"I have read this literary work and that in my opinion it is fully adequate, in scope and quality, as a masterpiece for the degree of Bachelor of Mechanical Engineering (Structure & Material)"

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Supervisor's Name	: NAZRI MD. DAUD
Date	: ....

MODELING AND SIMULATION OF HORIZONTAL WIND TURBINE BLADE

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This report submitted in partial
fulfillment of the conditions of the award of a
Degree in Mechanical Engineering (Structure & Material)

Faculty of Mechanical Engineering
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MAY 2010

"I declared that this project report entitled "Modeling and Simulation of Horizontal Wind Turbine Blade" is written by me and is my own effort except the idea and summaries which I have clarified their sources."

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UNTUK KEDUA IBUBAPA DAN KELUARGA TERSAYANG

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ABSTRACT

Wind turbine is a rotating machine that can convert the kinetic energy from wind source into mechanical energy. The mechanical energy will transfer the power into an electrical energy. This wind turbine used is to generate power from wind energy and a type of energy sources that can replace the existed energy sources. The blade design of wind turbine performs as a critical part because it affects the performance of the wind turbine. The related characteristics that can be determined are pressure distribution. This characteristic can be determined by using simulation software. The common software that used to simulate the wind turbine blade is fluent software. Besides that, there is other software that can be used in simulation. In this project, the simulation software used is fluent software to get the data of pressure distribution. Before the simulation is done by using fluent software, the design of blade will be created by using gambit that is the one of the part of CFD software. All the data gained from the simulation will be gathered into a table to define the pattern of the data occur from the simulation. This data will show the change of pressure with different angle of blade. There are four cases of angle with three different wind speed act as the variable on this simulation to make variable of data to be compared. After the simulation is done with fluent software, 30^{o} angle shows the highest value of pressure that is 119.00 Pa for 6.5 m/s, 137.00 Pa for 7.0 m/s and 154.00 Pa for 7.5 m/s wind speed. This 30^{o} angle blade become the best angle to produce more current for the wind turbine. All the data of pressure distribution will be compare with the data from the experiment of the fabricated wind turbine.

ABSTRAK

Turbin angin adalah sebuah mesin berputar yang dapat mengubah tenaga kinetik dari sumber angin menjadi tenaga mekanik. Tenaga mekanik akan memindahkan kuasa menjadi tenaga elektrik. Turbin angin ini digunakan adalah untuk menghasilkan kuasa dari tenaga angin dan merupakan alat yg boleh menghasilkan tenaga selain sumber tenaga yang sedia ada. Rekabentuk bilah turbin angin adalah bahagian penting kerana mempengaruhi prestasi turbin angin. Ciri-ciri berkaitan yang dapat ditentukan adalah pengedaran tekanan. Perisian umum yang digunakan untuk simulasi pada sudu turbin angin adalah perisian 'Fluent'. Selain itu, ada perisian lain yang boleh digunakan dalam simulasi. Dalam projek ini, perisian simulasi yang digunakan adalah perisian 'Fluent' untuk mendapatkan data pengedaran tekanan. Sebelum simulasi dilakukan dengan menggunakan software fluent, rekabentuk bilah akan direka dengan menggunakan langkah pertama yang merupakan salah satu bagian dari software CFD. Semua data yang diperolehi dari simulasi akan dihimpunkan ke dalam jadual untuk menentukan pola data yang berlaku dari simulasi. Data ini akan menunjukkan perubahan tekanan dengan sudut yang berbeza dari bilah. Terdapat empat situasi sudut dengan tindakan tiga kelajuan yang berbeza sebagai pembolehubah dalam simulasi ini untuk menghasilkan data yang akan dibandingkan. Setelah simulasi dilakukan dengan perisian, sudut 30^{o} menunjukkan nilai tertinggi tekanan iaitu 119.00 Pa untuk 6.5 m/s, 137.00 Pa untuk 7.0 m/s dan 154.00 Pa untuk 7.5 m/s kelajuan angin. Bilah 30^{o} menjadi sudut terbaik untuk menghasilkan lebih banyak kuasa atau tenaga untuk turbin angin. Semua data pengedaran tekanan akan dibandingkan dengan data dari amali turbin angin yang dijalankan.

