DESIGN AND DEVELOPMENT OF CROSS FLOW DELTA-WING WATER TURBINE FOR PAHANG RIVER

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Report submitted to the Department of Mechanical Engineering
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I certify that the thesis entitled "Design and Development of Cross Flow Delta-Wing Water Turbine for Pahang River" is written by Mohd Izzat b Kamarulzaman. I have examined the final copy of this thesis and in my opinion; it is fully adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering and Automotive. I am here with recommend that it be accepted in partial fulfillment of the requirements for the degree of Bachelor of Mechanical Engineering and Automotive.

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I hereby declare that I have checked this project and in my opinion, this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

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STUDENT'S DECLARATION

I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

Signature

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Dedicated to my beloved parents and friends

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ABSTARCT

This thesis presents the designing and developing of cross flow delta-wing water turbine for Pahang River. Cross flow turbine is a hydroelectric power source that is clean, renewable and low in manufacturing cost. Through the analysis of the water flow rates and head will obtained the most suitable type of water turbine system for the Pahang River. The main problem is to choose the best water turbine system suitable for flow rate and water source of Pahang River. Other than that, designing the most suitable propeller for the turbine is the main criteria to be taken in this research. River is a natural water source that has unpredictable water flow rates depends on the weather condition. The analysis and investigation of the propeller is to obtain the velocity streamline and pressure of different blade angle from different water velocities. The CFD simulations results of the different blade angles of the propeller are compared to obtain the best propeller design. The final propeller model is then fabricated using appropriate materials and technique.

ABSTRAK

Tesis ini adalah mengenai proses merekabentuk dan menghasilkan turbin air berasaskan aliran air Sungai Pahang. Turbin air ini menggunakan arus air sungai mengalir untuk menjana kuasa hidroelektrik yang bersih, tiada pencemaran, dan rendah kos pembikinannya. Proses penyelidikan tentang arus dan kedalaman air Sungai Pahang adalah untuk mengenal pasti jenis turbin yang paling sesuai untuk digunakan di kawasan ini. Masalah utama projek ini adalah untuk memilih jenis turbin yang bersesuaian dengan arus dan sumber air dari Sungai Pahang. Selain itu, kriteria utama penyelidikan ini adalah merekabentuk bilah kipas turbin yang paling sesuai. Sungai merupakan sumber air semula jadi yang mempunyai arus di luar ramalan bergantung kepada keadaan cuaca. Kajian dan penyelidikan dibuat ke atas bilah kipas turbin dengan berbeza sudut bilah dan halaju air sungai adalah untuk mengenal pasti arah aliran air dan tekanan yang dikenakan oleh air tersbut terhadap permukaan kawasan bilah kipas. Keputusan simulasi CFD untuk sudut bilah yang berbeza dibandingkan untuk memilih jenis bilah kipas yang paling berkesan. Model bilah kipas yang muktamad kemudian dihasilkan dengan menggunakan bahan dan teknik yang bersesuaian.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

CFD	Computational Fluid Dynamics
TEC	Tidal Energy Converter
DNA	Dynamic Network Analysis
GHT	Gorlov Helical Turbine
DC	Direct Current
AC	Alternating Current
MIG	Metal Inert Gas
PVC	Polyvinyl Chloride

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

This project is about designing and developing the cross flow delta-wing water turbine for Pahang River. This project deal with designing, fabricating the model and analyse it using CFD software.

1.2 PROJECT BACKGROUND

Water turbine is a machine that rotates and generates energy from moving water. This concept is known as the hydroelectric power. Hydroelectric power usually created from the large hydroelectric dam and it is one of the source that is mainly been used by many country to supply the electricity. But this power supply is not enough to provide the electricity outside of its region. The cross flow water turbine is another option to generate hydroelectric power without using any dam. This smaller type of turbine can be used to support electricity to the small village outside the power region by using the river flow or stream.

This project focuses on developing a cross flow water turbine that suitable to generate power from the tidal flow. This simpler design of turbine consists of a floating housing with nozzle that will inject the water to the propeller. There are basically many types of water turbine. The major styles are such as the impulse turbine, reaction turbine and submersible propeller turbine that each is ideally suited for different type of water supply. The various types of turbine are designed for different suitability depends on the water head and water flow rate at specific location.

1.3 PROBLEM STATEMENT

Most of the river in Malaysia had low water head. The flow rate depends on the depth and width of the river and the velocity are different in each sectional area of the river. The main problem for this research is to choose the best water turbine system that suits the flow rate and the water source of the Pahang River. Since there is many types of hydro turbines that can be used to produce electricity, there must be some advantages and disadvantages of each design and the best system need to be chosen to suits the water source from the river.

The other problem is to design a suitable propeller for the turbine. For the suitability of the turbine, some consideration must be taken such as the propeller type, the angle of attack of the propeller blades, number of blades for the propeller, and the material type of the propeller to get its best performance.

River is a natural water source that has unpredictable water flow rates that depends on the weather and head of water. The propeller should be tested in different weather conditions with various water velocities to consider the performance of the turbine.

1.4 OBJECTIVE

- To design and analyse of cross flow delta wing water turbine that suitable for Pahang River.
- Fabricating the designed model with suitable materials.

1.5 SCOPE OF PROJECT

The scope of this project is to study the Pahang River and discuss the river flow rate and design the suitable cross flow turbine based on the data obtained.

The literature review is about finding detail information about turbine blade and turbine system. The turbine blade will be rotating driven by a potential energy produced by the water flow rate. The rotations will directly rotating a gear that attached beside the propeller. The gear will then rotate the alternator or generator which directly will produces electricity.

In the modelling work, all parts in the water turbine system have been done using SolidWorks 2010. But there are focusing on propeller blade, the number of blades for the propeller, the angle of the blades, and the materials for the propeller design. The generators or alternators are not to be done since it is a mechanical part that could be obtained as a part to generate electricity.

Then, the designed propeller is analysed with CFD software to observe the water movement inside the turbine. The analysis is to determine the most suitable design of the propeller. The chosen design is then fabricated using appropriate materials and technique.

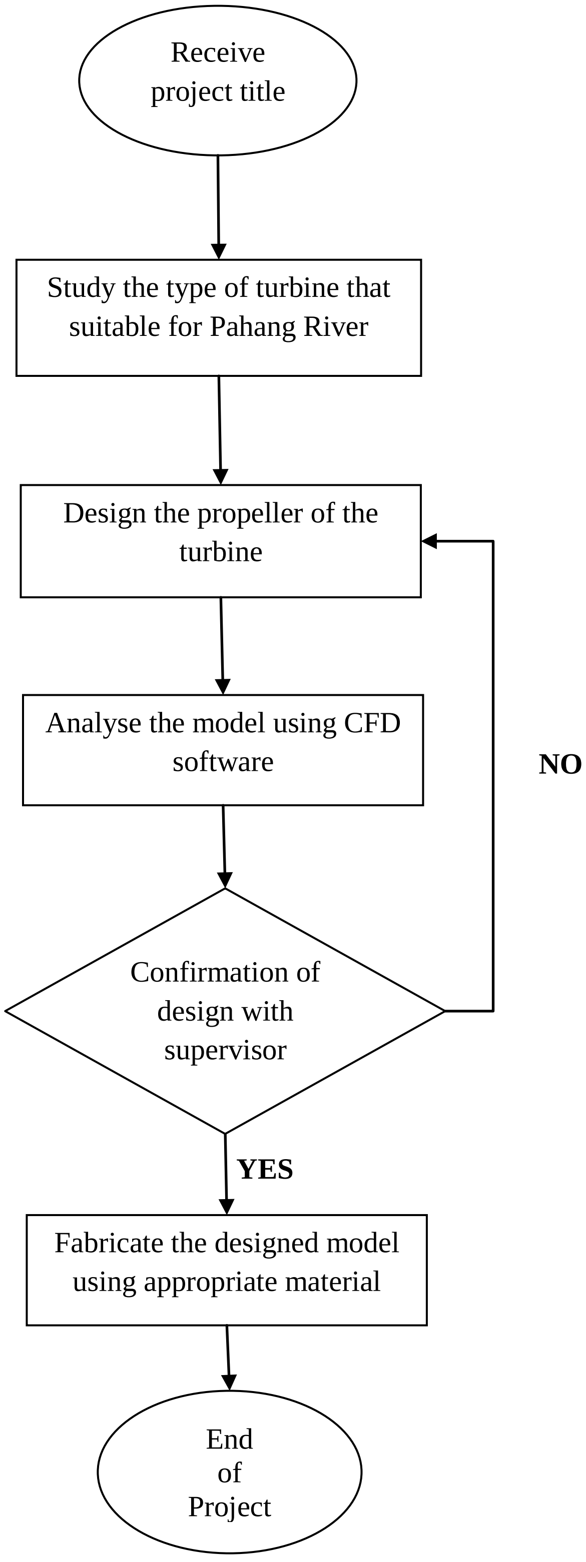


Figure 1.1: Flow Chart of the project

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Fossil fuels exhaustion and greenhouse gas emissions problems have to be settled for civilized life of descendants on the earth. One solution of these problems is hydropower utilization as renewable energy.

Hydropower is well-known as having the highest cost advantages, which is expressed as a ratio of cost to generated power, but known as the environmental destroyer for dam construction. As the result, hydropower stations for large power >100 kW have been already developed or stopped planning for construction, especially in Japan. The hydropower plant can be classified according to the electrical power size it produces as shown in the Table 2.1 below. Because of the high electricity demand for industry and household, the hydropower plant requires to produce as much power as possible to fulfil the demand. And as a result, most of the hydropower available nowadays is large hydropower class category.

Micro-hydropower is generally called for Power, $P < 100$ kW and often nano and pico-hydropower for $P < 10$ kW, and < 1 kW, respectively. The current development is oriented to river flow type, not dam type for micro-power. In micro-hydropower range, high head sites are in country-area with so low pollution that the generated power has to be transmitted to the consuming place with loss, and the appropriate places are not so many.

Table 2.1: Type of hydropower turbine

Power	Class of hydropower
> 10 MW	Large
< 10 MW	Small
< 1 MW	Mini
< 100 kW	Micro
< 5 kW	Pico

A large hydropower plant is build with large reservoir or dam that can lead to environmental damages and remove people from their roots as experienced in the development of Three Gorges Dam in China. This type of plant also has disadvantage which is the capacity of the power produced will reduces after certain amount of years due to sedimentation built-up. This leads most experts to agree that hydropower of more than 1 MW cannot be considered as renewable.

On the other hand, low head sites are in open field near urban area of consuming much electricity and lots of appropriate places are found for power generation. For developing micro-hydropower, low head sites should be considered and therefore focused. And on account of low head in this case, the increase of generating power depends on taking lots of flow rate into the turbine.

Recently, small hydropower attracts attention because of its clean, renewable and abundant energy resources to develop. However, suitable turbine type is not determined yet in the range of small hydropower and it is necessary to study for the effective turbine type.

