# DESIGN OF VORTEX TURBINE USING COMPUTATIONAL FLUID DYNAMIC ANALYSIS

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**THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF BACHELOR OF MECHANICAL ENGINEERING**

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# DECLARATION

I hereby declare that this project progress report entitled "Design of Vortex Turbine Using Computational Fluid Dynamic Analysis", submitted to Universiti Malaysia Sabah, is an original work under the supervision of Fadzlita Binti Mohd Tamiri, and it is submitted as a partial fulfillment of the requirement for the degree of Bachelor of Mechanical Engineering, which has not been submitted to any other university for a degree. I also certify that the work described is entirely mine, except for quotations and summaries of sources which have been duly acknowledged.

1st July 2022

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# ABSTRACT

This research project will be touch about the design of vortex turbine by using Computational Fluid Dynamics (CFD) Simulation. The purpose of the design turbine is to improve the efficiency of the vortex turbine and used it on the gravitational water vortex power plant (GWVPP). GWVPP is a renewable technology that will be use renewable energy sources to produce power. In this research project, it will be designing the curved blades with exchangeable baffle plates. So, the main character of this research paper is appearance of baffle plates on the vortex turbine. According to the discover of the research article, the presence of baffle plates can improve the torque and efficiency of the curved blade turbine. In order to see the effect of baffle plates, there are three types of baffles will be designed which are no baffles, 50% baffle and 100% baffle. For the experimental data analysis, it shows that the presence of baffle plates can improve the torque and efficiency of curved blade turbine. The larger the surface area of baffle plates, the baffle plates reserved more water mass impact on the surface area of each blade. Future work of this research paper is applying baffle plates on others type of vortex turbine such as flat plate, skewed blade, and twisted blade profiles.

# *ABSTRAK*

## *MEREKA BENTUK VORTEKS TURBIN DENGAN MENGGUNAKAN ANALISIS "COMPUTATIONAL FLUID DYNAMIC (CFD)"*

*Projek penyelidikan ini akan menyentuh tentang reka bentuk vorteks turbin dengan menggunakan Analisis "Computational Fluid Dynamic (CFD)". Tujuan pembuatan reka bentuk turbin adalah untuk meningkatkan kecekapan turbin vorteks dan menggunakannya pada loji kuasa pusaran air graviti (GWVPP). GWVPP ialah teknologi boleh diperbaharui yang akan menggunakan sumber tenaga boleh diperbaharui untuk menghasilkan tenaga. Dalam projek penyelidikan ini, ia akan reka bentuk bilah melengkung dengan plat penyekat yang boleh diubah suai. Jadi, watak utama penyelidikan ini adalah saiz plat penyekat pada turbin vorteks. Menurut penemuan artikel penyelidikan, kehadiran plat penyekat boleh meningkatkan tork dan kecekapan turbin bilah melengkung. Bagi melihat kesan baffle plate, terdapat tiga jenis baffle yang akan direka iaitu tiada baffle, 50% baffle dan 100% baffle. Daripada analisis data eksperimen, ia menunjukkan bahawa kehadiran plat penyekat boleh meningkatkan tork dan kecekapan turbin bilah melengkung. Lebih besar luas permukaan plat penyekat, plat penyekat menyimpan lebih banyak air pada luas permukaan setiap bilah. Untuk penyelidikan masa depan ini adalah mengaplikasikan plat penyekat pada jenis turbin vorteks lain seperti plat rata, bilah senget, dan profil bilah berpintal.*

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| | | |
|---|---|---|
| **GWVPP** | - | Gravitational Water Vortex Power Plant |
| **WVGS** | - | Water Vortex Generation System |
| **CFD** | - | Computational Fluid Dynamics |
| **PLA** | - | Polylactic Acid |

# CHAPTER 1

# INTRODUCTION

## 1.1 Background

Based on Our World in Data (2021), the graph shows the percentage between renewable energy and fossil fuels in producing electricity from 2000 to 2020 is still worrying because the percentage of using fossil fuels is higher than the renewable energy. From the data, it states that after 2 decades the use of hydropower to produce electricity is decreasing 0.82%. In this research, it will touch on micro-hydro power plants. Even though the percentage of micro-hydro power plants only contribute a small percentage to hydropower, the installation of micro-hydro power plants in rural areas will give a big impact for the society around that area, especially for those who cannot afford high rates electricity.