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CHAPTER 1

INTRODUCTION

1.1 Background

Wind turbine is a rotating machine which converts the kinetic energy from wind source into mechanical energy. It can be used directly that is called windmill and can be convert into electrical energy that is called wind generator, wind power unit (WPU) or wind energy converter (WEC). Based on the power output, wind turbine can be divided into different categories that are large, medium and small. Large turbines are connected directly to the grid and used in big power plants, while the small one are used to produce electrical energy that particularly suitable for villages or isolated homes of the grid. The more efficient mini wind turbine with a best power output is obtained by maximizing its power coefficient. Furthermore, to enable market penetration, it has to be inexpensive and simple to construct. Figure 1 shows the major turbine components for a wind turbine.

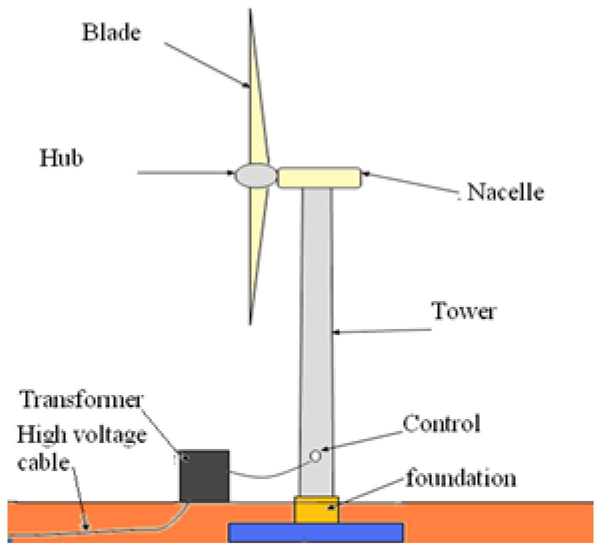

Figure 1: Major Turbine Components for a Wind Turbine

Many other countries such as America have used this kind of technology besides to have other choice of energy sources. Nowadays, all energy sources are reduced because of the age of the earth. Its need a new initiative to overcome this problem. Wind turbine is the one of the initiative that can replace the past energy source. The design of the drive train and the blade will affect the performance of the wind turbine.

1.2 Problem Statement

Energy is the most common sources that are important to all people in this world. Nowadays, the energy sources are became decrease that may interrupt people's routine. Wind turbine is the one device that can solve the problem. Wind turbine can generate power by using kinetic energy to electrical energy. Many manufacturers have developed many design of wind turbine blade for users. But, the design of this device can be improved by the performance to increase the power output with the inexpensive design. Then, the design must be analyzed to investigate the efficiency of the design blade by getting the data about pressure and velocity distribution.

1.3 Objectives

The objective of this project involved is to determine the pressure distribution on the blade of small wind turbine with different angle.

1.4 Scopes

The scope that focus in this project are;

1. Determination the pressure distribution of horizontal wind turbine blade.
2. Comparison of pressure distribution for blade with different angle.
3. Simulation of horizontal wind turbine blade by using fluent software.

1.5 Project Summary

Due to the problem statement, objectives and scopes of project, there are a few works must be completed including fabrication and simulation to be analyzed. The simulation regarded wind turbine blade is fabricated to be used in fluent for analyzing part. The fabricated blade must follow the specification with good mechanical and physical properties. The important in analyzing the blade is the performance to get more power output with the inexpensive design.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

A literature review in this chapter will content with just a simple summary of the sources such as journal and papers related to the horizontal wind turbine. In this chapter, it will also include some of the details about horizontal wind turbine, the power generating system

2.2 Modeling of the Wind Turbine Power Generating System

According to Ulas Eminoglu (2009) from the 'Modeling and Application of Wind Turbine Generating System (WTGS) to Distribution System', wind energy systems have been attracting the most attention as an environmentally being technology since it has become cost-competitive compared to the conventional forms of power generation. It converts the turbine's mechanical energy obtained from the wind into electrical energy through a generator. In the study, there are various types of WTGSs developed based on the steady-state model of the electrical machines.