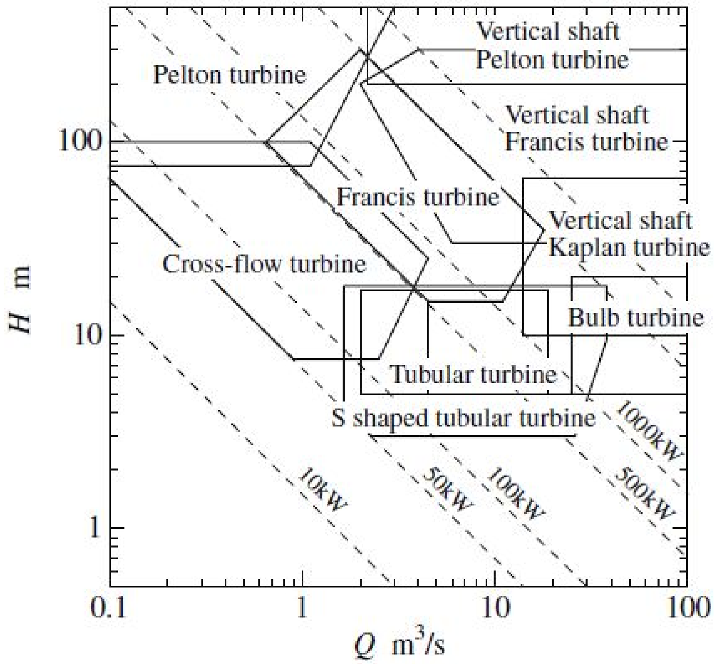


Figure 2.1: Selection chart of appropriate turbines.
H = head, *Q* = water flow rate.

Source: A. Furukawa et al. / Current Applied Physics (2010)

Moreover, relatively high manufacturing cost by the complex structure of the turbine is the highest barrier for developing the small hydropower turbine. Therefore, a cross-flow turbine is adopted because of its simple structure and high possibility of applying to small hydropower. This system also does not require dam, which is one of its advantages, meaning no environmental problem.

One of the most basic features of the cross-flow turbine is the simplicity of its constructions. The turbine is based on concepts from both impulse and reaction turbine designs, but in general it uses impulse behaviour. It uses run-of-river application method through penstock to provide the necessary head and flow rate to the turbine. This feature allows adaptability and flexibility to a variety of liquid, places, applications and power needs. The simplicity in the design reduces cost and makes it very suitable for small power development. This type of turbines has several advantages, but the design and the prediction of their hydrodynamic behaviour are more complex.

Hydroelectric power, using the potential energy of rivers, now supplies 17.5% of the world's electricity (99% in Norway, 57% in Canada, 55% in Switzerland, 40% in Sweden, 7% in USA). Apart from a few countries with an abundance of it, hydro capacity is normally applied to peak-load demand, because it is so readily stopped and started. It is not a major option for the future in the developed countries because most major sites in these countries having potential for harnessing gravity in this way are either being exploited already or are unavailable for other reasons such as environmental considerations. Growth to 2030 is expected mostly in China and Latin America.

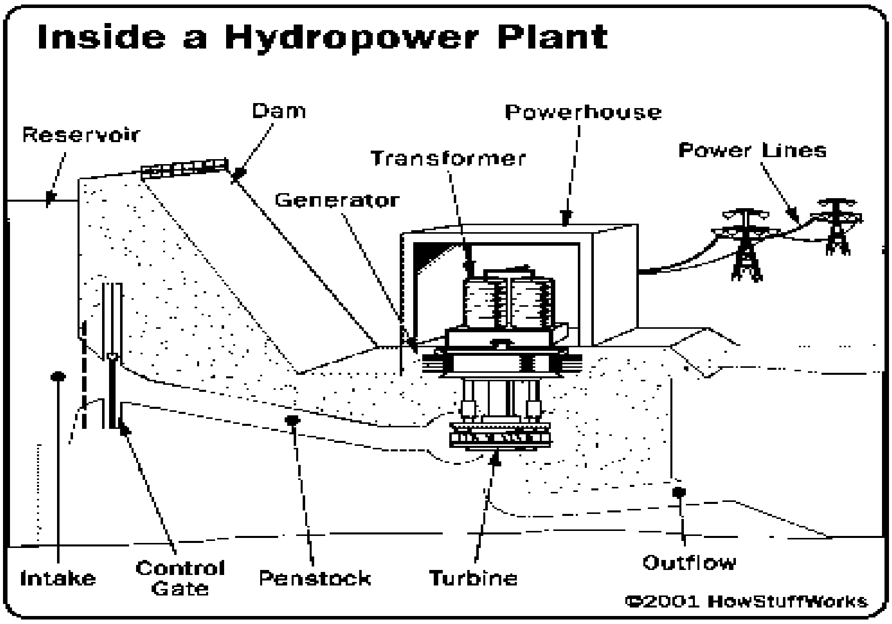


Figure 2.2: Inside Hydropower Plant

Source: How Stuff Works 2001

Hydro energy is available in many forms, potential energy from high heads of water retained in dams, kinetic energy from current flow in rivers and tidal barrages, and kinetic energy also from the movement of waves on relatively static water masses. Many ingenious ways have been developed for harnessing this energy but most involve directing the water flow through a turbine to generate electricity.

2.2 TIDAL STREAM GENERATOR

A tidal stream generator**,** often referred to as a tidal energy converter (TEC) is a machine that extracts energy from moving masses of water, in particular tides, although the term is often used in reference to machines designed to extract energy from run of river or tidal estuarine sites.

Certain types of these machines function very much like underwater wind turbines, and are thus often referred to as tidal turbines. They were first conceived in the 1970's during the oil crisis. Tidal stream generators are the cheapest and the least ecologically damaging among the three main forms of tidal power generation.

Tidal stream generators draw energy from water currents in much the same way as wind turbines draw energy from air currents. However, the potential for power generation by an individual tidal turbine can be greater than that of similarly rated wind energy turbine.

The higher density of water relative to air, which is water is about 800 times the density of air, means that a single generator can provide significant power at low tidal flow velocities compared with similar wind speed. Given that power varies with the density of medium and the cube of velocity, it is simple to see that water speeds of nearly one-tenth of the speed of wind provide the same power for the same size of turbine system.

However this limits the application in practice to places where the tide moves at speeds of at least 2 knots (1 m/s) even close to neap tides. Furthermore, at higher speeds in a flow between two to three metres per second in seawater a tidal turbine can typically access four times, as much energy per rotor swept area as a similarly rated power wind turbine.

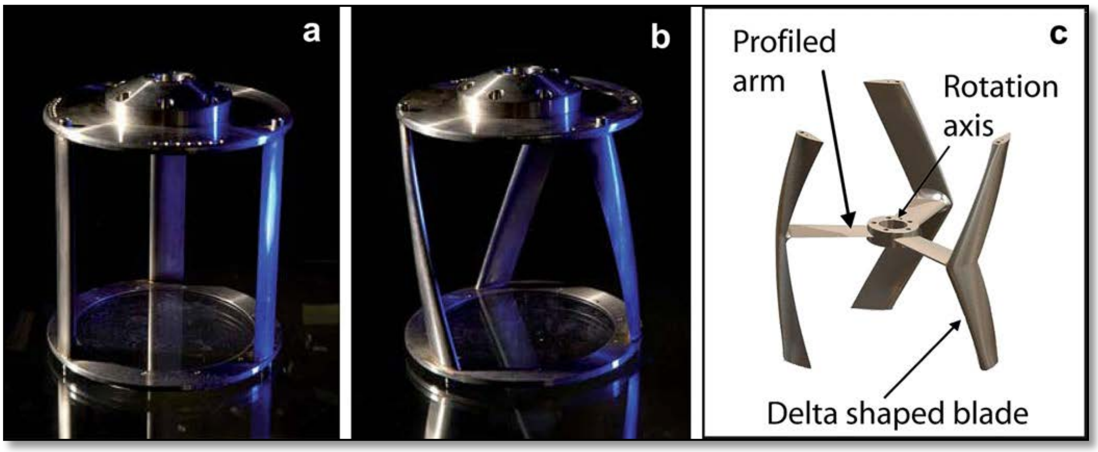


Figure 2.3: Three Cross-Flow Water Turbine scale models of different concepts: (a) Darrieus 1931, (b) Gorlov 1997, (c) Achard and Maitre 2004.

Source: J. Zanette et al. / Renewable Energy 35 (2010)

2.2.1 Darrieus Turbine

The Darrieus turbine is a type of vertical axis turbine used to generate electricity from the energy carried in the wind or water flows. The turbine consists of a number of aerofoils usually but not always vertically mounted on a rotating shaft or framework.

The Darrieus type is theoretically just as efficient as the propeller type if the wind or water speed is constant. But in practice this efficiency is rarely realised due to the physical stresses and limitations imposed by a practical design and wind or water speed variation. There are also major difficulties in protecting the Darrieus turbine from extreme conditions and in making it self-starting.

A propeller mounted on the front of the turbine is attached to an alternator inside the main turbine housing. When submerged in a fast moving water source, the propeller is rotated by the force of the passing water. Propeller style generators work well for locations with a fast moving, relatively deep stream or river, where a water diversion system is not possible, or when mounted on a moving boat. It also can be easily installed in a fast moving river or large stream.

2.2.2 Banki Turbine

The Banki Turbine consists of two parts, a nozzle and a turbine runner. The runner is built up of two parallel circular disk joined together at the rim with a series of curved blades. The nozzle, whose cross-sectional area is rectangular, discharges the jet the full width of the wheels and enters the wheel at an angle of sixteen degrees to the tangent of the periphery of the wheel.

The shape of the jet is rectangular, wide, and not very deep. The water strikes the blades on the rim of the wheel, flows through the blade, leaving it, passing through the empty space between the inner rims, enters a blade on the inner side of the rim, and discharges at the outer rim.

The wheel is therefore an inward jet wheel and because the flow is essentially radial, the diameter of the wheel is practically independent of the amount of water impact, and the desired wheel breadth can be given of the quantity of water.

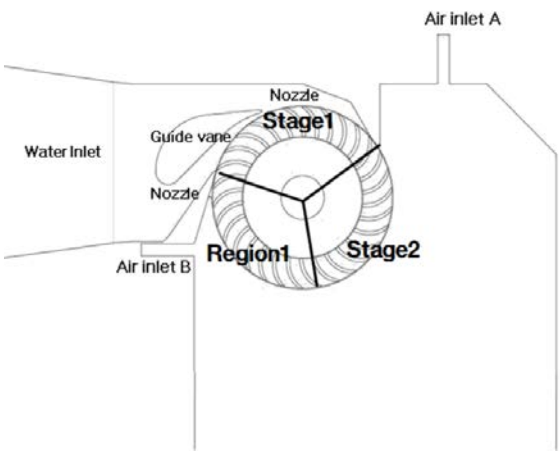


Figure 2.4: Concept of Banki Turbine

Source: IOP Conf. Series: Earth and Environmental Science 12 (2010)

2.2.3 Gorlov Helical Turbine

The Gorlov Helical Turbine (GHT) was specifically designed for hydroelectric applications in free flowing low head water courses. This type of turbine has benefits that make it valuable for generating hydroelectric power. It demonstrates superior power efficiency in free currents compared to other known turbines. The turbine rotates at twice the velocity of the water current flow.

The GHT can self-start in water current flows as low as two ft/s. The blade rotates in the same direction, independent of water flow direction. This is especially advantageous for tidal and wave energy systems and it also has no fluctuation in torque. Other advantage of GHT is it has no cavitations even at high rotating speeds and it allows construction of environmentally benign hydropower plants without dams.

The modular can be assembled vertically, horizontally or in any other cross-flow combination using a common shaft and generator for an array of multiple turbines. The modular design offers great flexibility, which can simplify and reduce the construction, expansion and maintenance cost of a power generating facility. The turbine is adaptable to local needs such as for the homesteads, villages, islands, cities, and even countries.

