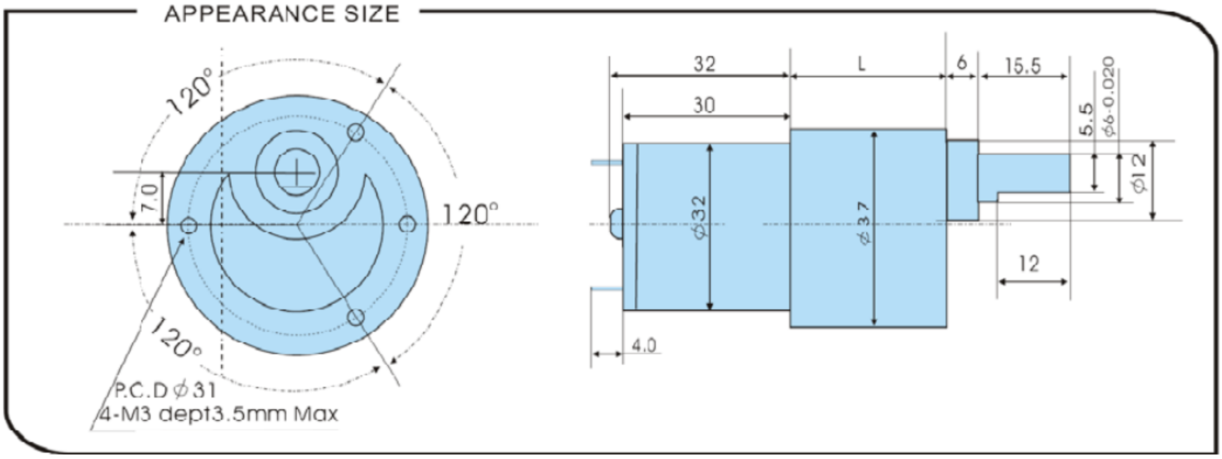
MOTOR CHARACTERISTICS



MOTORTORQUE/SPEED/CURRENT

Rated voltage	12VDC
No load speed	7000r/min
No load current	70mA
Rated torque	60gf·cm 5.88mN·m
Rated current	410mA
Rated speed	5200r/min
Stall torque	240gf·cm 23.5mN·m
Stall current	1.8A

APPEARANCE SIZE



Order Option							
Order Code	Input Voltage	Rated		Weight (g)	Power (w)	Diameter (mm)	L (mm)
		Speed (RPM)	Torque (mN.m)				
SPG10-30K	6	440	29.4	10	-	12	24
SPG10-150K	6	85	107.9	10	-	12	24
SPG10-298K	6	45	176.5	10	-	12	24
SPG20-50K	12	130	58.8	60	0.6	27.2	-
SPG30-20K	12	185	78.4	160	1.1	37	22
SPG30-30K	12	103	127.4	160	1.1	37	22
SPG30-60K	12	58	254.8	160	1.1	37	25
SPG30-150K	12	26	588	160	1.1	37	27
SPG30-200K	12	17	784	160	1.1	37	27
SPG30-300K	12	12	1176	160	1.1	37	27
SPG50-20K	12	170	196	300	3.4	37	23
SPG50-60K	12	56	588	300	3.4	37	26
SPG50-100K	12	34	980	300	3.4	37	26
SPG50-180K	12	17	1960	300	3.4	37	28