I hereby declare that I have read this report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Thermal-Fluids)

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WIND TURBINE BLADE OPTIMIZATION

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A report submitted in partial fulfillment of the requirements for the award of the degree of Bachelor of Mechanical Engineering (Thermal-Fluids)

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MAY 2006

I declare that this report entitled "Wind Turbine Blade Optimization" is the result of my research except as cited in the references.

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Date	**: 26th May 2006**

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ABSTRACT

This thesis presents and describes about a research for wind turbine blade and the methods for wind turbine blade optimization. The study is mainly focused on the three bladed horizontal axis wind turbine and the performance of the turbine. This thesis is also focused on the effect of changing the aerofoil section of the blades along its length. The design of the blade was developed by using Solidwork to reach the highest possible power output with the optimized design. The design of the blade is a one of the important factor that needs to be considered as it will affect to the performance of the wind turbine system. The comparison between the two bladed and three bladed was shown by the value of the chord, twist and the airfoil profile. Some formulas related to the development of wind turbine blade are also discussed.

ABSTRAK

Tesis ini menerangkan mengenai kajian yang dilakukan terhadap bilah turbin angin dan cara-cara untuk mengoptimumkan rekabentuk bilah turbin. Rekabentuk semula dibangunkan berdasarkan kajian yang dilakukan terhadap kajian terdahulu. Di dalam tesis ini kajian lebih tertumpu kepada turbin angin menegak yang menggunakan tiga bilah turbin sahaja. Daripada kajian yang dijalankan, prestasi turbin dapat dikenalpasti. Tesis ini lebih tertumpu kepada merekabentuk semula bilah turbin dan mengkaji kesan perubahan aerofoil serta putaran di sepanjang bilah turbin. Rekabentuk bagi bilah turbin dibangunkan menggunakan perisian Solidwork dan rekabentuk yang dibangunkan seharusnya menepati sasaran pembinaan turbin angin iaitu kuasa keluaran yang tinggi dengan rekabentuk yang optimum. Oleh kerana bilah turbin menjadi salah satu faktor penting dalam pembinaan sesebuah turbin angin, rekabentuk bilah menjadi salah satu penyumbang kepada prestasi turbin angin. Kajian ini turut membandingkan corak prestasi turbin angin yang menggunakan tiga bilah dengan turbin yang menggunakan dua atau empat bilah. Tesis ini turut merangkumi formula-formula penting dalam pembangunan model bilah turbin angin.

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List of Symbols

a	axial flow induction factor
a'	tangential flow induction factor
a_0	two-dimensional lift curve slope
a_1	constant defining magnitude of structural damping
A, A_D	rotor swept area
B	number of blade
c	blade chord
C_d	sectional drag coefficient
C_l	sectional lift coefficent
C_p	power coefficient
F	force
r	radius of blade element or point on blade; correlation coefficient
U_1	wind speed with the certain distance from rotor
U_2	wind speed at the rotor
U_3	wind speed after flow through the rotor
U_4	wind speed with the certain distance from rotor
P	aerodynamic power
R	blade radius
V	wind speed
T	rotor thrust

Greek

α	angle of attack
β	inclination of local blade chord to rotor plane
λ	tip speed ratio
ρ	air density
μ	non dimensional radial position
σ_r	rotor solidity

CHAPTER I

INTRODUCTION

1.0 Introduction

There are many factors that need to be considered while designing a wind turbine blade, such as strength, stability, vibration and cost. The blade must be designed to operate at the unpredicted environments and give a higher performance to maintain the lifetime of turbine. Therefore, the blade must be designed according to the surroundings and the wind velocity.

Wind turbine can be built in the variation of number of blade. The number of blade will determine the number of vibration modes that will affecting to the turbines through to increase the peak of its intensity. There are several methods that can be used to optimize the design of the wind turbine. Every design of the blade has advantages and disadvantages according to the airfoil templates used to produce the blade.

To design a wind turbine blade, there are many parameters to be considered. The parameters include number of blade, tip speed ratio (TSR), blade radius, wind speed, blade efficiencies and airfoil profile. These important parameters must be determined before calculating the chord, twist and the blade angle.

The development of the wind turbine blade can be performed by using common design software such as Autocad, Mechanical Desktop and Solidwork. Solidwork has more advantages from the others because its capability of 3D modeling much easier.

To perform the comparison of the wind turbine blade, a test to study the performance of the wind turbine blade needs to be performed. However, without the actual wind turbine, the alternative solution is using analysis software such CFX. Method of testing depends on to the blade size and the blade rotor.

From the design, the important parameters such as chord, thickness, angle of twist, airfoil profile, tip speed ratio and the angle of attack can be obtained. In this case study, these parameters will show the advantage of the design compared to other design. Each segment of the blade has a different load and characteristic.