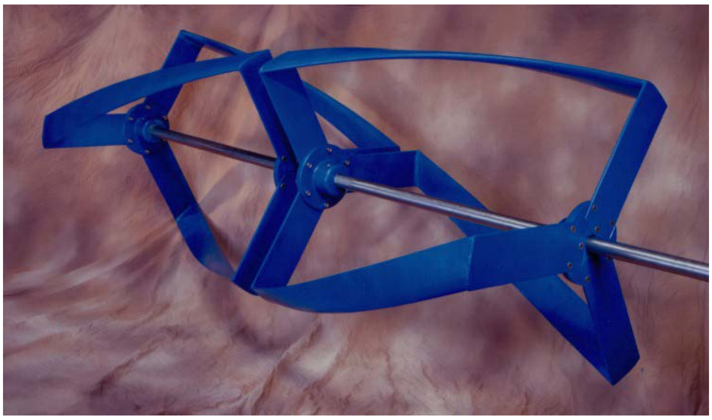


Figure 2.5: Triple helix propeller for Gorlov Hellical Turbine

Source: Alexander M. Gorlov, 2005

2.3 TURBINE TECHNOLOGY

The turbine is basically chosen by considering mostly on the water head and the available flow rate. In most cases, if the water head is small, the flow rate should be higher. The penstock and the turbine should be increased proportionally to support the increment. These parameters are important to provide standardized equipment, engineering designs and implementation methods specifically for that particular location.

The power produced by hydropower turbine can be calculated using the following equation:

$$P = \eta \rho g H Q \qquad (2.1)$$

$$H = h - h_f \qquad (2.2)$$

where,

$$h_f = f \frac{LV^2}{D2g} \qquad (2.3)$$

$$\eta = \eta_{turbine} x \, \eta_{generator} \qquad (2.4)$$

P = power output

η = total efficiency

ρ = density

g = gravitational constant

H = net head

Q = flow rate

h_f = head friction loss

f = Darcy friction factor

L = pipe length

V = jet velocity

D = pipe diameter

There are two types of turbine that are to be considered, the impulse and the reaction turbines. In most cases, the higher head sites will use the impulse turbines, and the reaction turbines are mostly used for low head sites.

Impulse turbine is embedded in the fluid and powered from the pressure drop across the device. The Pelton and Turgo turbines are suitable for high head sites which are larger than 50 m, and medium head ranging between 10 and 50 m. Crossflow turbine is suitable for medium and low head, which is less than 10 m.

Reaction turbines in the other hand operate with the flow hits the turbine as a jet in an open environment, with the power deriving from the kinetic energy. Francis turbine is used in medium water head while the propeller and Kaplan turbines are suitable for low head applications.

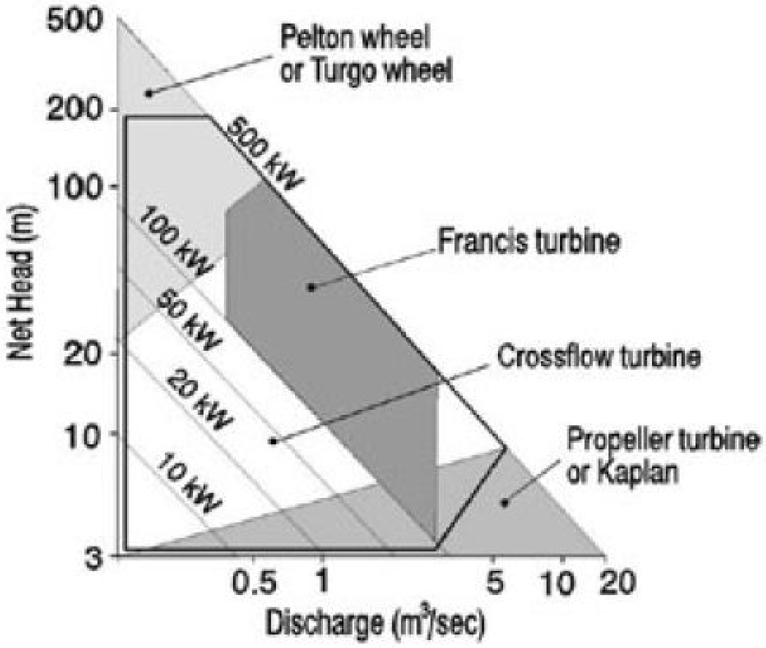


Figure 2.6: Head-flow ranges for small hydro turbines.

Source: Paish, O. 2002. Small Hydro Power: Technology and Current Status.

For this research, the turbine is designed for low head sites. There are some types that could be considered as option. The Kaplan and Francis turbines, which is mainly used for low head sites could be chosen. But those turbines have high initial capital cost and could lead to designing problem. The most suitable turbine to be chosen is from the propeller turbines or Michell-Banki turbines due to their cost and the potential power that it can produce.

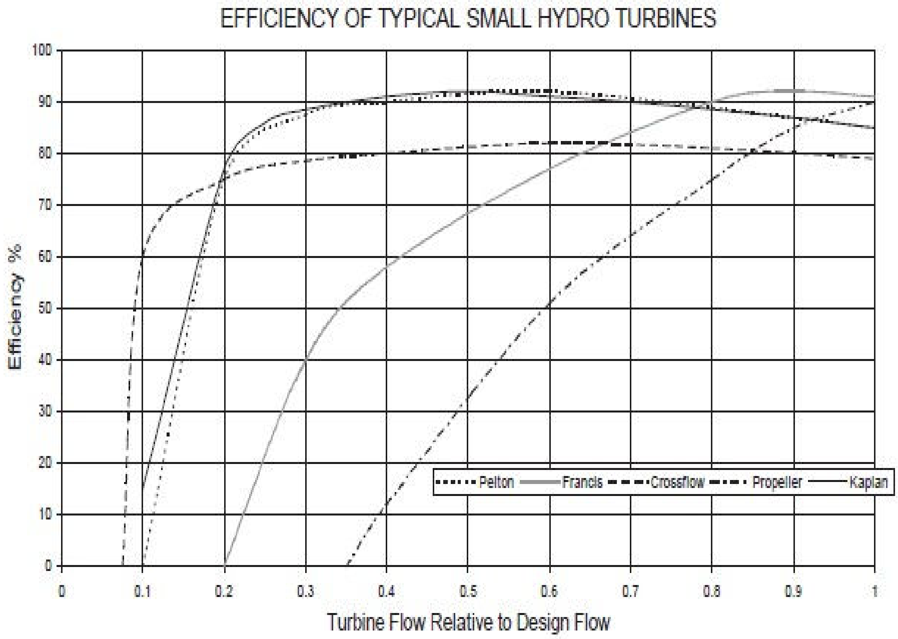


Figure 2.7: The efficiency of small hydro turbines.

Source: Kaldellis, J.K., Vlachou, D.S. and G. Korbakis. 2005. Techno-economic evaluation of small hydro power plants in Greece.

The correlation between specific speed and net head are given for the following turbines:

Crossflow:

$$\eta_s = \frac{513.25}{H^{0.505}} \quad (2.5)$$

Propeller:

$$\eta_s = \frac{2702}{H^{0.5}} \quad (2.6)$$

Kaplan:

$$\eta_s = \frac{2283}{H^{0.486}} \quad (2.7)$$

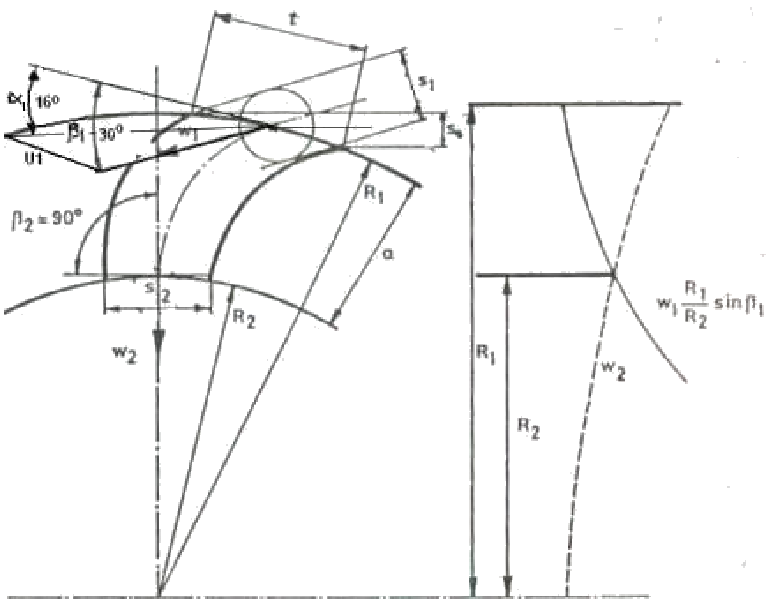


Figure 2.8: Blade spacing for cross flow Banki Turbine

Source: Ahmad Suhendra, May 2010 / Indonesian Renewable Energy Community

Cross flow turbine requirements:

Specific speed (rpm),

$$n_s = \frac{3.65 N_t \, x \, Q^{\frac{1}{2}}}{H_{nett}^{\frac{3}{4}}} \quad (2.8)$$

Absolute water velocity (m/s),

$$C = k_c (2gH)^{\frac{1}{2}} \quad (2.9)$$

where,

k_c = 0.967 (Coefficient dependent upon the nozzle)

Tangential velocity (m/s),

$$U_1 = \frac{(\,C\cos\alpha_1)}{2} \qquad (2.10)$$

Outside disc diameter (m),

$$D_1 = \frac{60U_1}{\pi N_t} \qquad (2.11)$$

Spacing of blades (m),

$$t = \frac{S_1}{\sin\beta_1} \qquad (2.22)$$

where,

$$S_1 = kD_1 \qquad (2.23)$$

$k = 0.075$ to 0.1 (respectively)

Number of blades,

$$Z = \frac{\pi D_1}{t} \qquad (2.24)$$

α_1 = angle between absolute velocity and tangential velocity

β_1 = angle between relative velocity and tangential velocity

2.4 GENERATORS

The generator converts the rotational power from the turbine shaft into electrical power. Efficiency is important at this stage too, but most modern, well-built generators deliver good efficiency.

There can be big differences in the type of power generated, however. DC (Direct Current) generators can be used with very small systems, but typically are augmented with batteries and inverters for converting the power into the AC (Alternating Current) power required by most appliances.

AC generators are normally used in all but the smallest systems. Common household units generate 120 VAC (volts AC) and 240 VAC, which can be used directly for appliances, heaters, lights, etc. AC voltage is also easily changed using transformers, which makes it relatively simple to drive other types of devices or transmit over long distances. Depending on your power requirements, you can choose either single-phase or three-phase AC generators in a variety of voltages.

One critical aspect of AC power is frequency, typically measured as cycles per second (cps) or Hertz (Hz). Most household appliances and motors run on either 50Hz or 60Hz (depending on where you are in the world), which in Malaysia uses 50Hz power frequency, as do the major grids that interconnect large power generating stations. Frequency is determined by the rotational speed of the generator shaft. The faster the rotation will generate a higher frequency.

Generator is a device that converts mechanical energy to electrical energy. The basic principle of a working generator is magnetism. The magnetism produces electricity. A bar made of steel will become magnetized if a current-carrying coil of wire is placed around it. The more turns the wire and the stronger the current, the more powerful the magnet will be. Using a soft core iron, which has less electrical resistance, in the coil, the magnetic force lines are concentrated and strengthened.

The pole shoes usually are magnets. But due to heavy and expensive, the magnet is replaced with wires wounded on the pole shoes. When the current passes these windings, the pole shoes become electromagnets. The poles are connected in series so that one pole will become the north pole and the other will be the south pole of the magnetic field. Inside the generator is a spinning central shaft. It is called as the armature. This armature will be turned by placing a pulley on one end and connected to the shaft of the turbine.