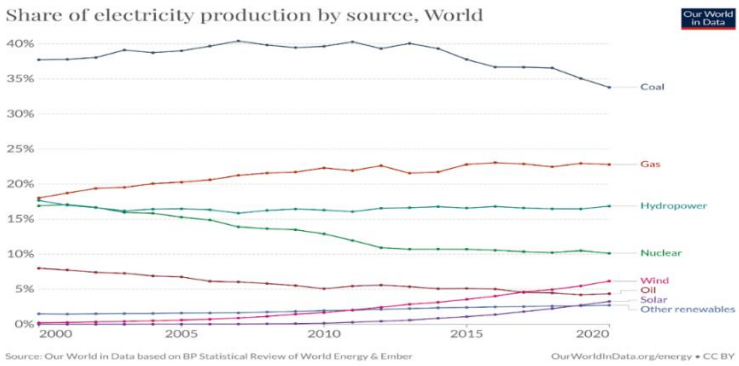


**Figure 1 : Share of electricity production by source, World**

Source: (Our World in Data, 2021)

The gravitational water vortex turbine is a green technology which will generate electricity from renewable energy. It mainly consists of two parts such as a runner and a tank which work by introducing a flow of water into the tank and utilizing the gravitation vortex created when the water drains from the bottom of the tank, a gravitation vortex type of water turbine which creates power (Nishi & Inagaki, 2017a). Because the maximum reported of Gravitational Water Vortex Power Plant has still not exceeded 100kW, it is now classified as micro hydropower (M. M. Rahman et al., 2017). When the micro hydro power plant run, the streams from the river will channeled into the basin which it is a vertical pool with a circular cross-section and has a small opening at the bottom. When water flows under the gravitational attraction, an artificial vortex is formed, which is responsible for power generation (Ullah et al., 2019).

**Figure 2: A General Gravitational Water Vortex Power Plant**

Source: (Singh, 2019)

Even though the idea of vortex flow and power generation from a free surface of water vortex was introduced by Viktor Schauberger and Brown in 1968, they acknowledge Franz Zotlöterer to be a forerunner of today's vortex hydropower technology because he not only invented but also marketed a worldwide renowned multipurpose technology (Sedai et al., 2016). When he was looking to efficiently aerate

the water, he invented the power plant too. The gravitational vortex is a water aeration breakthrough because previously, the energy is needed to aerate the water, currently, this approach employs a water aeration process to generate electrical energy (Dhakal et al., 2015).

The first patent for a hydroelectric power plant was made by Franz Zotloterer in 2004. In 2008, the concept of the idea was developed to increase vortex circulation by changing the shape of the previous basin from the rectangular channel to a cylindrical chamber with a tangential inlet and slanted baffle. In 2011, Zotloterer has been developed and patented the idea again by upgrading the runner which consists of a cylinder runner with a number of blades that spaced uniformly around the circumference to enhance hydraulic to mechanical energy transfer efficiency. In addition, the design of the runner will be equal to the head of the power plant. Another inventor who is Kouris has been developing the vortex turbine technology by focusing on the modularity which will reduce the civil works after a decade of the first patent from Zotloterer. In 2013, Aquazoom AG have been filed a patent on the turbine of the vortex power plant where they claim the efficiency of the power production (Sedai et al., 2016).

## 1.2 Problem Statement

In this 21 century, the explosion of the population does not only occur in urban areas, but it also occurs in rural areas. It is hard to supply electricity to rural areas due to the challenging installation and high cost. To fulfill the needs of electricity, renewable energy such as low head hydropower plants will be the best choice because it can be installed in difficult geographical terrain. In addition, it will be a good choice for its clean generation.

Although the vortex turbine can be worked finely to supply electricity, the performance of the vortex turbine is still not at its best. At a turbine speed of 40-50 rpm, a laboratory experiment revealed the maximum overall efficiency is 30% (Sritram &

Suntivarakorn, 2019a). In the water vortex turbine, the most important parts are the design geometry of the turbine blades because it can generate the power from the kinetic energy that produce by the water vortex.

Every type of vortex turbine will produce a different performance where there are many parameters on the vortex turbine that would influence the performance. There are many parameters on the vortex turbine that have been studied by other researchers such as the number of blades, presence of baffles, height, and angle on the turbine efficiency.

This research can be a good platform to improve the understanding and performance of vortex turbines. In addition, the development of vortex turbines as renewable energy technologies can be a good effect for the local community to use renewable energy technologies and get some ideas to improve the vortex turbine technology.