Calculation for every segment must be done to obtain a better design and performance. There are many methods to calculate the parameters. In this case study, the radius of the blade was set depending on the scale of the required turbine and the power output.

1.2 Statement of the problem

1.2.1 Purpose of study

The purpose of study is to identify the performance of the three-blades wind turbines in terms of changing the blade aerofoil section and the twist along the blades. By redesigning the blade using a current aerofoil template, the performance of the wind turbine can be determined by data analysis process in the performance testing process. A successful blade design must satisfy a wide range of objectives. The common problem in designing the blade is the suitable aerofoil template. Each aerofoil have its own characteristics. To apply the suitable aerofoil profile in the design, the condition of surrounding such as the wind speed must be obtained. The angle of attack for blade design depends on the aerofoil itself and it will influence the performance of the wind turbine. Twist also gives an effect to the performance. To reach the optimum twist in the blade design, the rotational speed of the blade rotor must be obtained. The angle of attack by the wind speed also influences the twist of the blade. To ensure this problem can be solved, wind speed from surrounding must be determined. The information from the weather forecast about the wind velocity and the test by the anemometer is several methods to determine the wind characteristic. From the results, the suitable profile and twist can be applied to the design.

1.2.2 Objectives of the study

This project is interested with the performance of the turbine in terms of optimization of the blade design. The objectives are as follows:

1) To study the current performance of three bladed horizontal axis wind turbine (HWAT)
2) To re-design and simulate the blade
3) To optimize the performance of the turbine.

1.2.3 Focus of the study

The study is focusing on the blade design and the aerodynamic design. The aerodynamic design addresses the selection of the optimum geometry of the blade external surface which includes the aerofoil family, chord, twist and the thickness distribution.

The scopes of project are as follows:

1) To design and test the effect of changing the aerofoil sections
2) To design and test the effect of twist of the blade along its length
3) Design and analysis using software such as Solidwork, CFX and Pheonics.
4) Comparison with the previous design.

1.2.4 Importance of the study

This study can be implemented to develop a wind turbine for electricity generation at Malaysia. The renewable energy can reduce the cost of the electricity generation. It also can minimize pollution and increase the productivity in the power generation process. This study also shows how important the application of the wind turbine and the advantages to applied it. Even the wind regime in Malaysia is not good as Europe, wind turbine still can be applied.

1.3 Gantt Chart

Year	2005					2006			
Month	*Ogos*	*September*	*Oktober*	*November*	*Disember*	*Januari*	*Februari*	*Mac*	*April*
Literature Review	X	X	X	X	X	X	X	X	X
Design		X	X	X	X				
Develop Simulation					X	X	X	X	
Analyze Results					X	X	X	X	
Report 1									
Chapter 1	X	X							
Chapter 2		X	X	X					
Chapter 3			X	X					
Draft 1			X	X					
Report 2									
Chapter 4					X	X	X		
Chapter 5						X	X	X	
Draft 1								X	X

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

This section will review about the previous researches and the results on the performance of the wind turbine blade and the optimization of the blade in terms of airfoil and blade twist. Although the wind turbine blade has gone through many phases of development, researchers still trying to improved the performance of the wind turbine. Several researches on the optimization of wind turbine blade are done and the result was applied to the real application and environment.

2.1 Type of Wind Turbine

There are two major types of modern wind turbine. Literature from *Http://en.wikipedia.org* shows there are different between these two types. The modern wind turbine is divided to two categories:

1. Horizontal Axis Wind Turbine (HAWT)
2. Vertical Axis Wind Turbine (VAWT)

Horizontal Axis Wind Turbine

This is the common design for the wind turbine now days. It has the main rotor shaft and generator at the top of the tower and it running horizontally where the blade must be pointed into the wind. The modern turbine also has a gearbox to increase the rotation to ensure it suitable to generate electricity.

Figure 2.1 Horizontal Axis Wind Turbine
(Courtesy of www.wikipedia.com)

Vertical Axis Wind Turbine

Vertical axis has the main rotor shaft running vertically. The advantages of this arrangement are that the generator can be placed at the bottom or near the ground so the tower doesn't need to support the gear box. This type of turbine did not require to be pointed to the wind. The operation of the vertical axis is more slower than the horizontal axis type where its have less efficiency because it's not pointed to the wind.

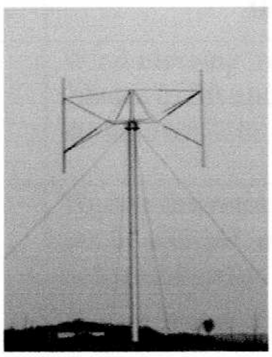

Figure 2.2 Vertical Axis Wind Turbine
(Courtesy of www.wikipedia.com)

2.2 Design and Component of Horizontal Axis Wind Turbine (HWAT)

Burton et al [Wind Energy Handbook, 2001] stated that the modern design of wind turbine required other auxiliary components to ensure it will work according to the requirement. Figure shows the conceptual design in the modern wind turbine and the function of every component. *Http:en.wikipedia.org* stated that the Vertical Axis wind turbine has a different design and component from the HAWT.

