Faculty of Manufacturing Engineering

DESIGN AND DEVELOPMENT OF HORIZONTAL AXIS WIND BLADE IN REGENERATIVE ENERGY SYSTEM FOR COOLING TOWER

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A thesis submitted
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DECLARATION

I declare that this thesis entitled “Design and Development of Horizontal Axis Wind Blade Regenerative Energy System for Cooling Tower” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : .....

Date : .....

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Manufacturing Engineering.

Signature :…….....

Supervisor Name :…….....

Date :…….....

DEDICATION

This thesis is dedicated

to my beloved parents and dearest siblings,

who have always been an infinite source of inspiration and love.

ABSTRACT

In Malaysia which is experiencing humid and hot climates throughout the year, usage of cooling tower is very common in most industry and company to cool down the machineries. The waste produced into the environment by these cooling towers is in the form of heat and wind energy. As an initiative for sustainable development, there is a need for development of an efficient and effective energy regenerative system. This thesis presents a work on design and development of such system, named Wasted Kinetic Energy Recovery System (WKERS) to harvest the discharged wind energy from a second source wind energy that is the cooling tower. Cooling tower provides the most suitable wind speed during operation, and the best part is that the wind supply is stable and constant. This study aims to determine the possibility of generating electricity using a regenerative system. In accordance with that, this study also aims to establish the most suitable blade design for the Horizontal Axis Wind Turbine (HAWT) of WKERS. Hence, three different types of blades, which are elliptical, swept and National Renewable Energy Laboratory (NREL) Phase VI blades were designed and their performances were evaluated for the application in WKERS. Firstly, the three blades were sketched and designed using SolidWorks software. Next, linear and rotational flow simulations were carried out using Computational Fluid Dynamics (CFD) analysis to determine the performance and efficiency of the different blade designs. The three blades were fabricated as prototypes. Experimental studies were carried out to validate the rotational speed of each wind turbine blade in order to evaluate the performances of each blade design. Simulation results showed that the blade with the best lifting effect was the swept blade, however more vortices were created after the trailing edge and caused high induced drag to the blade itself. Results obtained showed that the elliptical blade possess the best overall performances of the three proposed designs. The fabricated prototype of the elliptical blade produced up to 508 rev/min of average rotational speed and was the highest value compared to the other two blade types. The elliptical blade design was concluded as the best blade design for WKERS based on results of both simulations and experimental work.

REKA BENTUK DAN PEMBANGUNAN BILAH ANGIN PAKSI MENDATAR DALAM SISTEM TENAGA REGENERATIF UNTUK MENARA PENYEJUKAN

ABSTRAK

Malaysia mengalami iklim lembap dan panas sepanjang tahun, penggunaan menara penyejukan adalah sangat biasa di kebanyakan industri dan syarikat untuk menyejukkan jentera. Tenaga haba dan tenaga angin telah terjadi sisa yang dihasilkan ke dalam alam sekitar oleh menara penyejukan ini. Sebagai inisiatif untuk pembangunan mampan, kini terdapat keperluan untuk membangunkan sistem penjanaan semula yang cekap dan berkesan. Tesis ini membentangkan satu reka bentuk dan pembangunan sistem sedemikian, yang dinamakan Sistem Pemulihan Tenaga Kinetik (Waste Kinetic Energy Regeneration System - WKERS) untuk menuai tenaga angin yang dikeluarkan daripada tenaga angin sumber kedua iaitu menara penyejukan. Lagipun, menara penyejuk menyediakan kelajuan angin yang paling sesuai semasa operasi, dan bahagian yang terbaik ialah bekalan angin stabil dan berterusan. Kajian ini bertujuan untuk menentukan kemungkinan menjana elektrik menggunakan sistem regeneratif. Selaras dengan itu, kajian ini juga bertujuan untuk membina reka bentuk bilah yang paling sesuai untuk turbin angin paksi mendatar (Horizontal Axis Wind Turbine - HAWT) berdasarkan WKERS. Oleh itu, tiga bilah yang berbeza, iaitu bilah lonjong, bilah menyapu dan bilah Tenaga Makmal Tenaga Diperbaharui Kebangsaan (National Renewable Energy Laboratory - NREL) Fasa VI telah direka dan prestasinys telah dinilai untuk penggunaan di WKERS. Pertama sekali, tiga-tiga bilah telah direkabentuk dan direka menggunakan perisian SolidWorks. Seterusnya, simulasi aliran linear dan putaran dijalankan menggunakan analisis dinamik cecair pengkomputeran (Computational Fluid Dynamics - CFD) untuk menentukan prestasi dan kecekapan reka bentuk bilah yang berlainan. Tiga bilah telah difabulasi sebagai prototaip. Kajian eksperimental dijalankan untuk mengesahkan kelajuan putaran masing-masing bilah turbin angin untuk menilai prestasi setiap reka bentuk bilah. Hasil simulasi menunjukkan bahawa bilah dengan kesan mengangkat yang terbaik adalah bilah menyapu, namun lebih banyak vortex telah dihasilkan pada bahagian belakang bilah dan menyebabkan seretan teraruh tinggi ke bilah itu sendiri. Hasil yang diperoleh menunjukkan bahawa bilah lonjong mempunyai prestasi keseluruhan yang terbaik di antara tiga reka bentuk yang dicadangkan. Prototaip fabulasi bilah lonjong dihasilkan sehingga 508 rev/min kelajuan putaran purata dan paling tinggi berbanding dengan dua jenis bilah yang lain. Reka bentuk bilah elips disimpulkan sebagai reka bentuk bilah yang terbaik untuk WKERS berdasarkan keputusan kedua-dua simulasi dan kerja percubaan.

