UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BLADE-GENERATOR STRUCTURE ANALYSIS AND TOPOLOGY OPTIMIZATION OF SAVONIUS VERTICAL AXIS WIND TURBINE

This report is submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Mechanical Engineering Technology (Maintenance Technology) with Honours.

by

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TAJUK: **BLADE-GENERATOR STRUCTURE ANALYSIS AND TOPOLOGY OPTIMIZATION OF SAVONIUS VERTICAL AXIS WIND TURBINE**

SESI PENGAJIAN: **2017/18 Semester 1**

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APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Mechanical Engineering Technology (Maintenance Technology) with Honours. The member of the supervisory is as follow:

……………………………………

(Project Supervisor)

ABSTRAK

Era menggunakan tenaga angin untuk mengeluarkan tenaga elektrik telah bermula sejak lewat tahun 1800-an. Turbin angin adalah satu mekanisme yang digunakan untuk menukar tenaga kinetik angin kepada tenaga mekanikal melalui bilah turbin dan kemudian menukar tenaga mekanikal rotor ke tenaga elektrik melului penjana. Walaubagaimanapun, penjana yang sedia ada memerlukan tork yang tinggi untuk memulakan putaran, oleh itu kelajuan angin yang lebih tinggi diperlukan untuk memulakan putaran. Projek ini dijalankan untuk menganalisis pengedaran tekanan ke atas bilah turbin angin jenis Savonius yang direka apabila tenaga angin digunakan pada bilah. Reka bentuk bilah Savonius dihasilkan melalui rumah kualiti dan carta morfologi. 5 reka bentuk telah dipilih dan dibandingkan dengan kaedah Pugh untuk menentukan reka bentuk paling sesuai dalam kajian ini. Selepas reka bentuk dipilih, reka bentuk turbin angin dikaji dengan menggunakkan pengagihan kuasa yang berlainan di permukaan bilah. Analisa dilakukan dengan menggunakan Inspire 2017 yang mana pemutar dipasang pada posisi menggunakan sokongan dan analisa bermula setelah bahan-bahan dipilih. Pengedaran tegasan ke atas bilah disebabkan daya yang dikenakan akan diperolehi. Keputusan menunjukkan bahawa kebanyakan tekanan lebih tinggi di kawasan berhampiran dengan pemutar. Reka bentuk kemudian dioptimumkan melalui pengoptimuman topologi. Hasil daripada pengoptimuman menunjukkan bahawa reka bentuk bilah sudah dalam keadaan optimum, tiada bahagian yang perlu dikeluarkan daripada reka bentuk tersebut.

ABSTRACT

The era of using wind energy to produce electricity was started since the late of 1800s.Wind turbine is a mechanism that used to convert kinetic energy of wind energy to mechanical energy through the blades and convert the mechanical energy of rotor to electricity through generator. However, the generator existed needs a high torque to start the rotation, hence higher wind speed needed to be provided in order to initiate the rotation. This project is carried out to analyze the stress distribution over the blade of Savonius type vertical axis wind turbine designed as the wind energy is applied to the blade. The designs of Savonius blade is generated through house of quality and morphological chart. There are 256 alternatives generated through morphological chart. 5 designs are chosen and compared using Pugh Method to determine the design used in this research. After the design is decided, the design is analyzed by applying different force distribution over the blade surface. The analysis is carried out using Inspire 2017 which the rotor is fixed in position using support and the analysis started after the material of parts are chosen. The stress distribution over the blade due to the force applied will be obtained. The results show that most of the stress is higher at the area near to the rotor. The design later is optimized through topology optimization. The result of optimization shows that the blade design already in optimum state which no parts has to been deducted from the design.

DEDICATIONS

To my beloved parents and family,

my supervisor,

and to all my friends,

thanks for all support and ideas.

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First of all, I would like to express my deepest appreciation to all those who guiding me and encouraging me to complete this Final Year Project Report. A special gratitude to my supervisor, Mr Mohamed Saiful Firdaus bin Hussin, whose contribution in guiding from the start to the end of this project. I appreciate the valuable guidance and advices that given by my supervisor. Best regards to my family members that continuously support me and helping until the end of this project. I would also like to thank to my friends that provide assists in my design drawing and simulation processes. With all their effort and guide, this report is able to finish within the time given.

