DESIGN AND COMPARISON STUDY OF PELTON TURBINE FOR TORQUE POWER OUTPUT

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A thesis submitted in fulfillment of the requirements for the degree of Bachelor of Mechanical Engineering Technology (Maintenances Technology) with Honours

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DECLARATION

I declare that this Choose an item. entitled "Design And Comparison Study Of Pelton Turbine For Torque Power Output" is the result of my own research except as cited in the references. The Choose an item. has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Date	:	27/01/2022

APPROVAL

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Mechanical Engineering Technology (Maintenances Technology) with Honours.

Signature	:	
Supervisor Name	:	FEBRIAN BIN IDRAL
Date	:	27/01/2022

DEDICATION

Special dedication to my family, my supervisor, my lecturer, my friends, my fellow colleagues, my seniors and all faculty members for all care, supports, guides and believe in me.

ABSTRACT

The use of energy consumption in the world have increases rapidly in these few years. The shortage of the energy supplies becomes a big concern for users. This causes the needs for the renewable energy rises. Since the earth surface covered with 71% of water, therefore hydropower is one of the energy that contain huge potential to become biggest energy suppliances in the world. In this project, the pico-hydro power is introduced. This is because pico-hydro power is small and requires only low head. So, this could enable the application of the pico-hydro power in domestic use and small application and needs. But there is a concern on the power output of the pico-hydro power. This is the main problem that face by the pico-hydro power. There are many types of impulse turbine and reaction turbine. The reaction turbine is mentioned in this project to understand its characteristic and applications. So, in this study the Pelton turbine is used as the turbine for the pico-hydro power. The Pelton turbine is purposely to study for its parameter which is angle of deflection and number of buckets. The combination between these two parameters is important to obtain different combination with its power output. The Solidworks software is used for design and simulation purposes. The design of this Pelton turbine is based on the common use pipe for residential area and then calculates its parameter based on its jet ratio between jet and the turbine diameter. The vertically water drop system is referred and used as the inlet velocity of the turbine. The outlet of the turbine is designed bigger diameter than the inlet this is to prevent the water stuck in the turbine casing because this is to prevent the water stored in the casing affects its rotations. As the experiment on the power output is carried out to study the effects of the turbine geometry on the water flow are inspected and analyzed.

ABSTRAK

Pengunaan tenaga dalam dunia telah meningkat dengan pantas berbading dengan tahun yang lepas. Kekurangan pembekallan tenaga telah menjadi kebimbingan yang besar kepada pengguna. Hal ini telah menyebabkan tenaga yang boleh diperbaharui telah meningkat. 71% permukaan dunia merupakan air dan ini menjadikan tenaga hidro sebagai salah satu tenaga yang berpotensi. Kuasa hidro pico telah diperkenalkan dalam projek ini. Hal ini disebabkan kuasa hidro pico bersaiz kecil dan memerlukan tekanan air yang rendah. Kuasa hidro pico ini telah menunjukkan potensi yang tinggi dalam pengunaan domestik. Kebimbangan besar terhadap penggunaan kuasa hidro pica adalah output kuasanya. Hal ini merupakan kelemahan kuasa hidro pico. Terdapat pelbagai turbin tindak balas dan turbine impuls. Turbin tindak balas telah ditumpu dalam projek ini dan mengkaji ciri dan aplikasinya. Dalam kategori turbin tindak balas turbin kaplan(turbin pelton) telah digunakan sebagai turbin untuk kuasa hidro pico dalam projek ini. Terdapat parameter turbin pelton yang penting akan menjejaskan kuasa tork. Parameter yang diwujudkan dalam kajian ini ialah bilangan baldi dan sudut pesongan. Perisian Solidworks digunakan untuk reka bentuk dan simulasi. Reka bentuk kuasa hidro pico ini adalah berdasarkan pengaipan disekitar perumahan. Hal ini telah menentukan penggunaan nisbah jet iaitu nisbah diameter salur masuk dengan diameter turbin. Selain itu, diameter salur keluar adalah beasr berbanting dengan diameter salur masuk. Hal ini bertujuan untuk mengurankan air yang sangkut dalam selongsong dan mengelakkan air tersebut menganggu putaran turbin. Eksperimen bagi kuasa output telah dijalankan untuk mengenalpasti kesan geometri turbin terhadap aliran air. Selain itu, kesan turbin terhadap kuasa output telah dikaji dan dianalisis.