The commutator is a component that attached to the armature. These segments are electrically insulated from the armature. Then there is brush which is held in spring loaded brackets and that pressure holds them against the commutator. The brushes can wear out over times and require replacement.

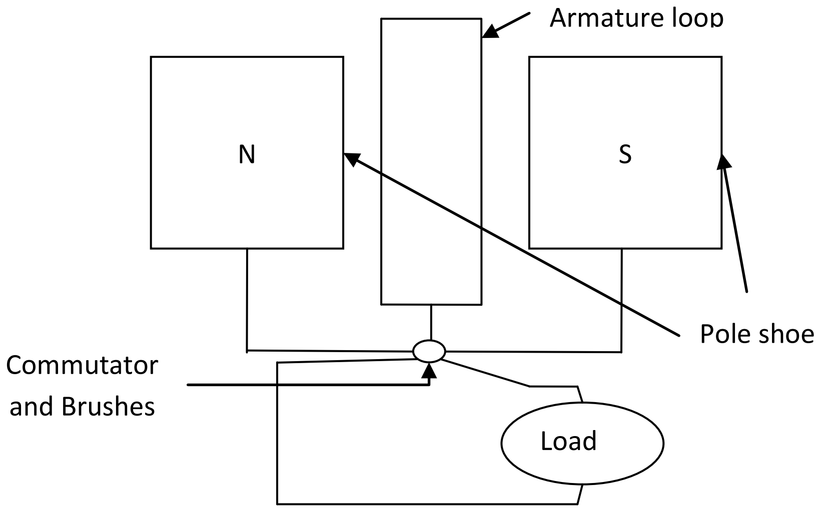


Figure 2.9: Schematic diagram of a generator

When generator works, the generator armature will start to spin with a weak residual magnetic field in the iron pole shoes. As the armature spins, it begins to build voltage. The voltage then will be impressed on the field windings through the generator regulator. This process will increase the strength of the magnetic field. The increasing magnetic fields will produce more voltage in the armature. This voltage can be increased continuously, but is limited to a pre-set peak.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter shows how the design of the cross flow turbine is done. The designs were made based on the literature review of the cross-flow water turbine system. The fabrication process of the designed propeller is also shown in this chapter.

3.2 LITERATURE REVIEW

There are some concepts that been taken from the literature review on the type of propeller for cross flow water turbine such as the Banki turbine, Achard and Maitre Turbine, Darrieus turbine and Gorlov turbine.

The propeller design is chosen for type of turbine that can operate in low water head and various water velocities. From the literature review research, the most suitable turbine that uses nozzle influence to turn the propeller even in low water head is the Banki Turbine.

3.3 SOLIDWORKS DESIGN

The scope of design is to design the propeller of the turbine. The propeller design must be assembled to the turbine housing. The turbine housing consists of the nozzle for the propeller. The purpose of the nozzle is to increase the velocity of the water before it hits the propeller.

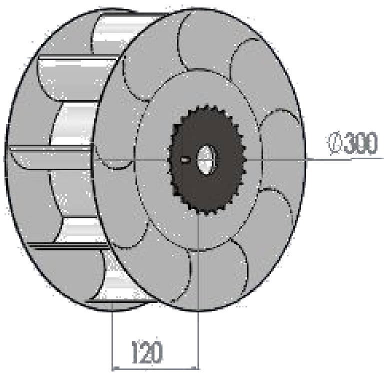


Figure 3.1: Isometric view of the propeller.

The propeller size is designed based on the tip of the nozzle which is 12 cm wide by 6 cm height. And the designs vary by the number of blades and the blade angle of the propeller. A gear is attached to the propeller for the connection between the propeller and the generator. The gear ratio is 2:1 where the larger gear is placed at the propeller and the smaller gear at the generator. This will make one turn of propeller turns the generator twice.

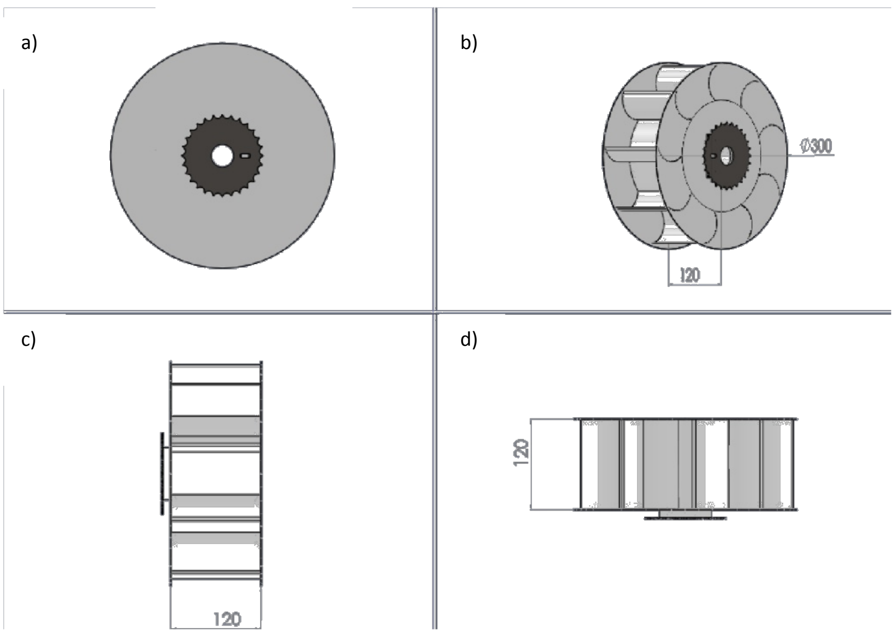
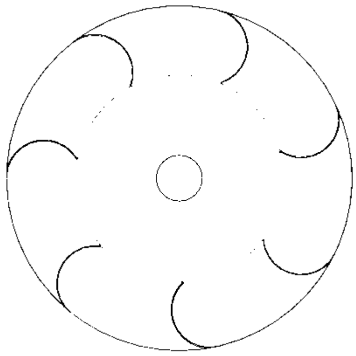
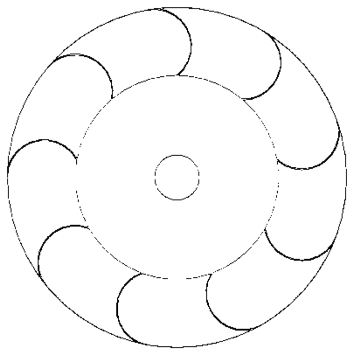
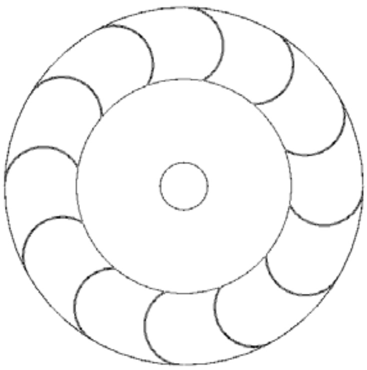


Figure 3.2: Propeller in different view prospect:
a) side view, b) isometric view, c) front view, d) top view.

3.3.1 The Number of Blades

The design of propeller varies the number of blades. This variety is to choose the one that suit the nozzle tip well. The spacing between each opening of two blades must be the size of the nozzle tip. The reason is to ensure that the water hits the surface of the blade and fill the volume so that it can give the best amount of pressure to the surface plane. This will give the best performance of the propeller to spin and to avoid the efficiency of the propeller reduced.

Table 3.1: Propeller design of different number of blades

Model	Number of Blades	Propeller Design
A	7 blades	
B	9 blades	
C	12 blades	

3.3.2 The Angle of the Blades

From the above design, the most suitable number of blades is nine blades. The design is then tested for the angle of the blades. The angle is important to calculate the best angle of the blade and to compare which angle will give the highest pressure and the best streamline flows at the blade surface. The higher the pressure and smoother the streamlines flow for the blade, the more efficient the propeller will be.

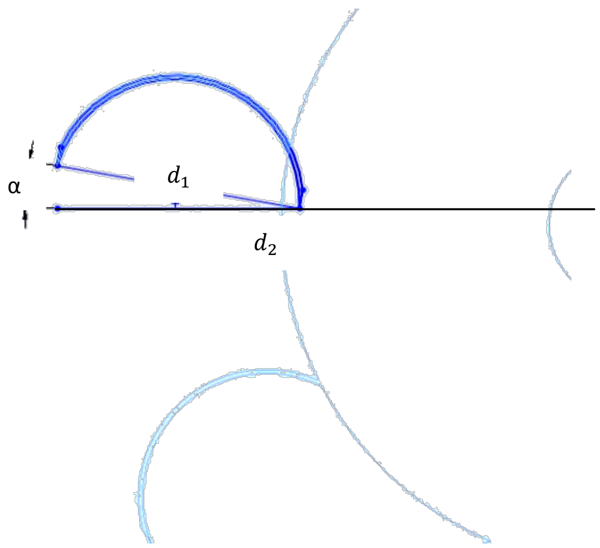


Figure 3.3: Angle of blade

α = angle of blade
d_1 = distance of blade
d_2 = distance from centre of propeller

Table 3.2: Propeller designs with different angles of blade

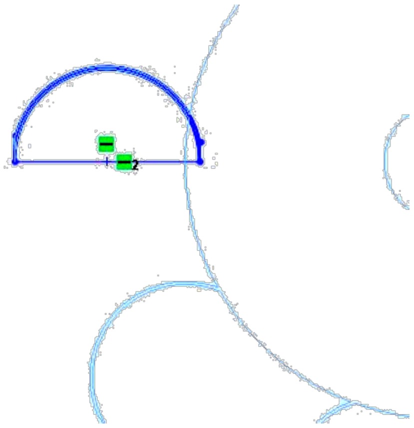
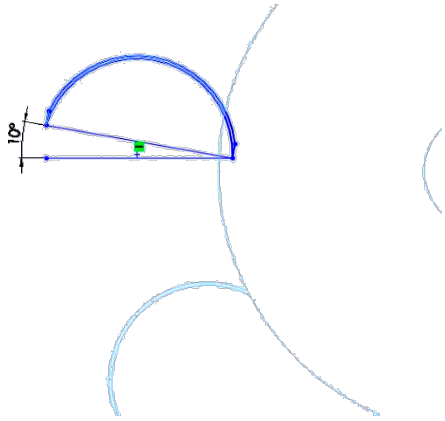
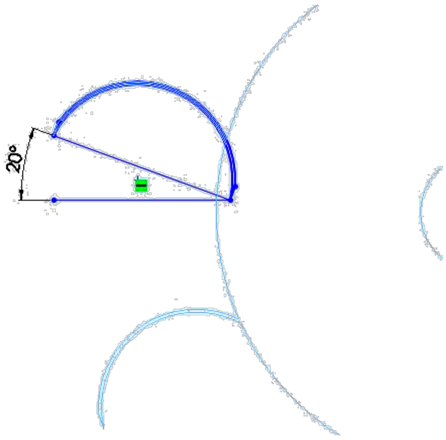
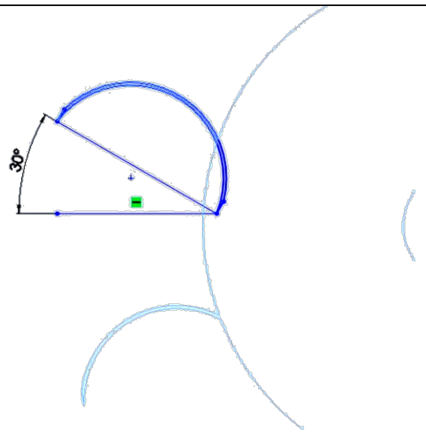
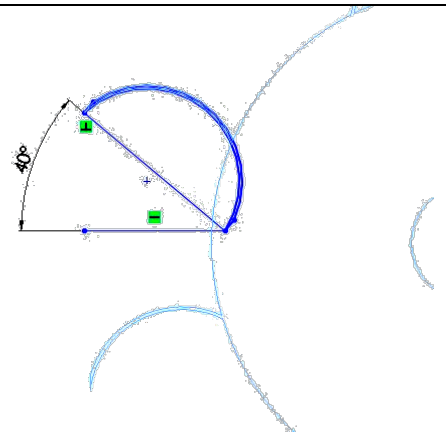
Model	Blade Angle, α	Propeller Design
B1	0 degree	
B2	10 degrees	
B3	20 degrees	

Table 3.2: Continued

Model	Angle of Blades	Propeller Design
B4	30 degrees	
B5	40 degrees	

3.4 ANALYSIS OF THE ANGLE OF THE BLADES

The analysis of the blades is done by using FLUENT software. FLUENT is software that can analyse a body that undergo flowing situations. By using the FLUENT analysis, we can determine the water streamlines and pressures acted to the surface of the blades. Different angle of blades will be tested by this software to determine which angle of blades is the most efficient design.