2.3 Design of Non-Twisted Wind Turbine Blade

In this journal written by R. Lanzafame and M. Messina, 'Design and Performance of a Double Pitch Wind Turbine with Non-Twisted Blades', a new layout for small wind turbine blades has been presented. The new wind turbine blade is subdivided into two parts, each non-twisted, with a variable chord along the radius, a particular pitch angle, and a winglet to connect the two parts. The optimum choice of pitch angle provides the best blade aerodynamic condition and maximizes the power coefficient. To choose the correct pitch angles, a model-based design was needed. The code enabled the wind turbine power coefficient in the design wind speed to be maximized, and the wind turbine performances in all the off-design operating conditions to be evaluated. In the final stage, the performance of the new wind turbine was compared with those of standard non-twisted blades wind turbine which highlighted the advantages of the new design. It offers optimum aerodynamic flow and presents a power output gain in all the wind-speed ranges.

Beside that, to create an inexpensive wind turbine, the blades can be non-twisted with a variable chord along the rotor radius. This type of wind turbine produces lower performances both in design and off-design operational conditions. There are some comparisons of the non-twisted and twisted wind turbine blade shown in Figure 2.

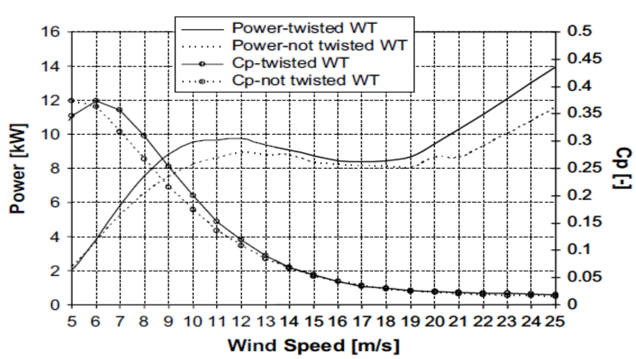

Figure 2: Performance Comparison between Twisted and Non-Twisted Wind Turbine Blade

(Source : R. Lanzafame, M. Messina, (2009))

2.4 Dual Rotor Wind Turbine Generator System

Reviewed from the J.H. Moon et.al (2009), "Modeling, Control, and Simulation of Dual Rotor Wind Turbine Generator System", introduced a dual rotor wind turbine generator system which consists of two rotors. The one is small auxiliary rotor at the upwind location and the other relatively larger main rotor at the downwind location. The general equations of motion for the constrained multi-body system were used to obtain the dynamic model for this new wind turbine generator system, and a nonlinear simulation program was developed to predict its performance and test the pitch control algorithm. Blade element and momentum theory and a simple flow interaction model were used to calculate the aerodynamic forces and torques. The doubly fed induction generator was treated as a single rotating body requiring a torque for power production.

In this journal, it also explains about lift and drag forces created by the rotor blades that will eventually provide the thrust force and torque to the WTGS. As was mentioned, given the aerodynamic and geometrical characteristics of the rotor blades, the power and torque coefficients are calculated using the blade element and momentum theory. The properties of the blade will affect lift and drag forces and can make the performance higher. An example of the blade is shown in Figure 3.

Figure 3: Blade 3-dimensional Shape

(Source : T.S. No et.al, (2009))

2.5 Simulation of Wind Turbine Blade

According to Nilay Sezer-Uzol and Lyle N. Long (2006), “3D Time Accurate CFD Simulations of Wind Turbine Rotor Flow Fields”, Three-dimensional flow properties of rotating blades are an essential feature of any wind turbine aerodynamic simulation. While important information can be learned from two-dimensional and non-rotating simulations, some aspects of the physics of wind turbine aerodynamics and noise must be obtained from rotating blade simulations. Three dimensional flows over rotating blades can be significantly different than the flow over a wing, and there can also be dramatic differences between 2-D and 3-D simulations.