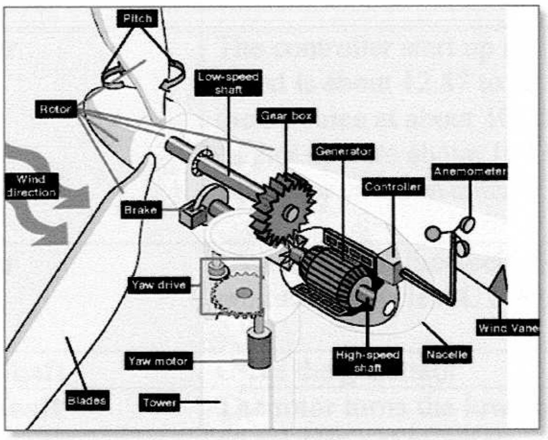

Figure 2.3 Conceptual Design for Three-Bladed Turbine
(Courtesy of www.wikipedia.com)

Table 2.1 Definition of Wind Turbines Components

COMPONENTS	DESCRIPTIONS
Blades	Wind blowing over the blades causes the blades to lift and rotates. Most common turbine has 2 or 3 blade.
Disc Brakes	To stop the rotor in case of emergency. It can be applied mechanically, electrically or hydraulically.

Gear Box	Gears connect to the low speed shaft to the high speed shaft and increase the rotational speeds from about 30 to 60 rpm to about 1200 to 1500 rpm, the rotational speeds required by most generators to produce electricity. The gearbox is costly and heavy part of the wind turbine and engineers are exploring direct drive generators that operate at lower rotational speeds and it will annihilate the gearbox application.
Controller	The controller start up the machine at wind speed is about 12.87 to 25.7 km/ h and shut off the machine at about 104.6 km/h. Turbines cannot operate above 104.6 km/ h because the generator could overheat.
Generator	Usually an off-the-shelf induction generator that produce 60 cycle AC electricity.
High Speed Shaft	Drive the generator
Low Speed Shaft	The rotor turns the low speed shaft at about 30-60 rotation per minutes.
Nacelle	The rotor attach to nacelle, which sits at top of the tower and includes the gear box, low and high speed shafts, generator, controller and brake. A cover protects the components inside the nacelle. Some nacelle is large enough for technician to stand inside while working.
Yaw Drive	Upwind turbines face into the wind; the yaw drive is used to keep the rotor facing into the wind as the wind direction changes. Down wind turbine, it doesn't require a yaw drive.
Rotor	The blades and the hub together are called the rotor.
Pitch	Blades are turned or pitched, out of the wind to keep the rotor from turning in the winds that are too high or too low to produce electricity.
Wind Vane	Measures wind direction and communicate with the yaw drive to orient the turbine properly with respect of the wind.

2.3 Performance of Horizontal Axis Wind Turbine

2.3.1 Comparison between three bladed and two bladed wind turbine

James L.Tangler [Tangler, 2000] stated the three bladed rotors is more exceptional design compare with the two bladed. Most of the commercial machine and large wind turbine using a three bladed rotor. The three bladed rotors offer the following advantages over the two bladed configurations. For a given radius and airfoil thickness, more blades result in lower blade stiffness. With three blades, appropriate flap stiffness is still achievable to avoid tower collapse and the blade loading is low enough to avoid noise.

Figure below shows that aerodynamic efficiency also increases with increasing the blade number.

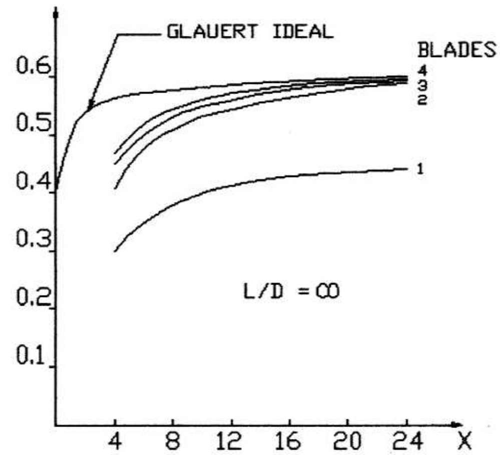

Figure 2.4 Glauert Ideal Turbine

(Courtesy of National Renewable Energy Notes)

From the figure, the increasing number of blade from one to two result in a six percent in aerodynamic efficiency, whereas increasing the number two to three percent. Further increase in blade number sacrifice too much blade stiffness for minimal increase in aerodynamic efficiency. *Burton et al* [Wind Energy Handbook, 2001] has describe a test to determine the efficiency of the power output from both turbine. To do the comparisons, the suitable wind turbine was chose. The specification of these wind turbines is as shown in Table 2.2.