3.4.1 First Step of Analysis: SolidWorks 2010 Software

The first step of the analysis is to crop the surface area of the propeller that will make contact with the water supplied from the nozzle. The box shaped at the top is assumed as the external flow from the river. The cropping is done by extruding the surface area without merging it. Then, the part is isolated so that we can get the area of contact for one blade to be tested in the FLUENT software.

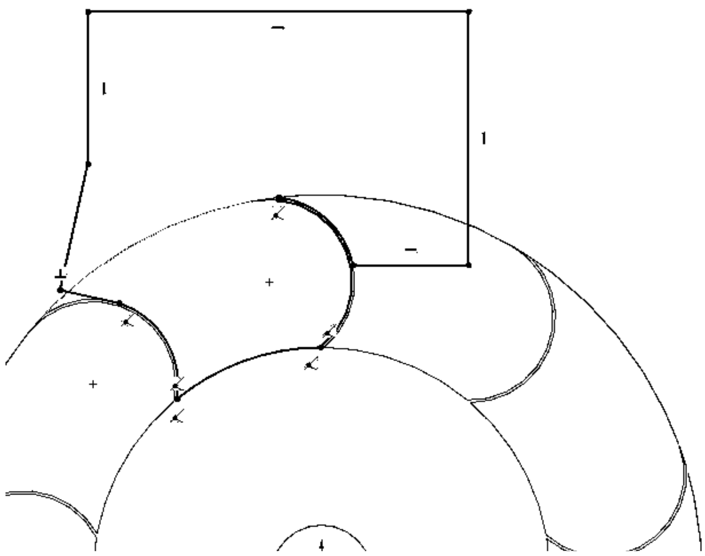


Figure 3.4: Creating the area of contact for each blade

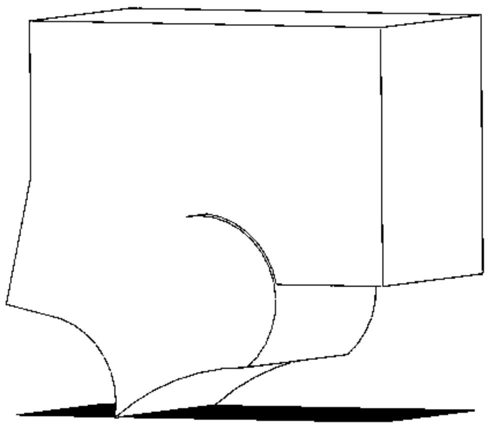


Figure 3.5: Isolated surface of contact of the blade

3.4.2 Second Step: FLUENT Software

The isolated surface contact is then imported to the FLUENT software for further analysis. Then, the part is set as fluid type, water, with the inlet is at the flat surface of the body. The curved surface is set as the blade surface and the both end surface set as the outlet.

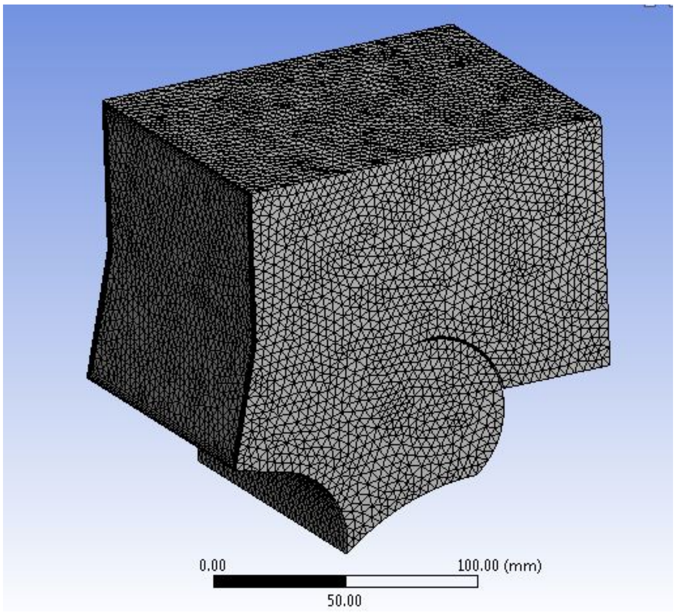


Figure 3.6: Isolated surface contact area meshing result

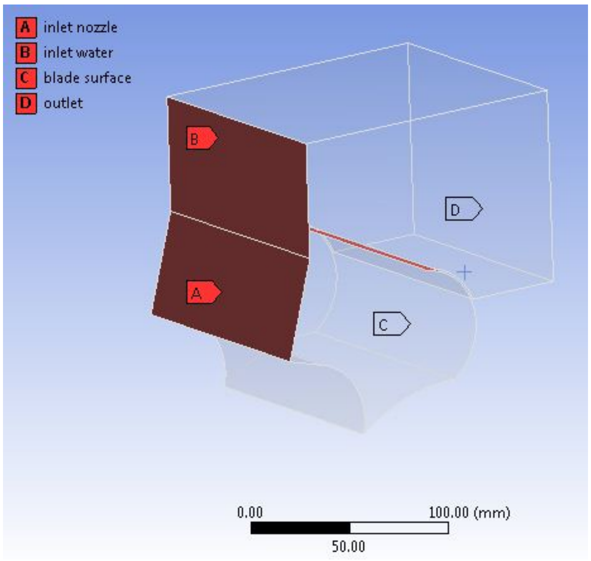


Figure 3.7: Inlet surfaces. A) Nozzle water inlet, B) External flow water inlet

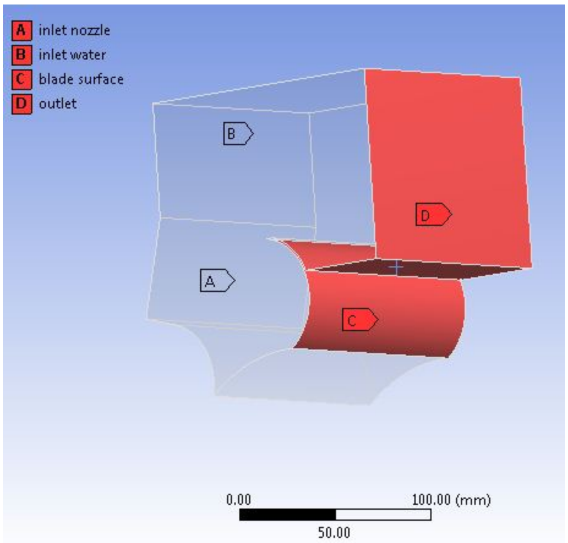


Figure 3.8: Outlet surfaces. C) Blade surface, D) Water Outlet

The analysis is continued by setting up the problems such as the boundary condition, number of iterations, value of the water inlet, and so on. The velocity of the nozzle water inlet is set to be 1.8 m/s and the external flow velocity is 0.25 m/s. The analysis is then started for each angle of blades which is zero degree, ten degree, twenty degree, thirty degree, and forty degree. The results are then observed from the software. The pressure at the blade surface and the velocity streamline is then taken for comparison.

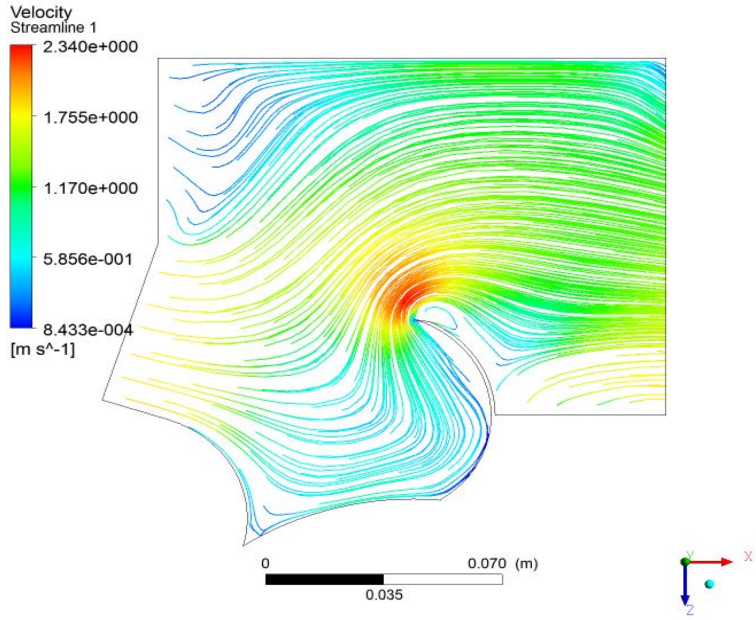


Figure 3.9: The velocity streamline of the water flow

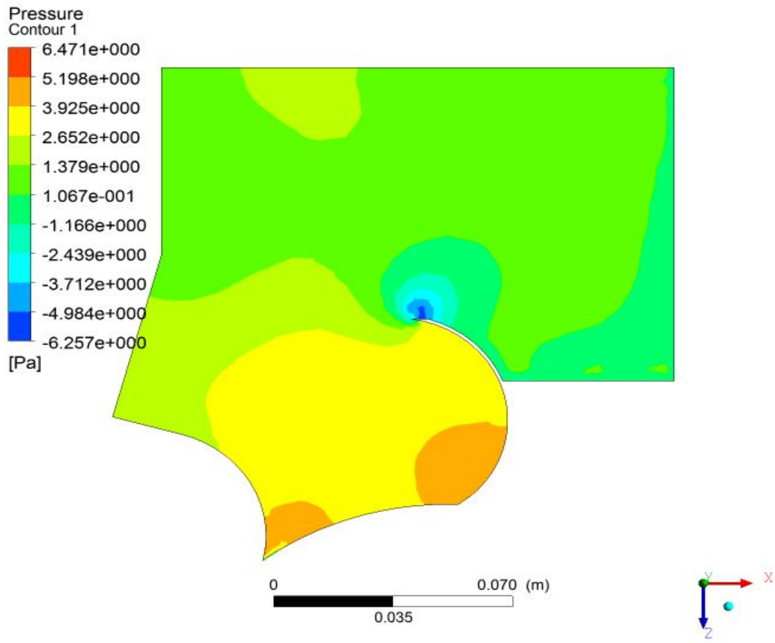


Figure 3.10: The pressure contour observed

For the next analysis, the value of the water inlet velocity is changed for the readings in different water flow condition. First test is for the drought condition. The water flow velocity is reduced and assumed as 0.1 m/s for the external flow and 0.72 m/s at the nozzle inlet. For the monsoon season or stormy weather, the water velocity is assumed to be 1 m/s for the external water flow velocity and 7.2 m/s for the nozzle inlet velocity.