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LIST OF ABBREVIATIONS, SYMBOLS, AND NOMENCLATURE

ABET	-	Accreditation Board for Engineering and Technology
ATOM	-	Abaqus Topology Optimization Module
CFRP	-	Carbon Fiber Reinforced Polymer
FEA	-	Finite Element Analysis
GFRP	-	Glass Fiber Reinforced Polymer
GPa	-	Giga Pascal
g/cm^3	-	Grams per cubic centimeter
HAWT	-	Horizontal Axis Wind Turbine
kg/m^3	-	Kilograms per cubic meter
m	-	Meter
m^2	-	Square meter
MPa	-	Mega Pascal
MW	-	Mega Watt
m/s	-	Meters per second
N	-	Newton
NURBS	-	Non-Uniform Rational Basis Spline
NVH	-	Noise-Vibration-Harshness
Pa	-	Pascal

PC	-	Polycarbonate
PE	-	Polyethylene
PP	-	Polypropylene
VAWT	-	Vertical Axis Wind Turbine

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

The issues of global warming due to combustion of fossil fuels have become more and more critical and by time, the fossil fuel resources will become limited. Hence, there are many types of renewable energy that had been discovered until now to replace the fossil fuels, which include wind energy, solar energy, biomass etc. However, among all types of renewable energy, wind energy has more advantages compare to others which is available in all countries and no matter day time or night time. Besides that, it is the cheapest type of renewable energy and it is clean. It also does not cause pollution like combustion of fossil fuels which emit unwanted gas. The importance of wind energy had been acknowledged by peoples for a long time. Wind energy had been used by peoples as a power to navigate the sail boats for thousands of years. Besides that, the wind energy also had been used as an alternative to pump water and grind grain. The era of producing electricity using wind energy was started since the late of 1800s. The first wind turbine was created by Charles Brush of United States in 1888. The innovation of Poul La Cour after Charles Brush was a success in 1891 to 1918 and this innovation has helped rural areas in Denmark to provide electricity (Rivkin and Silk, 2013). The success of this innovation has been extensively use and improve until now. The wind turbine can be generally classified into two types based on its rotation axis, which are Horizontal Axis Wind Turbine (HAWT) and Vertical Axis Wind Turbine (VAWT). A HAWT has a horizontal rotor shaft and its generator and components are located at the top of tower. However, a VAWT has a vertical rotor shaft which different from HAWT and its rotor and components are located at the bottom.

The VAWT has more advantages compare to HAWT as it can receive wind from any direction not like HAWT only can receive wind from the front of the rotor. VAWT also able to operate even in low wind speeds area and easier for maintenance since its generator and components are located at the bottom. Besides that, the size of VAWT is smaller than a HAWT which more suitable to be install in residential areas. The VAWT can be further divided into many types based on their designs. The three major types of VAWT that often employed are Savonius type, Darrieus type and Giromill type. Savonius type VAWT was invented by a Finnish scientist, S. J. Savonius in 1922 which is basically consist of two half-cylinder which attach to the rotor and form a S-shape blade from top view (Hardisty, 2009) The design of Savonius type VAWT is shown in **Figure 1.1**. Darriues type VAWT was invented by a French engineer, G. J. M. Darrieus in 1931 which has two or three narrow curved blade that surround the rotor (Breeze, 2015). The design of Darriues type VAWT is shown in **Figure 1.2**. However, Giromill type VAWT has been included in the Darriues's patent which also known as H-rotor which has few straight blades that attached to the rotor by horizontal support (Tong, 2010). The design of Giromill type VAWT is shown in **Figure 1.3**. Although VAWT is able to operate at low wind speed, however, the efficiency of power generation is lower compare to HAWT (Dvorak, 2014). Hence, the VAWT will be analyze in this study in order to enhance the efficiency of power generation. Among many types of VAWT, only the Savonius type VAWT will be focus in this study.

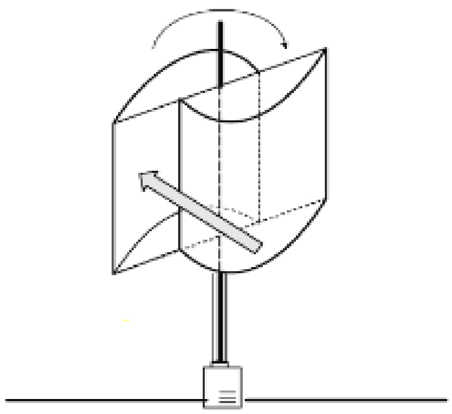

Figure 1.1: Savonius Type VAWT. (Northrop and Connor, 2013).

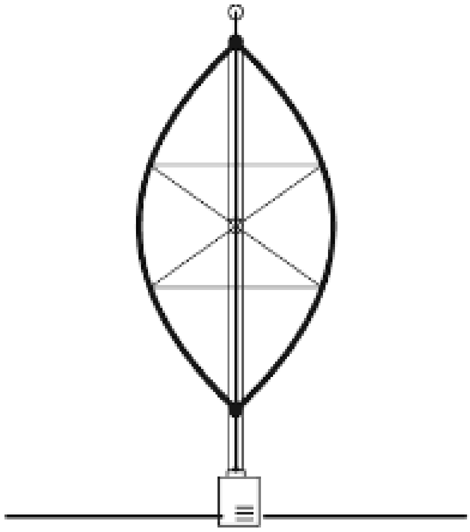

Figure 1.2: Darrieus Type VAWT. (Northrop and Connor, 2013).