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LIST OF SYMBOLS AND ABBREVIATIONS

F	-	Force
m	-	Mass
a	-	Accelerations
ρ	-	Density
CFT	-	Cross flow turbine
PAT	-	Pump as turbine
RP	-	Rapid Prototyping
CV	-	Control volume
P	-	Pressure
h	-	Height
g	-	Gravitational Force
v	-	Velocity of water
Φ_{sr}	-	Speed ratio

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CHAPTER 1

INTRODUCTION

1.1 Background

Nowadays, the non-renewable energy is reducing but the needs of human beings to energy are increasing. The non-renewable energy will be used up in the future and it will take a very long period for recovery. Previously, the gas and fuel are categorized as non-renewable energy that are used to produce electricity. Due to the concerns, there are many types of renewable energy is introduced which are solar and hydro. For example, hydropower (dam, ocean wave) and solar (solar panel). The introduction of renewable energy is purposely to replace non-renewable energy.

Hydropower is the renewable energy that emphasis because it is considered as most suitable and efficient renewable energy because Earth's surface is covered by water, which about 71%, where about 96.5% of the water are saltwater.(Peter H. Gleick, 1993) Hydropower has been used since 1878 in United Kingdom, the first house that started using hydropower is Cragside in Northumberland by William Armstrong, 1st Baron Armstrong. The technology of the 1st hydropower is utilized gravity dam (Sadd el-Kafara) in history which built around 2950-2750 B.C which is around 1500 years earlier than the first house that started used hydropower. (Heloisa Yang, Matt Haynes, Stephen Winzenread, 1999) The dam is built as a gravity dam then is replaced by a modern arched gravity dam. An arch dam is a dam that design curvely which possible to carries major parts of its water load horizontally to the abutments by arch action.(Rahman et al., 2020) Now, there are more than 38,000 dam is constructed. In Malaysia, there are 11 dams (updated till 2019) that are used in hydropower (Lee et al., 2018). The oldest dam in Malaysia is “the Bukit Merah Dam” and the largest dam are located in the state of Sarawak “the Bakun Dam” and even in 2015, the dam is categorized as the largest dam in Southeast Asia. (Moses, 2009)

There is classification for hydropower based on its power output. For examples, small-hydro, mini-hydro, micro-hydro and pico-hydro are hydropower plants that provides alternative ways to generates electricity without causing any damage towards environment (Musa et al., 2018). Figure 1.1 shows the classification of the hydropower with referencing towards its power output. Pico-hydropower is defined as a type of small-scale green energy that possible to produce less than 5kW and capable with different type of conditions. Basically, the pico-hydropower can build up on a small run-of-river approach with a small plant that build on land and even using the sources from household appliances. Whereas pico-hydro power required a small land and low flowrate that does not damage and influence the landscape or even habitat at surroundings.

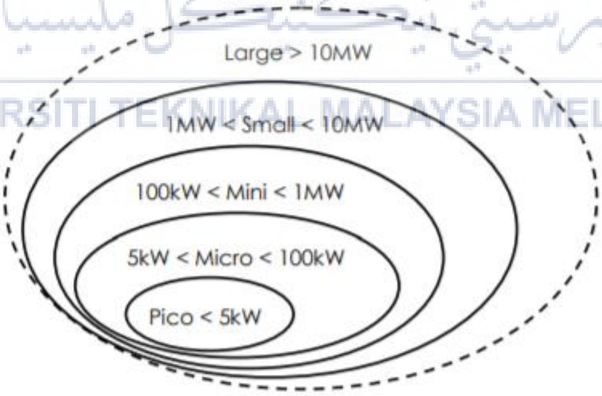

Figure 1.1 Classification of the type of hydropower

(Farriz et al., 2015)

Since the technology becoming more advanced the size of hydropower unit can be minimized, the small hydropower is becoming more important for human needs. By using a small flowrate to produce a power that can be used for small housing needs. In Figure 1.2 the production layout for a pico-hydro turbine system is defined. Based on the figure below, the design process includes selection of turbine types, calculations of turbine capacity and component parts design which is the important process to succeed a pico-hydro turbine. (Ebhota & Inambao, 2017)

