Faculty of Engineering

DEVELOPMENT OF IN-STREAM CROSS FLOW MICRO HYDRO TURBINE

Siti Mas Arena binti Liakbar

Master of Engineering
(Mechanical and Manufacturing Engineering)
2013

UNIVERSITI MALAYSIA SARAWAK

BORANG PENGESAHAN STATUS TESIS

Judul: **DEVELOPMENT OF IN-STREAM CROSS FLOW MICRO HYDRO TURBINE**

SESI PENGAJIAN: 2011/2012

Saya **SITI MAS ARENA BINTI LIAKBAR**

mengaku membenarkan tesis * ini disimpan di Pusat Khidmat Maklumat Akademik, Universiti Malaysia Sarawak dengan syarat-syarat kegunaan seperti berikut:

1. Tesis adalah hakmilik Universiti Malaysia Sarawak.
2. Pusat Khidmat Maklumat Akademik, Universiti Malaysia Sarawak dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Membuat pendigitan untuk membangunkan pangkalan Data Kandungan Tempatan.
4. Pusat Khidmat Maklumat Akademik, Universiti Malaysia Sarawak dibenarkan membuat salinan tesis ini sebagai bahan pertukaran antara institusi pengajian tinggi.
5. **Sila tandakan (√)di kotak yang berkenaan:

[ ]	SULIT	(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA RASMI 1972)
[ ]	TERHAD	(Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/ badan dimana penyelidikan dijalankan)
[√]	TIDAK TERHAD	

Disahkan oleh

(TANDATANGAN PENULIS) (TANDATANGAN PENYELIA)

Alamat Tetap: No 17, Lot 3744, Blok 26
Taman Univista
94300 Kota Samarahan
Sarawak.

Assoc. Prof Dr. M. Shahidul Islam

Tarikh:

Tarikh:

CATATAN:
* Tesis dimaksudkan sebagai tesis bagi Ijazah Doktor Falsafah, Sarjana dan Sarjana Muda.
** Jika tesis ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh tesis ini perlu dikelaskan sebagai SULIT atau TERHAD.

APPROVAL SHEET

This Master Thesis, which entitled "*Development of In-Stream Cross Flow Micro Hydro Turbine*", was prepared by **Siti Mas Arena binti Liakbar** as a partial fulfillment for Master of Engineering (Mechanical and Manufacturing Engineering) is hereby read and approved by:

Assoc. Prof. Dr. M. Shahidul Islam
Project Supervisor
Faculty of Engineering
Universiti Malaysia Sarawak

Signature: ____________________
Date : ____________________

DEVELOPMENT OF IN-STREAM CROSS FLOW MICRO HYDRO TURBINE

SITI MAS ARENA BINTI LIAKBAR

This project is submitted in partial fulfilment of the requirement for the Master of Engineering (Mechanical and Manufacturing Engineering)

Faculty of Engineering
UNIVERSITI MALAYSIA SARAWAK
2013

Specially dedicate to my loving family, who has supported and encouraged me through good time and hard time

ACKNOWLEDGEMENT

In the name of Allah, the Most Gracious and the Most Merciful

Alhamdulillah, all praises to Allah for the strengths and His blessing in completing this thesis. Special appreciation goes to my supervisor, Assoc Prof Dr M Shahidul Islam, for his supervision and constant support. He inspired me greatly to work in this project. Not forgotten, my appreciation to my co-supervisor, Dr. Syed Tarmizi Syed Shazali and Dr Thelaha Masri for their support and knowledge regarding to this project.

I would like to express my appreciation to financial support given by Research & Innovation Section, JKR Malaysia Training & Research Division and Faculty of Engineering, UNIMAS.

Many thanks go to my lecturer Abg Mohd Nizam Abg Kamaruddin and all technician staff of the Mechanical Engineering Department and Chemical Engineering Department for their advice, opinion and help throughout this project. Sincere thanks to all my friends especially Hafiza and Akmal for their kindness and moral support during my study.

Last but not least, my deepest gratitude goes to my beloved parents; Mr. Liakbar Matusin and Mrs. Jeriah Ali Hassan and also to my sisters for their endless love, prayers and encouragement. To those who indirectly contributed in this research, your kindness means a lot to me.