Table 3.3: Water velocity at different water condition

Season	**Nozzle inlet**	**External flow**
	Water velocity, m/s	
Drought	0.72	0.10
Normal	1.80	0.25
Monsoon	7.20	1

3.5 FABRICATION PROCESS OF THE PROPELLER

The fabrication process of the propeller model started after the analysis process completed. The best blade angle from the analysis process is twenty degree angle which has the best criteria for the propeller to work efficiently.

The model is fabricated using two types of material which is stainless steel and plastic model. The dimensions of the design are based on the SolidWorks Software design.

3.5.1 Fabrication of the Stainless Steel Model

The design of the turbine propeller must be durable. Durability is important to make sure that the propeller can withstands the pressures and forces from the water without being damaged. This is important to make sure that the efficiency of the turbine will not be reduced in long term usage. As a solution, the stainless steel is used as the material of the propeller. The stainless steel metal sheet is about 1 mm thick. The blades, covers and the inner plate of the propeller are all using the same type of material.

For the blade curves, a steel pipe with the diameter of 6 cm is used as the reference. The steel sheet is then bended into a semicircular shape and then it is cut by using the hand grinder with cutting blade. Same as the inner diameter of the propeller, by using the same method as above, the inner hollow is made by the same stainless steel sheet.

For the propeller side cover, a round with diameter of 30 cm is measured on the metal sheet. The shape is cut off and the round edge is shaped using the grinder. The hard part of this process is to make its round edge. If the round shape is not equally same, the propeller will not turn smoothly. Then, a hole at the centre of the round is drilled to fit the shaft.

The blades and the inner hollow is then placed and marked at the cover metal sheet before it is welded. The welding process starts after all the components of the propeller are all marked. The components are welded using the MIG welding machine. The gear is also welded to the body of the propeller. Lastly, the shaft with bearings is installed to the propeller.

Figure 3.11: Complete assemble of the stainless steel propeller model

3.5.2 Fabrication of the Plastic Model

The purpose of this model is to build a lighter model which can also increase the efficiency of the propeller. A lighter model need less work force to spins the propeller and all the forces created from the water will be used entirely to rotate the propeller. This will accordingly increase the rpm of the propeller. Light propeller will also reduce the energy losses for rotating the propeller and make the propeller to work at its best performance.

The material for this propeller type is using the PVC pipes and prospect plastic. The PVC pipe diameter is 6 cm for the blades, 3 cm for the shaft and bearing holder, and 18 cm diameter for the inner hollow.

For the blades, the PVC pipe is cut into half of the diameter to get the semi-circular shape. The inner hollow and the shaft holder are measured 12 cm in height before it is then cut using handsaw. The prospect plastic is then cut into a round shape with the diameter of 30 cm. Then, the prospect is shaped using the grinder to soften and shape the round edge. Hole is then drilled at the centre of the prospect for the shaft entrance.

After all of the propeller components are ready, they are then marked before being glued together. The angle of the blades is calculated correctly at an angle of 20 degree. The inner hollow and the shaft holder must be exactly at the centre of the rounded shape prospect plastic.

All of the components are then glued together using the PVC glue. The components must be placed correctly since this glue is fast-dried type. It is important to make sure the angle of blades is still correct after being glued. Then, the glued components is sealed using the Silicon to cover up the joints. This is to prevent leaking and will make the efficient of the propeller decreased. Lastly the shaft and bearings are installed to the propeller.

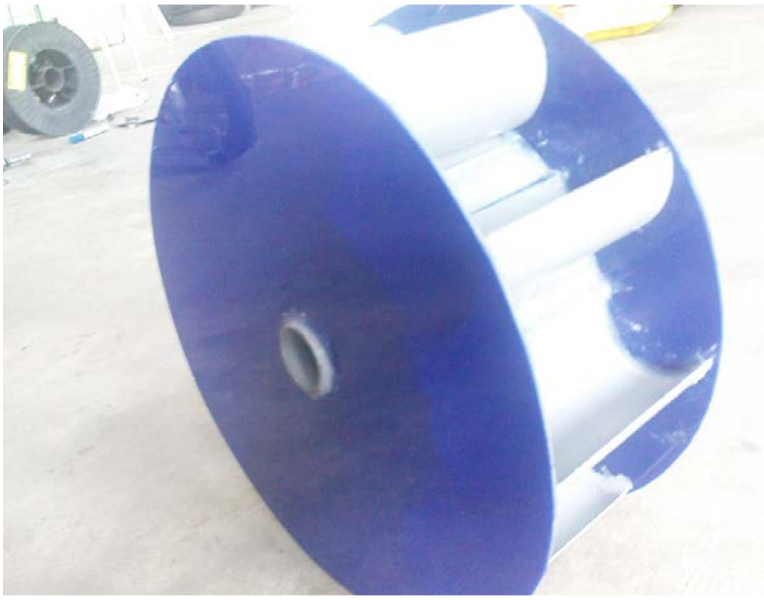


Figure 3.12: Complete assemble of the plastic propeller model

CHAPTER 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter shows the results of the analysis and the result of the model testing. The data observed from the analysis process as shown in Chapter 3.4 is collected and will be discussed in this chapter.

4.2 ANALYSIS OF THE BLADES

The data of the analysis is recorded and discussed. The various angles of blade model is analysed by the FLUENT software to identify the velocity streamline of the water medium and the pressure contour acted on the surface blade.

4.2.1 Analysis of the Blade Angles

The streamlines starts from the inlet surface which is from the nozzle inlet with the velocity of 1.8 m/s. The water then hits the surface of the blades and creates pressure at the surface of the blade. The pressure applied is the force that will pushes the surface of the blade and turns the propeller.

Table 4.1: Simulation results of the velocity streamline

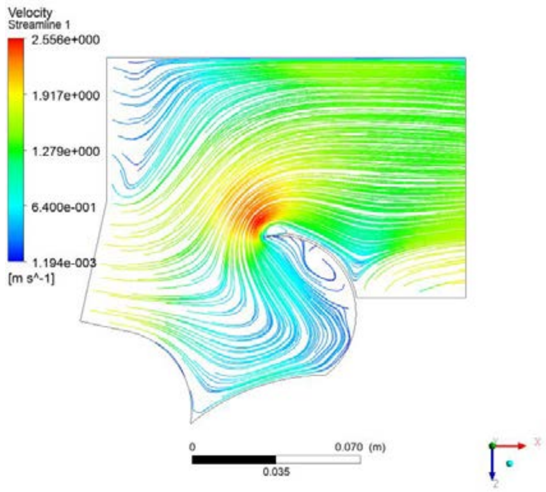
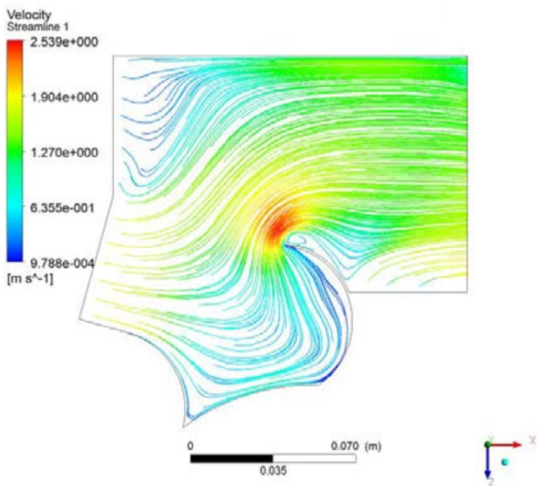
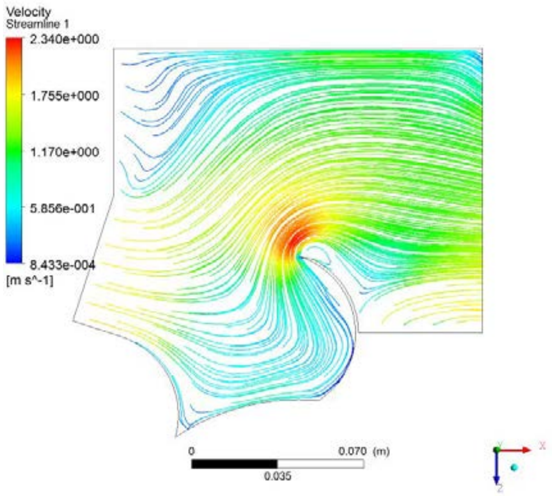
Model	Blade Angle, α	Velocity Streamline Simulation
B1	0	
B2	10	
B3	20	

Table 4.1: Continued

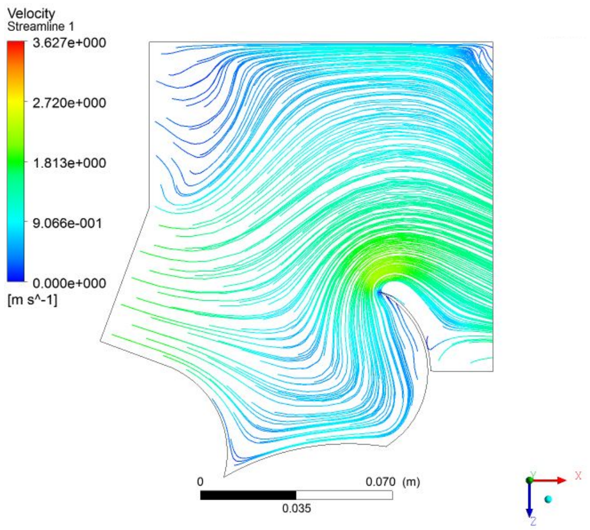
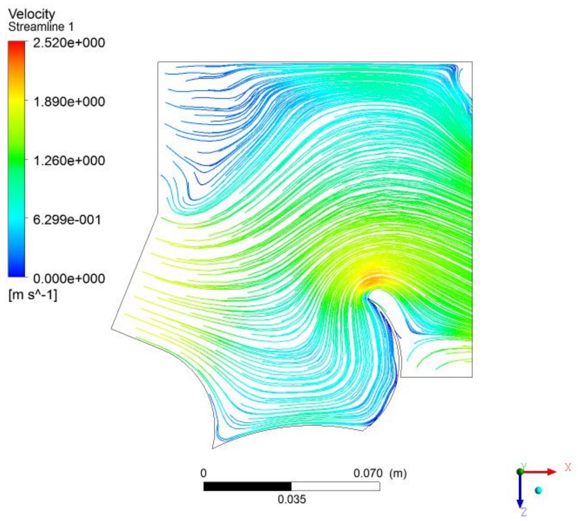
Model	Blade Angle, α	Velocity Streamline Simulation
B4	30	
B5	40	