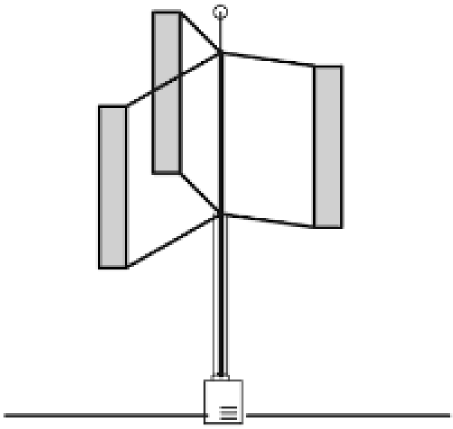

Figure 1.3: Giromill Type VAWT. (Northrop and Connor, 2013).

1.2 PROBLEM STATEMENT

The ability of wind energy on replacing the use of fossil fuel resources has been discovered by engineers over the world. The engineers had proved that the wind energy is a potential to become a reliable energy. The wind turbine is the mechanism that receiving wind energy while generator is the mechanism that able to convert the mechanical energy of rotor of wind turbine caused by wind energy to electrical energy. However, the generator available is a high torque generator which needs wind energy with higher speed to initiate the rotation. When wind energy with high speed is applied to the blade of wind turbine, the stress experienced over the blade which receiving the wind energy may exceeds the maximum stress of the blade can withstand.

1.3 OBJECTIVES

There are few objectives need to be achieves in this research, which are:

1. To design the concepts of Savonius type VAWT using Pugh method.
2. To analyze the displacement and stress applied to the structure by wind.
3. To optimize the blade design using topology optimization.

1.4 SCOPE

This research project will focus primarily on the Savonius type VAWT only. The Savonius type VAWTs will be design with various blade designs based on requirements listed and the blade design use for analysis will be chosen through Pugh Method. The design chosen will be analyze to determine the displacement and stress distribution over the blades when wind force is applied to the blades. The wind speeds are manipulated in the range of 0-24 m/s in order to determine the effects of displacement and stress distribution of blade when apply to different wind speed. After the displacement and stress distribution of blade are obtained, the blade will be optimized through topology optimization.

CHAPTER 2

LITERATURE REVIEW

2.1 TYPES OF WIND TURBINES

Wind turbines are mechanisms that used to convert kinetic energy of wind to mechanical energy through the blades and convert the mechanical energy of rotor to electricity through generator. The electricity generated by the wind turbines can be used as a residential scale power system. Modern wind turbines can be classified in two types based on its rotating axis, which are Horizontal Axis Wind Turbine (HAWT) and Vertical Axis Wind Turbine (VAWT).

2.1.1 HORIZONTAL AXIS WIND TURBINE (HAWT)

A HAWT is a type of wind turbine which has a rotor that rotates horizontally. HAWT normally has a drive shaft and generator which located at the top of the tower. A HAWT normally has blades that receive the wind energy, a rotor that transfers the rotation of blades to the generator, a generator that converts the rotation to electricity, a yaw bearing that changes the blades position according the wind direction, and a tower that provides support to other components. Normally, the rotor is directly connected to the generator for small wind turbine applications. The largest HAWT in the world which named Enercon and Repower was constructed by a Northern German companies (Castellano, 2012). The Enercon E-126 was constructed with overall height of 198 m and diameter of 126 m. Enercon E-126 is able to delivers power up to 7 MW. The construction of Enercon E-126 is shown in **Figure 2.1**. Repower M5 was constructed with overall height of 183 m and diameter of 126 m. Repower M5 is able to delivers power up to 5 MW. The construction of Repower M5 is shown in **Figure 2.2**. This kind of wind turbines are most common used today. This is because HAWT able to receives strong wind due to the height of tower that keeps the blades always at high altitude. Besides that, HAWT is a high efficient turbine because of the blades design that able to receive power from wind continuously when rotates. However, HAWT only able to functions when the wind stream flows from the front of the rotor. HAWT's blades position need to be rotate according to the wind direction. Furthermore, the maintenance of HAWT is difficult to be carried out due to the position of drive shaft and generator that located at the top of tower.

Figure 2.1: Enercon E-126. (Lafe, 2013)

Figure 2.2: Repower M5. (Chadha, 2013)