### 1.3 Research Objectives

The main objective of this research is to upgrade the design of the curve blade vortex turbine's runner by using computational fluid dynamic analysis. Besides, several objectives need to be achieved which are: -

1. To analyze the result of water flow of the water vortex generation system by using CFD simulation.
2. To develop 3D modeling for the runner of the vortex turbine with baffles
3. To fabricate the vortex turbine with exchangeable baffles
4. To study the effects of baffles on curved blade turbine on the performance of GWVPP

## 1.4 Scope of Works

To start the research, the background study of renewable energy technologies regarding vortex turbines is carried out by reviewing past research papers and enhancing the understanding of the title. Then, it is important to have a literature review on how past research does the CFD Simulation and do performance requirements.

The main scope of this research will be based on the design process, the CFD Simulation process, and analyze the CFD Simulation data result of the water flow process. In the process of design, the existing Water Vortex Power Plant System will be developed in 3D modeling by using Solidwork software. So, the parameter of the existing Water Vortex Power Plant System will be collected in the past research paper. Besides that, it needs to design the curved blade by using Solidwork software too. To design a curved blade, the calculation will be done to design a new curved blade. So, it means there are two 3D modeling need to be done.

In the process of simulation, the CFD simulation will be simulated by using Solidwork and Ansys Software. So, both the existing Water Vortex Power Plant System and the runner will be simulated. The simulation will fix the initial parameter of the simulation. So, the validation of the research can be obtained.

After the process of the simulation, it will continue with the process of analyzing the CFD Simulation result. The first data that will be analyzed is the CFD Simulation result for the existing Water Vortex Power Plant System. From the CFD Simulation results, the data to design the curved blade can be extract. After design the curved blade, it will be proceeded to design three types of baffle plates which are no baffle, 50% baffle, and 100% baffle. After design process, student will fabricate the design by using 3D Printer machine. Lastly, the prototype of curved blade turbine with exchangeable baffles plates will be test on Hydraulic Lab to find the efficiency of the prototype. To test the prototype, Prony brake system will be used on the experimental work to compare the effect of baffle on the different value of load. All the processes will be documented for the future researcher.

## 1.5 Research Methodology

### 1.5.1 Literature review

In order to get some idea and understanding of vortex turbines, past research on design and development have been studied. By studying and reviewing the past research, it will be carried out to find the information on the standard, theories, calculation, how to design, and how to evaluate the efficiency or performance of the vortex turbine.

### 1.5.2 Design selection

While studying and reviewing the past research, the design of the past research on the vortex turbine power plant system will be recorded. The data that will be recorded will focus on the height of the water, the height of the channel from the bottom of the basin, the outer diameter of the vortex turbine, the width of the inlet, and the width of the inlet neck channel. Those designs will be converted into 3D modeling by using Solidworks software. Then, the design of the runner will be depending on the result simulation of the existing vortex turbine power plant system and the calculation.

### 1.5.3 CFD Simulation

The 3D modeling of vortex turbines in Solidworks software will be exported into the Ansys file. The computational fluid dynamic simulation will be done either in Solidworks or Ansys simulation. Even though every past research has different initial parameters will doing the CFD Simulation. This research will stick to one initial parameter to ensure the validation of this research.

### 1.5.4 Vortex Turbine Efficiency or Performance Evaluation

After completing the simulation, the data of the simulation will be recorded such as the velocity of water at the outlet. The main objective of this title is to be evaluating the performance of the vortex turbine. From the simulation, the vortex profile can be defined. It will represent the data in form of a graph and table. The data will be recorded and documented for future research to do improvement.