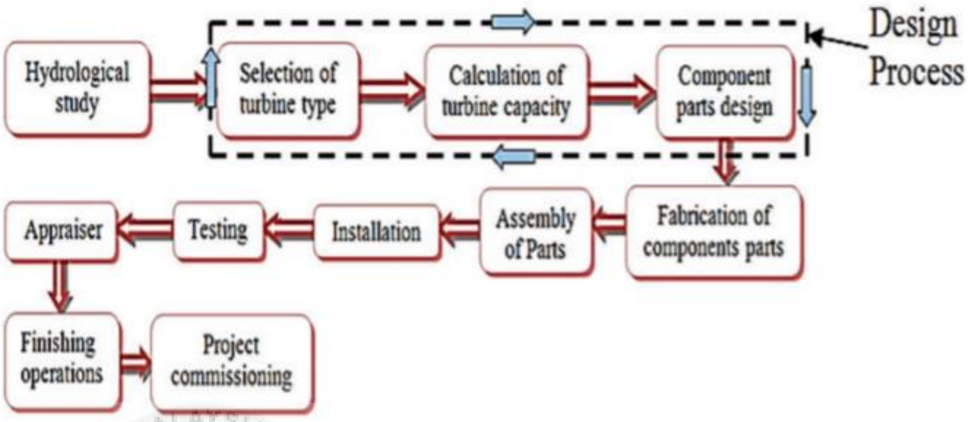

Figure 1.2 Production Flow for Pico-Hydro Turbine

(Ebhota & Inambao, 2017)

1.2 Problem Statement

There is a concern of the worldwide nations about the increases of energy consumptions. (Sadorsky, 2009) According to Hassan et al., Malaysia also shows a big trend of increases of energy consumptions. This shows the increases of the needs of renewable energy to replace non-renewable energy and ensure the energy supplies. There are many hydro powers introduced, but mostly it required high head or big surface area to build and this will cause habitat to be destroyed. This causes the needs of small size hydro power increases but the instability of the small size hydropower becoming the main concern of its potentials. The pico-hydro power is one of the small size hydropower that having a high potential for domestic use. Although the power output of the pico-hydro power is low, but it still can support some low power appliances. There are few types of pico-hydro power turbine that can be used in domestic field which are, impulse turbine and reaction turbine. In this project, the Pelton turbine is selected as pico-hydro power. Pelton turbine is impulse type of turbine. Since the efficiency of the turbine is important for pico-hydro power, hence design optimization is important to ensure the torque produced is maximized. However, the simulation is important because it could illustrate the succeed of the pico-hydro power.

Therefore, this study is carried out to investigate the characteristic of the Pelton turbine as pico-hydro power.

1.3 Research Objective

The objectives are as follows:

a) To design Pelton turbine with variable parameter

b) To analyse the simulated power output

c) To compare the best combination of parameter

1.4 Scope of Research

The scope of this research are as follows:

- The Solidworks used to sketch and design the water turbine
- The designed turbine is simulated in Solidworks Software
- To analyse the simulated power output results from Solidworks Software
- Comparison study to identify the best combination of parameters

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter is purposely to discuss the literature review from textbooks, journals or conference paper that related with this project to achieve the objectives of this project.

2.2 Basic principles

Basically, momentum of the body theory is referred. When the moving water pass through a turbine. This involves the transfer of energy from water to the turbine. According to the Newton's 2^{nd} law of motions, the force (f) will make a body to accelerates by an amount which known as accelerations (a) that is inversely proportional to its mass (m) (Kraus et al., 2020). This shows when a force continues acted on the turbine the turbine will starts to move and accelerate. The momentum equation is then can be derive from the Newton's 2^{nd} law (Cengel & J. M. Cimbala, 2014). While the Newton's 3^{rd} law states when a body exerts a force on a second body, the second body will exert an equal and opposite force on the first.

For a rigid body of mass, m. The Newton's 2^{nd} law is expressed as below

$$\boldsymbol{Newton's\ 2^{nd}\ law}: \quad \boldsymbol{F = ma = \frac{dV}{dt} = \frac{d(mV)}{dt}} \tag{1}$$

Where 'F' is the net force acting on the body and 'a' is the acceleration of the body under the influences of 'F'

The linear momentum or the momentum of body basically is the product of the mass and the velocity of a body (Caughey, 2004). The momentum of a rigid body of mass ‘m’ that with a moving of the velocity ‘v’ is ‘mv’ (Cengel & J. M. Cimbala, 2014). According to the Newton’s 2nd law that have expressed in Eq 1 can also be state as the rate of change of momentum of body which is equal to the net force acting on the body. This statement is important that Newton’s original statement about 2nd law, which is more appropriate for the use in fluid mechanics when determine the force generated in the results for velocity change in fluid streams. Therefore, the Newton’s 2nd law is always referred to the linear momentum equations and can be expressed more generally as.

$$\sum \boldsymbol{F} = \frac{\boldsymbol{d}}{\boldsymbol{dt}} \int_{sys} \boldsymbol{\rho \vec{v}\, dv} \tag{2}$$

Where dm = ρdV is the mass of a differential volume element dV, and ρV dV is the momentum. Therefore, Newton’s 2nd law can be stated as the sum of all external forces acting on a system is equal to the time rate of change of linear momentum of the system. This system is available for a coordinate system that is at rest or moves with a constant velocity which called an inertial coordinate system or an inertial reference frame.