ABSTRACT

The advancement of present world is largely depending on fossil fuel which is a proven cause of global warming. This research has been undertaken to develop an in-stream low velocity water turbine by extracting green energy in order to reduce burning of fossil fuel and to uphold the concept of sustainable environment. This research aims to develop a laboratory scale (LST) and prototype cross flow micro hydro turbine (CFMHT) by extracting kinetic energy from in-stream water. Ducting system and flywheel concept have been incorporated into structure of CFMHT for increasing energy extraction and to maintain uniform speed in turbine operations. The results reported in this thesis have shown that at duct angle 45^o both in inlet-outlet, LST has extracted 2.3 Watt at water velocity 0.5 m/s which contributed to generate turbine speed 70 RPM. On the other hand, prototype turbine test at duct angle 45^o both in inlet-outlet have shown that at water velocity 0.3 m/s, energy extraction was 5.42 Watt which contributed to turbine speed 18 RPM. Development of micro hydro turbine has huge used in off grid areas for providing clean energy. This energy will contribute to grow small scale agriculture projects and SME which will create employment opportunities. This study suggests for further study by improving its energy extraction efficiency and developing a feasible installation system in in-stream water for continuous operations.

ABSTRAK

Kemajuan dunia sekarang sangat bergantung kepada bahan api fosil yang merupakan punca pemanasan global. Kajian ini telah dijalankan untuk membangunkan turbin dalam aliran air perlahan dengan mengekstrak tenaga hijau dalam usaha untuk mengurangkan pembakaran bahan api fosil dan untuk menegakkan konsep persekitaran mampan. Kajian ini bertujuan untuk membangunkan skala makmal (LST) dan prototaip aliran silang mikro hidro turbin (CFMHT) dengan mengekstrak tenaga kinetik daripada air dalam aliran. Menyalurkan konsep sistem dan roda tenaga telah dimasukkan ke dalam struktur CFMHT untuk pengekstrakan tenaga yang semakin meningkat dan untuk mengekalkan kelajuan seragam dalam operasi turbin. Keputusan yang dilaporkan dalam tesis ini telah menunjukkan bahawa pada sudut 45^o di kedua-dua masuk keluar saluran, LST telah diekstrak 2.3 *Watt* pada halaju air 0.5 m/s yang menyumbang untuk menjana kelajuan turbin 70 RPM. Selain itu, ujian prototaip turbin pada 45^o di kedua-dua masuk keluar saluran telah menunjukkan bahawa pada halaju air 0.3 m/s, pengekstrakan tenaga adalah 5.42 *Watt* yang menyumbang kepada turbin RPM kelajuan 18. Pembangunan mikro hidro turbin banyak digunakan di kawasan grid off untuk menyediakan tenaga bersih. Tenaga ini akan menyumbang untuk mengembangkan projek pertanian berskala kecil dan PKS yang akan mewujudkan peluang pekerjaan. Kajian ini mencadangkan untuk kajian selanjutnya dengan meningkatkan kecekapan pengeluaran tenaga dan membangun satu sistem pemasangan dilaksanakan dalam air untuk operasi berterusan.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES

NOMENCLATURE

V	- Water velocity (m/s)
V_i	- Inlet water velocity (m/s)
V_o	- Outlet water velocity (m/s)
ΔV	- Velocity drop (%)
P_b	- Energy extraction (W)
T	- Torque (Nm)
P_s	- Shaft power (W)
LST	- Laboratory scale turbine
CFMHT	- Cross flow micro hydro turbine
RPM	-Revolution per minute

Subscripts

i	- inlet
o	- outlet
b	- blade
s	- shaft

CHAPTER 1

INTRODUCTION

1.0 Background of Study

Malaysia is well endowed with both conventional and renewable sources of energy; and these energy sources have been contributing significantly to rapid growth of Malaysian economy. Among the conventional energy sources fossil fuel is the component which composed of gas, oil and coal; on the other hand, in Malaysia, the main part of renewable energy is hydroelectricity; however, the share of fossil fuel in Malaysian fuel mix is about 93% (Penny *et al.*, 2010).

It has been recorded that the burning of fossil fuel is the main cause of global warming (Ong *et al.*, 2011) and by products of this fuel such as CO_2, SO_2 and NO_x are the threatening factors to environment. Indeed, these gases are also known to be greenhouse gas. Eventually, these gases are contributing to increase pollution density in air and makes ecosystem unbalance (Cowan & Harmon, 2007). The current estimated emission, due to burning of fossil fuel in Malaysia in the year 2010, is about 56,643,906 ton; and the significant part is coming from manufacturing industries. Nowadays, Malaysia is moving toward industrial economy; obviously, which will create more electricity demand. This information indicates that Malaysian economy is going to be highly depending on energy. If this country continue to grow with fossil fuel energy; the present ecosystem will be unbalanced; which may lead towards unsustainable economic development. In order to maintain a sustainable industrial growth and economy, pollution free energy production is essential. To address this sensitive issue, R&D on energy sector is essential. Indeed, the current research project has been undertaken to meet this challenge; with a target for developing a technically and economically feasible water turbine suitable for Malaysian environment. It is obvious to state that this research project was served a small part of the requirement for developing micro hydro turbine for producing electricity from green energy sources.