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3D	-	3-Dimensional
AC	-	Aerodynamic Centre
AoA	-	Angle-of-Attack
AR	-	Aspect Ratio
BCA	-	Boeing Commercial Airplane
CAD	-	Computer-Aided Design
CFD	-	Computational Fluid Dynamics
DP	-	Decimal Places
FiT	-	Feed-in Tariff
FKP	-	Manufacturing Engineering Faculty
HAWT	-	Horizontal Axis Wind Turbine
LCD	-	Liquid-Crystal Display
MAC	-	Mean Aerodynamic Chord
MMGS	-	Millimetre, Gram, and Second
MMO	-	Mach Maximum Operating
MTOW	-	Maximum Takeoff Weight
MW	-	Megawatt
NASA	-	National Aeronautics and Space Administration
NREL	-	National Renewable Energy Laboratory

r	-	Radius
ROI	-	Return on Investment
RoR	-	Rate of Return
RPM	-	Revolutions per Minute
S	-	Wingspan
SEDA	-	Sustainable Energy Development Authority
T	-	Taper Ratio
TSR	-	Tip Speed Ratio
UTeM	-	Universiti Teknikal Malaysia Melaka
VAWT	-	Vertical Axis Wind Turbine
WKERS	-	Wasted Kinetic Energy Recovery System

LIST OF PUBLICATIONS

J. B. Goh, Z. Jamaludin, F. A. Jafar, M. Mat Ali, M. N. Ali Mokhtar and C. H. Tan, "Analytical Study on Different Blade-shaped Design of HAWT for Wasted Kinetic Energy Recovery System (WKERS)," *IOP Conference Series: Material Science and Engineering*, vol. 210, no. 1, 2017.

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CHAPTER 1

INTRODUCTION

This chapter highlights the background of this research that focusses on design and development of a waste energy recovery system for sustainable environment and industrial eco-system. The content of this chapter includes the problem statement, research objectives, scopes and the thesis outline. The background covers the energy resources and introduction of renewable energy practices in Malaysia highlighting the important of embracing elements of sustainability especially by engaging innovations in area related to conversion of waste energy into some other beneficial form of energy.

1.1 Background

Energy resources are limited since the world energy demand increases in accordance to the population growth and the economic development. Growing concern in Malaysia has arisen about the energy consumption and its adverse environment impacts. Energy is commonly extracted from fossil fuels like coal, natural gas and petroleum which are also the primary sources for energy for the rest of the world (EIA, 2015). Over-harvesting of fossil fuels brings negative impacts to human health and environment especially through the emissions of greenhouse gases (Chong et al., 2014).

Hence, to develop a long-term sustainability, the utilization of renewable energy such as solar, wind, rain, tides and waves is encouraged. As a mean to minimize the negative impacts on energy supply chain in Malaysia, renewable energy has been considered as the