$$\begin{pmatrix}\text{The sum of all}\\ \text{external forces}\\ \text{acting on a CV}\end{pmatrix} = \begin{pmatrix}\text{The time rate of change}\\ \text{of the linear momentum}\\ \text{of the contents of the CV}\end{pmatrix} + \begin{pmatrix}\text{The net flow rate of}\\ \text{linear momentum out of the}\\ \text{control surface by mass flow}\end{pmatrix}$$

Figure 2.1 The relationship of CV and linear momentum

(Cengel & J. M. Cimbala, 2014)

According to the figure above, the $\vec{V_r} = \vec{V} - \overrightarrow{V_{CS}}$ is the fluid velocity which relative to the control surface (for use in mass flow rate calculations at all locations where the fluid crosses the control surface), and $\vec{V}$ is the fluid velocity as viewed from an inertial refrenced frame. Besides, the produced of $\rho(\vec{V_r} \cdot \vec{n})\, dA$ representing the mass flow rates through an area element dA into or out of the control volume.

If the net force exerted on the system is zero, the system's momentum will remain constant, thus the momentum of such system is conserved. This is called the principle of conservation of momentum. This concept has been extremely useful tool in analysis of the impact of collisions. For contrast, after shooting the momentum of the loaded rifle has to be zero because the momentum of the rifle is zero before shooting, thus it has that same momentum in opposite directions. So, the vector sum of both items must be zero. The vector quantities in this type of case are force, acceleration, velocity and momentum. The momentum is multiple velocity constants; thus, the direction is similar to the velocity direction.

Nevertheless, the momentum of fluid is used to explain the reaction of a turbine. This is because the turbine required a steady flow with one inlet and one outlet. The mass flow rate that flows between turbine is a constant. In momentum of fluid theory, the force in a fixed control volume is an average of inlet and outlet. Based on the figure below, the reaction force on the support can causes the turbine to move and started to rotate.

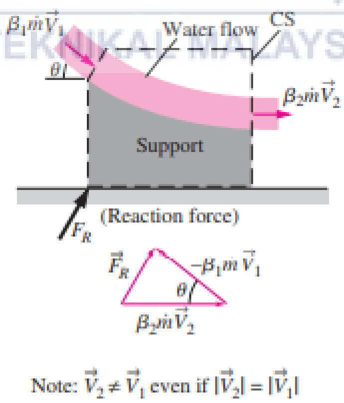

Figure 2.2 The reaction force on the support

(Cengel & J. M. Cimbala, 2014)

2.3 Type of Turbine and Suitability

Basically, there are two major of hydro turbine which are impulse and reaction. Based on Figure 2.3, these approximate data can helps in determination type of turbine selected in projects and its applications thru head classification (Matt Deady, 2017). There are few conditions that needed to be concern when choosing a suitable turbine. The turbine application range chart in Figure 2.4 can also be referred when choosing a suitable turbine by create an area on interest and by looking at the area of interest the selection of turbine can be clearly known (Williamson et al., 2014).

Head Classification	**Turbine Type**		
	Impulse	*Reaction*	*Gravity*
High (>50m)	• Pelton • Turgo		
Medium (10-50m)	• Crossflow • Turgo • Multi-jet Pelton	• Francis (spiral case)	
Low (<10m)	• Crossflow • Undershot waterwheel	• Propeller • Kaplan • Francis (open-flume)	• Overshot waterwheel • Archimedes Screw

Figure 2.3 Turbine types selection based on Head Classification

(Matt Deady, 2017)

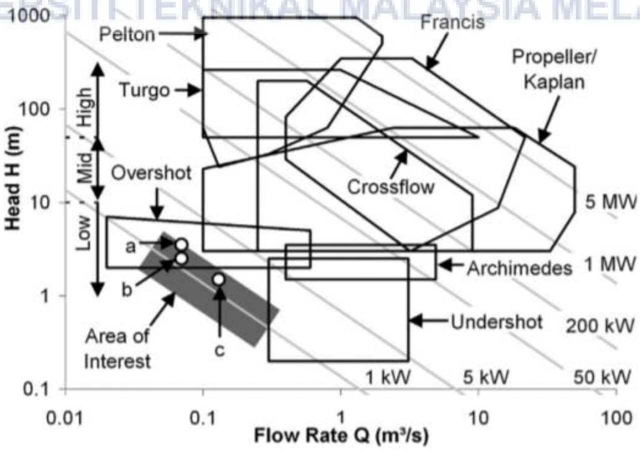

Figure 2.4 Typical turbine application range chart

(Williamson et al., 2014)