In addition, rotating blades can have significant radial flow and also the blade speed varies linearly from root to tip. The three-dimensional wake of a rotating blade can remain in close proximity to the blade for a long period of time compared to the wake of a wing. By incorporating time dependent boundary conditions, either a gust or turbulent incoming flow can be introduced. Chyczewski et.al have done this in the past with jet noise predictions, to simulate turbulence levels inside the nozzle and their effect on the jet shear layers and noise. For these reasons, time-accurate three-dimensional and compressible rotating blade simulations are essential. There have been several CFD studies of wind turbine flow fields using different approaches in the literature.

2.6 Two-Dimensional Aerodynamics

Reviewed from Martin O.L. Hansen (2008), “Aerodynamics of Wind Turbines”, wind turbine blade is long and slender structures where the span wise velocity component is much low than the stream wise component, and its therefore assumed in many aerodynamics models that the flow at a given radial position is two dimensional and that 2-D aerofoil data can thus be applied. Two-dimensional flow is comprised of a plane and if this plane is described with a coordinate system where the velocity component in z-direction is zero.

In order to realize a 2-D flow it is necessary to extrude an aerofoil into a wing of infinite span. On a real wing the chord and twist changes along the span and the wing starts at a hub and ends in a tip, but long slender wings, like those modern gliders and wind turbine. Shown in Figure 4, the local 2-D data for the forces can be used if the angle of attack is corrected accordingly with the trailing vortices behind the wing. This effect will be dealt with later, but it is now clear that 2-D aerodynamics is of practical interest even though it is difficult to realize.

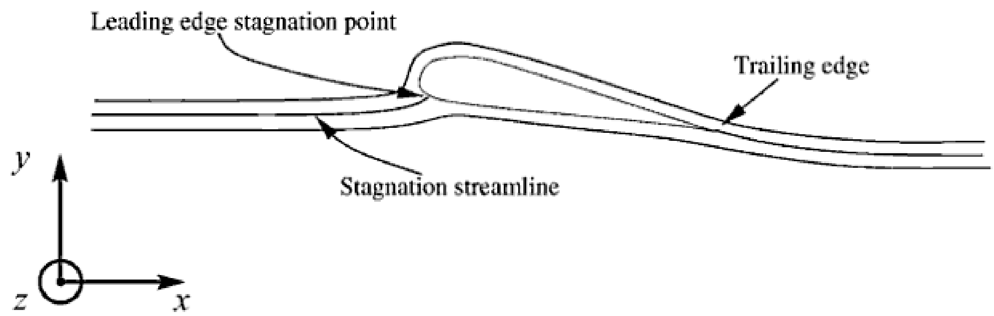

Figure 4: Schematic View of Streamline past an Aerofoil

(Source : R. Lanzafame, M. Messina, (2009))

CHAPTER 3

METHODOLOGY

This project involved two parts of procedure which is designing and simulation. For this project, it may use the software called Computational Fluid Dynamic (CFD) to generate the data from the fluid flow cases. There are two parts of CFD that is Gambit and Fluent. Gambit part is to design the geometry of the cases by using step by step procedure. It starts with vertex, followed with edges, then faces and lastly volume. To create a new model, it must start with vertex and end by volume to get a valid geometry. Then, the model from Gambit will exported to fluent by the mesh file. In the fluent software, it will start to simulate the model by setting up all the condition for the model. It is including the boundary condition, fluid type and many more due to the cases.

3.1 Proposed Project Methodology

The project methodology of this project can be more easily described by producing a type of flowchart that consists of certain step involved to finish the project. This flowchart in Figure 5 will show the flow of the process of analyzing horizontal wind turbine blade with all method used in this project.