Table 4.2: Simulation results of the pressure contour

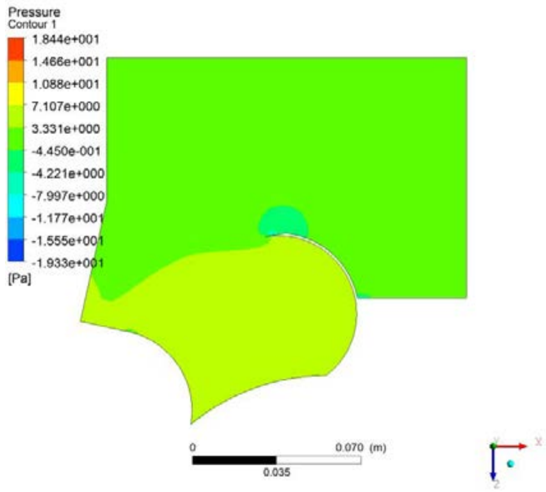
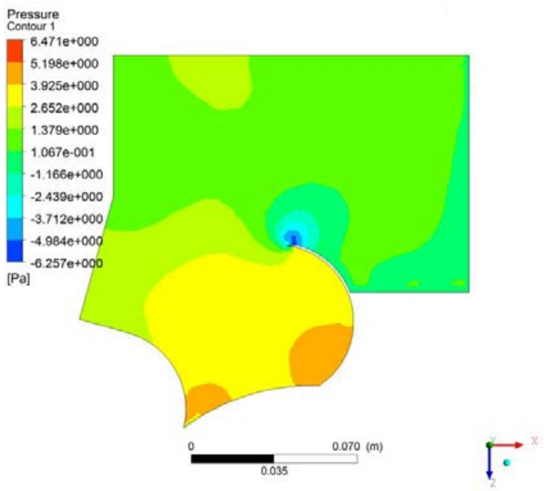
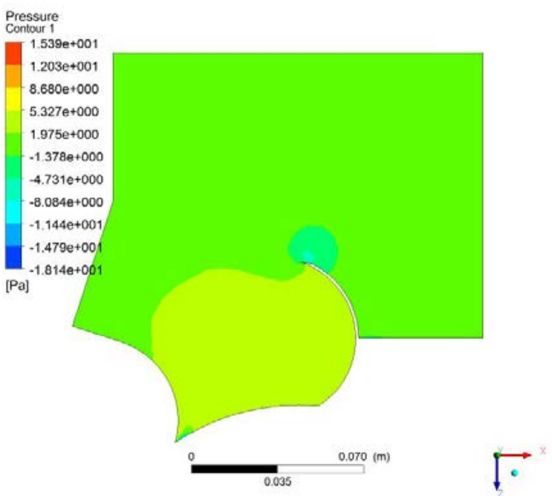
<table>
<tr><th>Model</th><th>Blade Angle, α</th><th>Pressure Contour Simulation</th></tr>
<tr><td>B1</td><td>0</td><td>
</td></tr>
<tr><td>B2</td><td>10</td><td>
</td></tr>
<tr><td>B3</td><td>20</td><td>
</td></tr>
</table>

Table 4.2: Continued

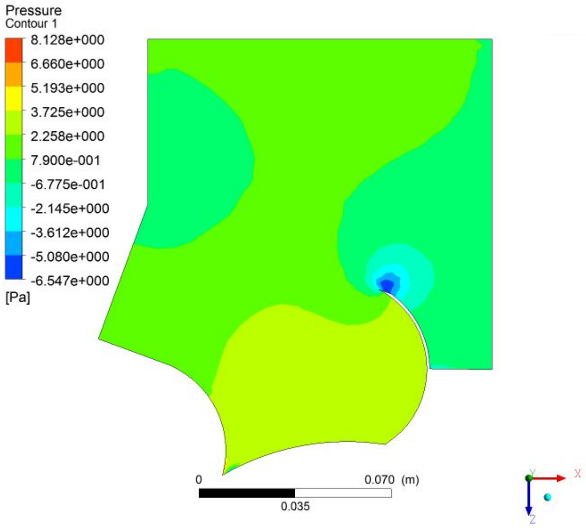
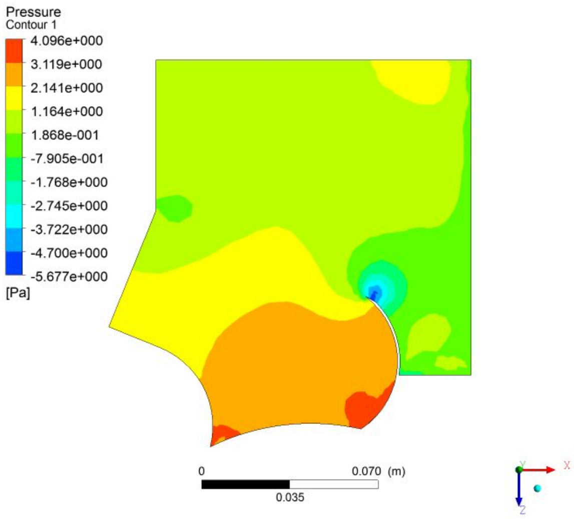
Model	Blade Angle, α	Velocity Streamline Simulation
B4	30	
B5	40	

Table 4.3: Pressure observed from the simulation on the surface blade

Model	Pressure, Pa
B1	4.83197
B2	3.80495
B3	3.51633
B4	2.97043
B5	2.89489

From the data observation, the most suitable blade angle according to the velocity streamline and the pressure acted at the blade surface is B3 propeller model with blade angle of 20 degree.

The selection is based on the model's velocity streamline. The streamline of this model flows fluently compared to the B1 and B2 model. This is shown at the point near to the surface blade where the vortices created are low compare to both the models. The angle opening also allows the external flow to contact the blade surface thus influencing the rotation of the propeller. So that the propeller will not only rotates depending on the water velocity from the nozzle but also will continuously supported by the external river flow.

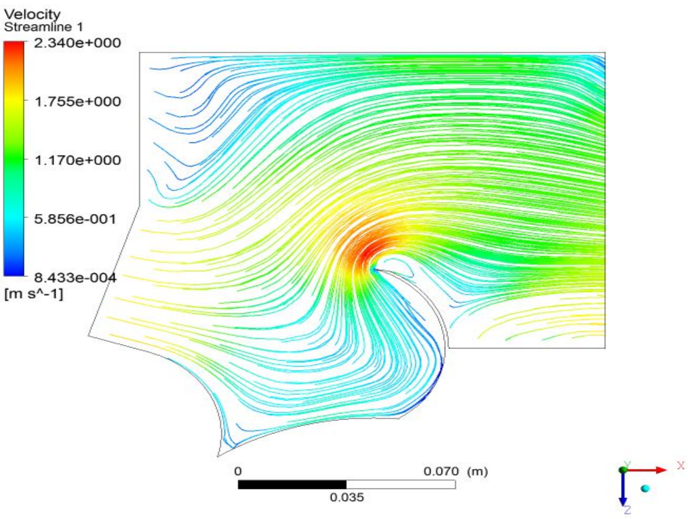


Figure 4.1: Velocity streamline of propeller model B3

Propeller model B4 and B5 also have better water velocity streamlines than B3 model. But the wide angle of opening reduces the pressure that acted on the surface of the blade. The pressure is much loss to the external flows due to the deflection of the blade is tends towards the outside of the propeller. Even though the water streamline of both models are better, the pressure acted to the surface blade that makes the difference in choosing the best angle of the blade. The propeller model B3 is the best model to be chosen from the analysis according to the streamlines flow and the pressure on the surface of blade.

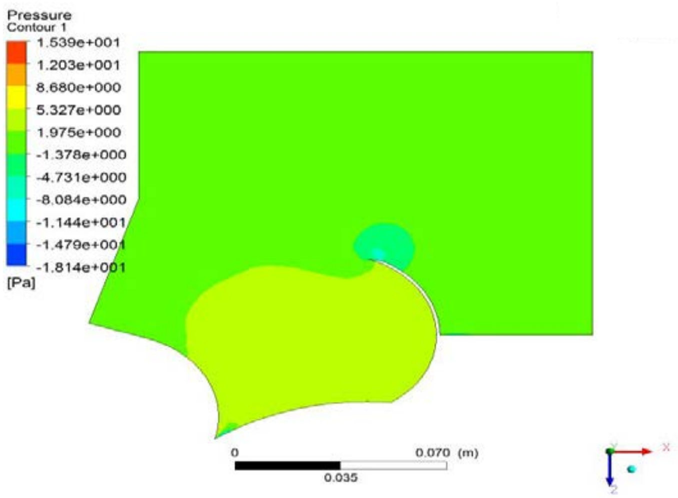


Figure 4.2: Pressure contour of propeller model B3

4.2.2 Analysis for Different Weather Condition

The propeller model B3, is then tested with different weather condition. The purpose of this analysis is to observe the water velocity streamline and the effectiveness of the model at different conditions.

For the normal season condition, the water inlet velocity is assumed as 1.8 m/s at the nozzle inlet and 0.25 m/s for the external water flow. For the drought season, the water inlet velocity is assumed as 0.72 m/s at the nozzle inlet and 0.1 m/s for the external water flow. Finally for the monsoon or stormy season, the water inlet velocity is assumed as 7.2 m/s at the nozzle inlet and 1.0 m/s for the external flow. The observation data is recorded on the table below.

Table 4.4: Pressure values for different weather condition

Season	Nozzle inlet	External flow	Pressure, Pa
	Water velocity, m/s		
Drought	0.72	0.10	0.5934
Normal	1.80	0.25	3.5163
Monsoon	7.20	1	59.5590

For the drought season, the water velocity is reduced due to the low of head. When the velocity of water is low, the velocity streamline tends to circulate more inside the propeller area. When the water hits the blade wall, the water velocity will reduce and the external flow has the higher velocity than the flow at the propeller area. The higher external water velocity will make the inside water attracted to the external flow.

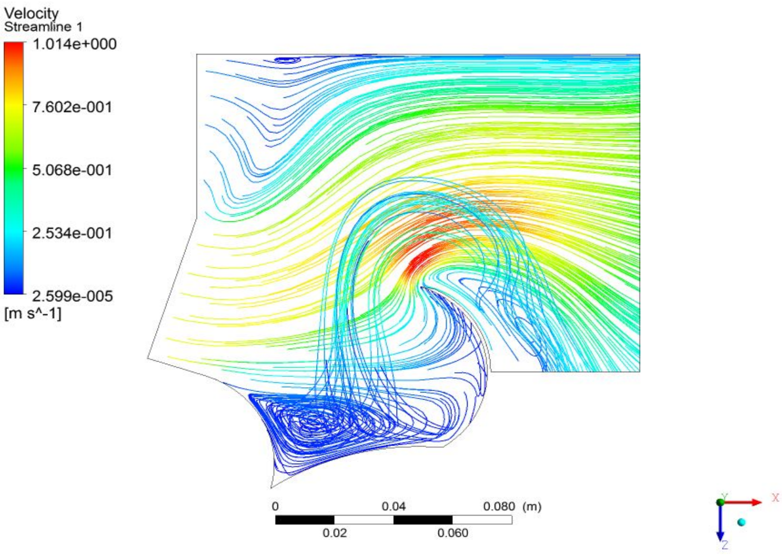


Figure 4.3: Velocity streamline in drought season for B3 propeller model

The model is then analysed for the monsoon weather condition. The head of water will increase in this condition thus will increase the water velocity of the river. For this condition, the pressure applied at the surface of blade is very high. The velocity streamline for this condition is unpredictable. Lots of turbulent flow will occur and forms thick wake behind the blade surface.