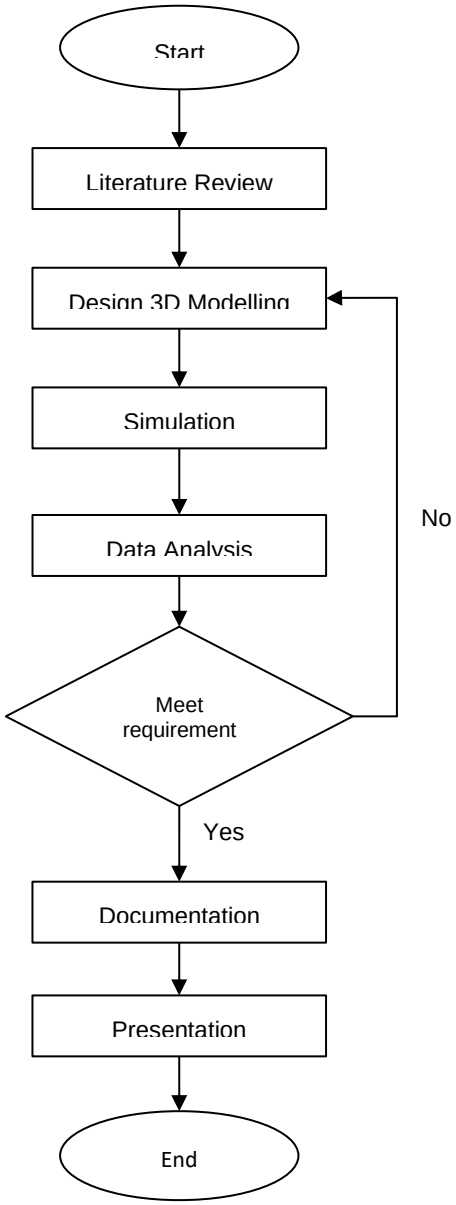


**Figure 3 : Previous Project Flowchart**

## 1.6 Equipment

The research will only focus on computational fluid dynamic simulation and experimental which means the equipment that will be used are a laptop, 3D Printer, and Prototype of water vortex generation system in Hydraulic lab of Universiti Malaysia Sabah. The software that will be used is Solidworks, Ansys Simulation, and Ultimaker Cura software.

## 1.7 Research Expected Outcomes

The outcome of this research should be achieved the objectives of the research. Then, I hope that the research is able to: -

1 Able to know the factor that can decrease the performance of a vortex turbine
2 Able to present the data by using CFD Simulation and Experimental
4 Able to show the result of three different designs to the reference
5 Able to show the effect of baffles on turbine performance

## 1.8 Research Contributions

This project is important to optimize the performance of the vortex turbine. The research can contribute vortex turbine knowledge to other researchers, students, and local communities. Besides that, the research title can contribute some setup starter and simulation data to other researchers to analyze the result. Lastly, this research is able to contribute to the development of the new design of runners and apply it to the local communities. So, by using the new design of the runner, it can improve the efficiency of the vortex turbine power plant.

## 1.9 Research Commercialization

In the vortex turbine design, the runner of the vortex turbine can be developed successfully and used widely by the local communities to decrease the use of fossil fuels to produce electricity. So, it can reduce dependence on the use of fossil fuels in generating electricity in Malaysia. In addition, introduce the use of renewable energy more widely to the local communities especially the use of micro-hydropower plants. The gravitational water vortex power plant do not need a large power plant station. The cost of GWVPP is cheaper which means its suitable for communities that live in rural areas.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Overview

Before determining the water vortex generation system and design of the turbine, the past research of the water vortex generation system was reviewed. In this chapter, some types of vortex turbines that are studied by the research will be discussed based on the geometry of the turbine with respect to torque and efficiency. Performance parameters such as the number of blades and baffle on the blade are also discussed. This chapter serves to build and document the base of background knowledge that was used to design the vortex turbine.

## 2.2 Hydropower

According to Shinn (2018), renewable energy is energy that comes from natural sources or processes that will be constantly replenished, also referred to as clean energy. This can be shown from the sunlight and wind that keep shining and blowing. Many types of renewable energy sources are used nowadays which are solar energy, wind energy, biomass, geothermal and tidal, and wave energy (Shinn, 2018). Hydropower is one of the types of renewable energy source also where there are proven technologies that operate with more than a century of experience.

According to Breeze (2019), the hydropower plant can be classified into four categories which are micro hydropower, mini hydropower, small hydropower, and large

hydropower. The smallest plant called micro hydropower has capacities around 1 to 100kW. Mini hydropower has capacities around 100kW to 1MW. Next, the small hydropower has a capacity of around 1MW to 10 or 30MW. Lastly, large hydropower has a capacity above 10 to 30MW.

## 2.3 Turbine

To turn the power plant generator, the device that has been used to harness the kinetic energy from the fluid such as water, steam, and the air is a turbine where the turbine will convert the energy into rotational motion (useful work). While the fluid flows across the blades, it will be trapping part of the energy as rotational motion (Afework et al., 2021). When the water flows through a turbine's blade, it will lose the kinetic energy which means after it goes through the blade, the kinetic energy will become lesser than the starter kinetic energy. To generate the electricity, the turbine will be mounted with the shaft wheel.

### 2.3.1 Classification of turbines

To classify the type of turbine, it will be divided into two categories which are impulse turbine and reaction turbine.

It will be called an impulse turbine if the kinetic energy of the fluid contacts the turbine blades thru the nozzle and moves the turbine wheel. According to Amardeep (2019), an impulse turbine is also called a tangential flow turbine because water strikes the blade tangentially. A set of rotating machinery of impulse turbines operated at atmospheric pressure which is usually used for high head and low flow rates.

It will be called a reaction turbine if the torque was developed by the reaction of the pressure of gas or water. The reaction turbine's operation can be described by Newton's third law where the action and the reaction were equal and opposites (Saif,