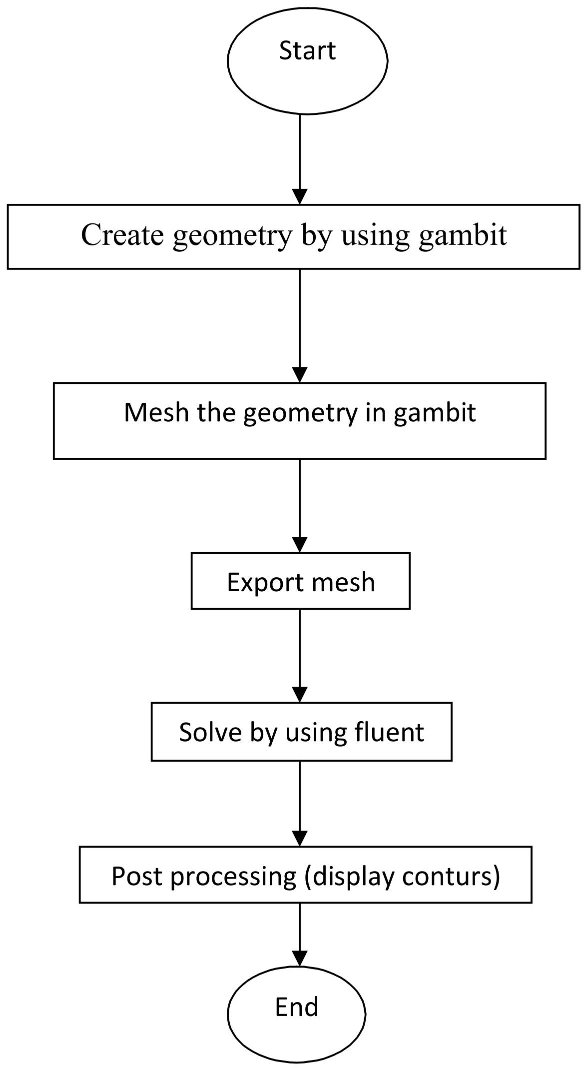

Figure 5 : Flowchart of the Methodology

3.2 Design of Horizontal Wind Turbine Blade

The design of the blade will be created by using gambit in CFD software. From the gambit, the geometry created can be extruded by using sweep command. For the information, CFD is a part of Computer Aided Engineering (CAE) that have high demand in industry. This software included two dimensional and three dimensional cases. For this current project, it required to use three dimensional cases to valid the requirement of the title of project. There are some procedures or step that must be followed while create the blade geometry.

Modeling is one of the critical stages due to the influence of the final results. Some action that might be important during the design process is creating the basic shape of the model. By using gambit, it must started by creating the vertex or coordinate for certain point. Then, it will be sweep to get a three dimensional model. This model will mesh with the same software.