Recently, micro-hydro projects are becoming popular to society for generating electricity due to no fuel cost for them. Micro hydro converts the kinetic and potential energy of flowing water through water turbine shaft to generator for producing electricity. Most large scale hydro usually install with dam to ensure maximum power output. In contrast, most in-stream micro hydro water flow is used in turbine blade, after which it is returned to main stream. The efficiency of most micro hydro generators founds in a range of 30 to 70%. The micro hydro system is suitable for "run-of-the-river" installations because it is not connected to the grid and also suitable for remote rural areas. As dam is not required to operate in-stream micro hydro systems, the capital cost of this type of turbine is less compare to the large scale hydro systems (Hislop, 1992). Latest studies on micro hydro system suggest that this source is reliable and friendly to environment compare to other sources of energy. It also provides solution with energy supply for remote and hilly areas where the extension of grid system is not economically and technically feasible (Nathan *et al.,* 2009). But the main constrain in operations of this type of turbine are; insufficient water flow and in case of water velocity less than 1 m/s ($V < 1$ m/s). In these two cases this turbine is fully inefficient.

1.1 Research Problem Statements

Malaysian electricity generation is heavily dependent on fossil fuels and the share of renewable energy in the electricity generation is insignificant. Although it is a commonly known fact that the fossil fuel sources in Malaysia are finite and gradually depleting and at the same time burning of fossil fuels is the main sources of emission of greenhouse gases. For that reason, research project of green energy should be taken to develop a green and economically electricity generation system suitable for Malaysian economy.

Indeed, energy extraction by turbine blades is the main issue of this research project but the optimization of energy extraction is key factor of success of this research project. The flow direction of water stream at inlet and outlet points of turbine could play a vital role in releasing its inherent kinetic energy to turbine blades. Hence controlling water flow direction need consider for optimizing energy extraction.

On the other hand, most of commercial available micro hydro turbine are suitable operate at water velocity more than or equal 1m/s. However, major percentages of people are living in rural area where water velocity is about 1m/s or less. This is a constraint of using commercial available micro hydro turbine. Hence, developing a micro hydro turbine which is suitable to operate at low water velocity is key analytical factor needs to address carefully in order to design efficient micro hydro turbine.

1.2 Objectives of Research

The main objective of this study is to develop an in-stream low velocity CFMHT and test for characterizing operating performance. In order to achieve research objective, this research is focused on the following specific objectives:

1. To simulate:
    - i. Energy flow through turbine
    - ii. Energy extraction and shaft power
2. To develop laboratory scale CFMHT for studying operating behaviour of turbine
3. To develop prototype CFMHT for studying operating behaviour of turbine

The operating behaviour of turbine is focused on:

- i. Effect of flywheel on Turbine RPM
- ii. Effect of inlet water velocity on energy extraction
- iii. Effect of velocity drop on energy extraction
- iv. Effect of duct angle on energy extraction
- v. Effect of water velocity on turbine rotation
- vi. Effect of velocity drop on turbine rotation
- vii. Effect of turbine RPM on shaft power
- viii. Combine effect of inlet velocity and velocity drop on energy extraction
- ix. Combine effect of inlet water velocity and turbine rotation on energy extraction

1.3 Research Novelty

The theoretical aspect of this research provides a novel approach in operating turbine at low speed water current with higher extraction energy. The practical aspect of this research has managed to address the issue of global warming by producing green electricity where can be applied at rural area. The turbine has produced electricity without fuel which gives a sense of low cost electricity without pollution. The invented turbine has a wide use in off-grid area especially in remote location. Furthermore it has power to support rural economy by proving energy for processing small scale agro products and domestic use.

1.4 Thesis Outline

This report contains five chapters which include introduction, literature review, research methodology, result and discussion, and conclusion.

Chapter 1 describes the introduction of project which includes background of the study, energy supply and power generation, Malaysia energy policy, effect of fossil fuel on environment, green energy, source of renewable energy, problem statements, research objectives, research novelty and these outline.

Chapter 2 focuses on the literature review that referred to turbine classification, overview on micro hydro project, research and development of micro hydro in Malaysia, and development of energy transmission for micro hydro turbine.

Chapter 3 elaborates more on the research method of developing micro hydro turbine system. Simulation, procedure of developing and testing laboratory scale and prototype cross flow micro hydro turbine, data analysis method and data processing method also describes in this chapter.