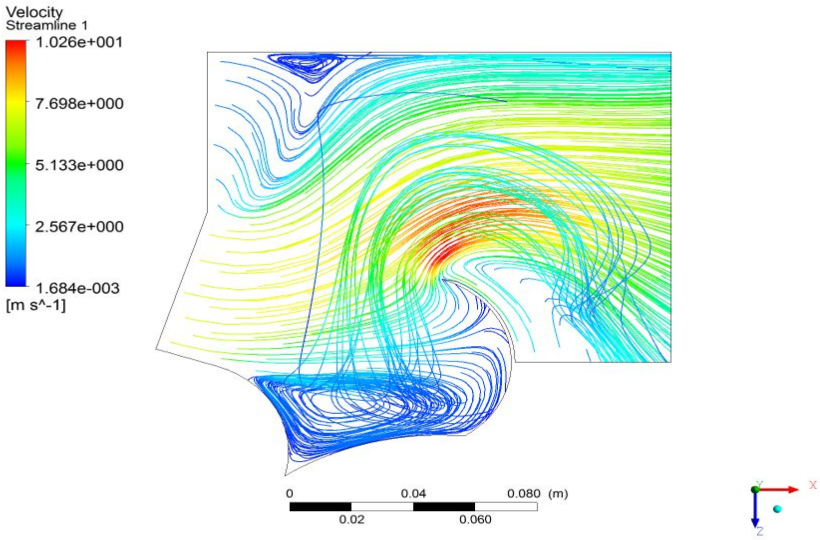


Figure 4.4: Velocity streamline in monsoon season for B3 propeller model

4.3 MATERIALS OF MODELS

The propeller model is fabricated in two types of material which is PVC plastic and stainless steel. Both models have their own advantages and disadvantages. The stainless steel is build for durability but the model is heavy and vice versa to the PVC plastic model which is lighter but less durable.

Since the river flow is tidal type flow, the material chosen must be light to ensure that the propeller can rotates even in low water head. The propeller must also suitable for the turbine housing which is floating type housing. The propeller weight must also not affect the buoyancy of the housing to maintain the stability of the housing while floating.

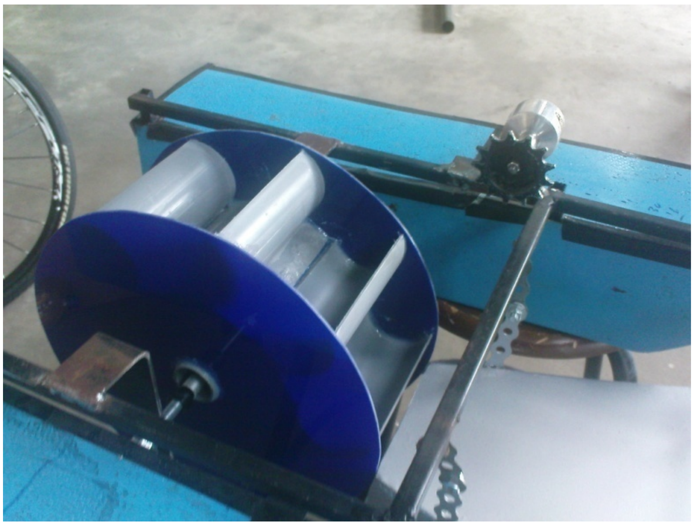


Figure 4.5: The propeller installed to the turbine housing.

CHAPTER 5

CONCLUSION

5.1 INTRODUCTION

This chapter will discuss about the conclusions and recommendations of this project based on the analysis and experiment done.

5.2 THE WATER TURBINE SYSTEM

This Chapter has been discussed detail of outcome, assumption and further research about this system. Basically, this system has met the objective of this project, which is to design and analyse of cross flow delta-wing water turbine for Pahang River.

The best design for the water turbine system that suits the flow rate and the water source of the Pahang River is the propeller with 9 blades and having 20 degree of blades angle. The number of blades is determined based on the nozzle tip opening. The blades are divided equally and the spacing between the two blades is measured. The most suitable number of blades is 9 because of the spacing between the two blades is about 12 cm wide by 6 cm height. Each blade is designed at the angle of 20 degree based on the velocity streamline and pressure contour applied at the blade surface.

The FLUENT software is used to analyse the propeller to picture the actual velocity streamline and pressure contour acted at the blade surface theoretically. Since propeller with 20 degree angle of blade gives the more fluent streamline and good pressure at the surface blade, it can be considered as the most efficient propeller designed.

The best type for the propeller material must be light so that it can rotate even at low head and low velocity of water. The best material type is plastic materials because it is light and the cost of manufacturing is lower than steel.

5.3 RECOMMENDATIONS

This type of turbine is an environmentally safe. It is suitable for Pahang River because it can operate even in low head and velocity of water. The well-known hydroelectric turbine usually uses dam to create the high head of water. Even though the power generates is high, it effects the nature because of the dam construction. So, the cross-flow turbine is suitable for generating electricity without affecting the nature.

Other than that, this project should be regarded as a contribution in the current develops of micro and nano devices that could be used in medical, in environmental and energy application.

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Selection chart of appropriate turbines. S 129.

Mockmore, C.A, Merryfield, F., 1949. The Banki Water Turbine

The nozzle, whose cross-sectional area is rectangular, discharges the jet the full width of the wheels and enters the wheel at an angle of sixteen degrees to the tangent of the periphery of the wheel. (5-6).

Zanette, J., Imbault, D., Tourabi, A., 2010, A design methodology for cross flow water turbines

Three Cross-Flow Water Turbine scale models of different concepts: (a) Darrieus 1931, (b) Gorlov 1997, (c) Achard and Maitre 2004. (998).

Razak, J.A., Ali, Y., Alghoul, M.A., Application of Crossflow Turbine in off-grid pico hydro renewable energy system

The power produced by hydropower turbine can be calculated using the following equation. (520).

Paish, O., 2002. Small Hydro Power: Technology and Current Status

Head-flow ranges for small hydro turbines

Kaldellis, J.K., Vlachou, D.S. and G. Korbakis. 2005. Techno-economic evaluation of small hydro power plants in Greece

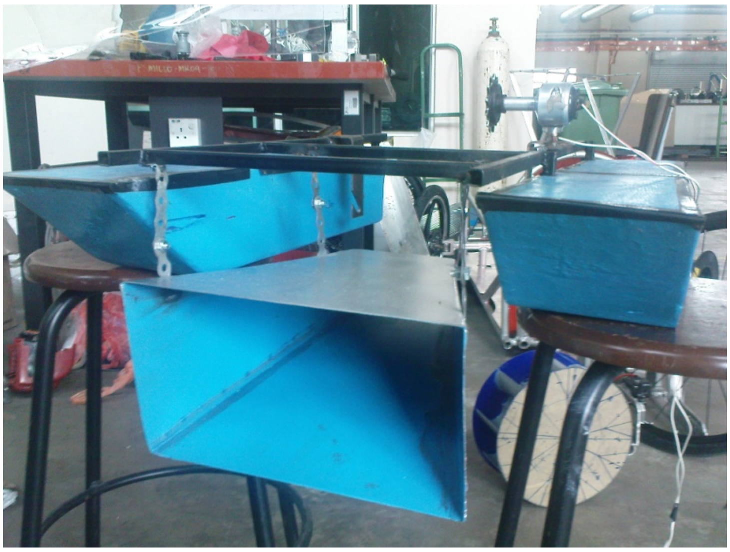
The efficiency of small hydro turbines

Suhendra, A., 2010, Indonesian Renewable Energy Community

Cross flow turbine requirements

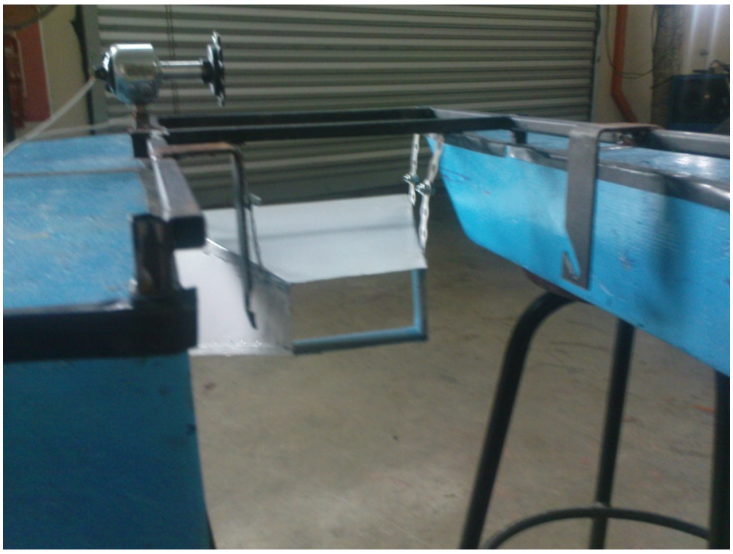
APPENDIX A1

THE TURBINE HOUSING WITH THE WATER INLET NOZZLE



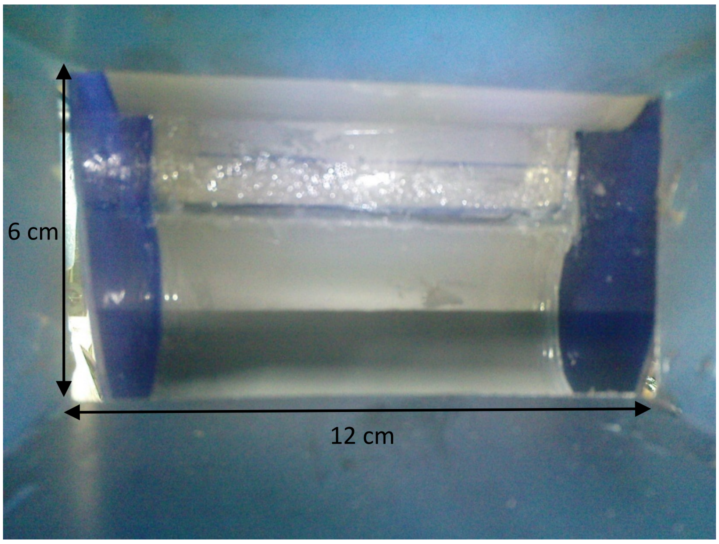
APPENDIX A2

THE NOZZLE TIP OF THE TURBINE SYSTEM



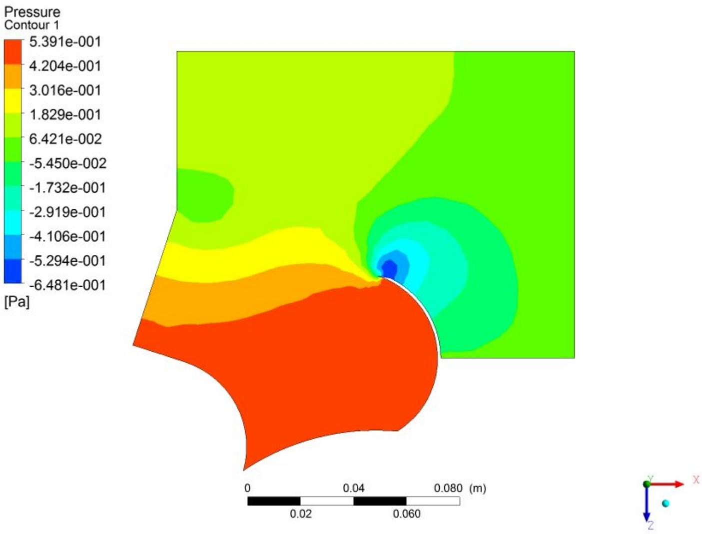
APPENDIX A3

THE SIZE OF NOZZLE TIP FITS THE SPACING OF MODEL B PROPELLER



APPENDIX B1

PRESSURE CONTOUR FOR DROUGHT SEASON FOR PROPELLER MODEL B3



APPENDIX B2

PRESSURE CONTOUR FOR MONSOON SEASON FOR PROPELLER MODEL B3