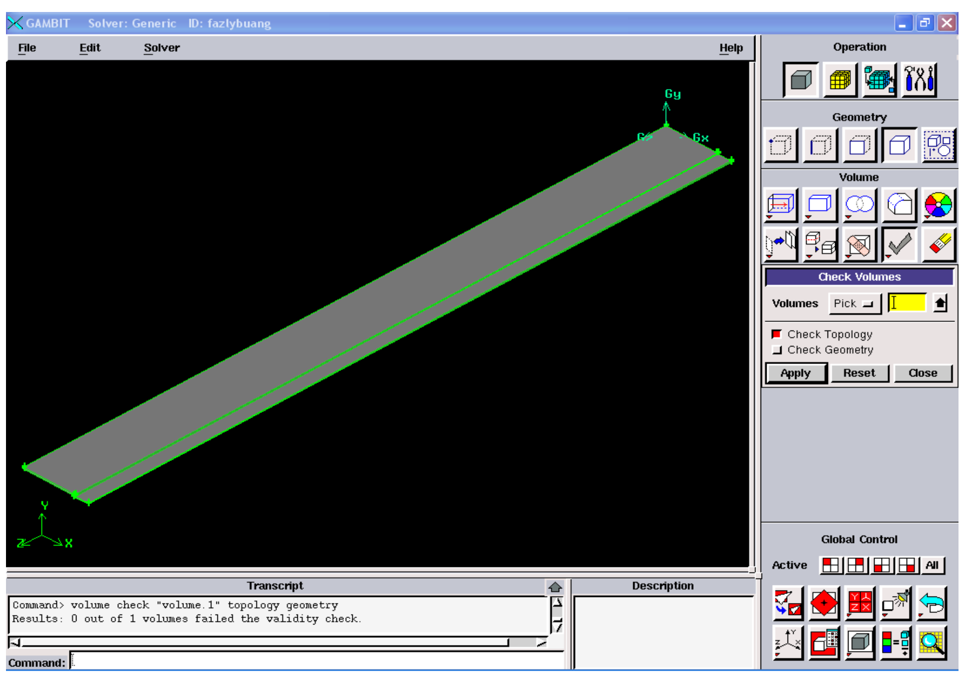

Figure 6: Isometric view of blade design

For this kind of case, it is an external flow analysis. So, the geometry or model must have a boundary for the simulation to solve the case. In this project, the square boundary used to create the velocity inlet and outlet flow. Then, the geometry of the blade will be cut through to build a surface to be analyzed. This step will produce a hole with the shape of the blade. All the dimension of the model are followed based on the real dimension in milimeter.

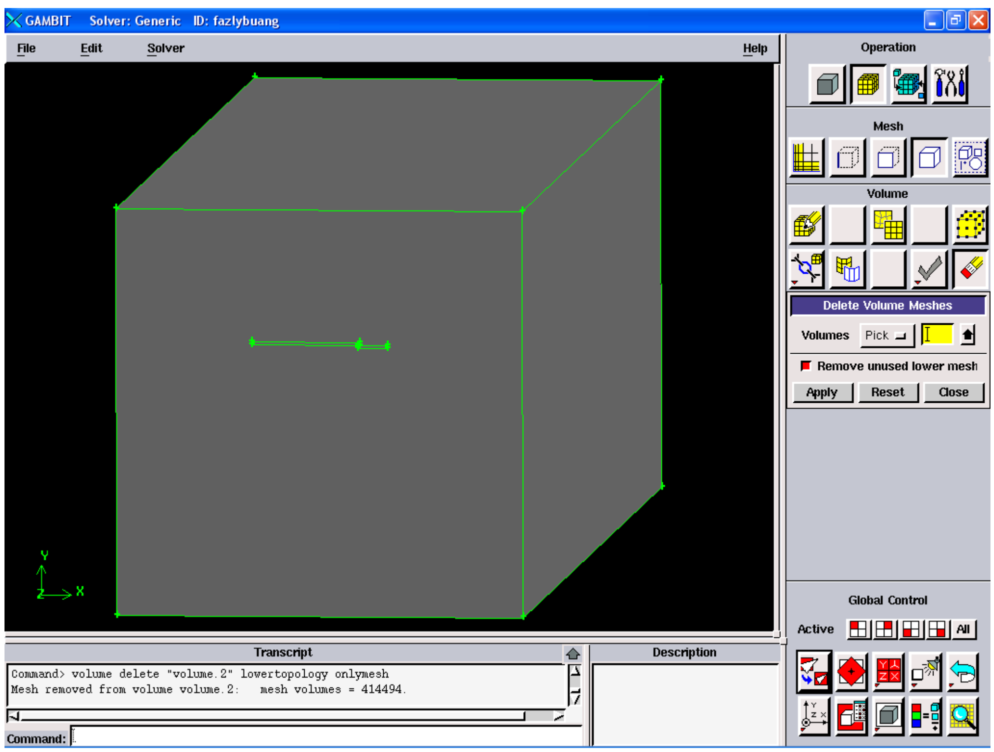

Figure 7: Blade with boundary