DESIGN A WIND VENTILATOR TURBINE FOR DOMESTIC APPLICATION USING ANSYS

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DECLARATION

I declare that this project report entitled "Design a Wind Ventilator Turbine for Domestic Application Using ANSYS" is the result of my own work except as cited in the references.

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APPROVAL

I hereby declare that I have read this project 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-Fluid).

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Date : 16/6/2017.

DEDICATION

To my beloved mother and father

ABSTRACT

Performance of an engineering device are mainly depends on its ability to adapt and functional at the most extreme conditions. This project mainly highlight on the design of wind ventilator turbine with and without tubercles added. The objective of this report is to to compare the CFD analysis result of drag and lift coefficient among three blade design. The blade with 15, 8 and without tubercle was put on a test. The geometry of the blade was generate using SOLIDWORK software before transferred to ANSYS software by changing the file to IGES format. The geometry was then edited to satisfy the real situation condition. Mesh was generated and the boundary condition of the model was set to avoid any error occur. The simulation was made using standard k-epsilon model. Inlet velocity of the test section was set for four different values and the calculated solution result of ANSYS was recorded and plotted. The result shows that the blade that having more tubercles are more likely to have a better input on lift coefficient. Meanwhile the drag coefficient resulted an increase pattern of graph for all simulation test conducted with different maximum values. Ratio of lift and drag force also be considered in order to compare the best blades design. By using calculation method, it is also shows that the more tubercles present on the blade edge, the higher and consistent the ratio would be which affect the effectiveness of the device.

ABSTRAK

Prestasi peralatan yang menggunakan prinsip kejuruteraan bergantung kepada kebolehan alat tersebut berfungsi walaupun dalam keadaan yang ekstreme. Projek ini khususnya mengkaji rekabentuk bilah ventilator angin turbine. Objektif kajian ini ialah untuk membandingkan keputusan analisis CFD bagi pekali heret dan naik antara tiga jenis bilah yang berbeza. Bilah yang mempunyai 15, 8 dan tanpa tuberkel telah diuji. Geometri bilah tersebut telah dijanakan menggunakan perisian SOLIDWORK sebelum dipindahkan ke perisian ANSYS dengan mengubah fail kepada format IGES. Geometri tersebut di edit bagi memenuhi kehendak pada keadaan yang sebenar. Jaringan dan keadaan garis sempadan model tersebut telah ditetapkan bagi mengelakkan sebarang kesilapan berlaku.simulasi telah dibuat menggunakan model k-epsilon piawai. Kelajuan masuk kajian tersebut telah ditetapkan kepada empat nilai yang berbeza dan keputusan kiraan solusi ANSYS telah direkod dan diplot. Keputusan menunjukkan bilah yang mempunyai teberkel yang lebih banyak lebih berpotensi mendapatkan keputusan akhir yang lebih baik berdasarkan nilai pekali naik. Sementara itu, pekali heret menunjukkan keputusan menaik dalam graph bagi kesemua simulasi. Nisbah heret dan naik juga patut diambil kira untuk membandingkan bilah yang lebih bagus.dengan menggunakan kaedah kiraan, ia menunjukkan bahawa kehadiran teberkel yang lebih banyak , lebih tinggi dan konsisten nisbah akan terhasil dimana mampu memberi kesan kepada keberkesanan alat tersebut.

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I would like to thank my course mates for giving me their support, patience and encouragement. Finally, I would like to thank my family for their support.

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ABBREVIATIONS

mm	Millimeter
m	Meter
pa	Pascal
m/sec	Meter per Second
Fmin	Minimum Force
Nb	Number of Blades
Nu	Number of Electroactive Material
Vw	Wind Speed
km/h	Kilometer per Hour
l/s	Litter per Second
cm	Centimeter
mph	Meter per Hour
RPM	Rotation per Minutes
rad/s	Radian per Seconds
kg/m^3	Kilogram per Meter Cube

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

As a country that experienced low average of annual rainfall with 50.0 mm to 350.0 mm (Meteorological Department Malaysia), Malaysian populations prefer to install air conditioning for human comfort. Which resulted the increase of chlorine gas released into atmosphere. Therefore, wind ventilator turbine was designed as alternative to reduce global warming and provide humidity comfort as well.

This device is also known as air driven fan which mean it is free energy consumption device. Equipped with a numbers of blade, the wind ventilator turbine is said to be able to operate in low-wind velocity condition at least 5 mph. This device is super light since it is made from galvanized steel or aluminum construction in 12-inch and 14-inch sizes. These vents use the natural force of wind and air pressure to spin and vent out stale attic air.

Before any product come across the market, it need to be fully tested to prevent any malfunction which may lead to a disaster. To avoid any loss of time and virtue, a software named ANSYS was created that make these engineers job become more interesting and easier. This software can be used to simulate interactions of all disciplines of physic, structural, vibration, fluid dynamics, heat transfer and electromagnetic for engineers. Besides that, determining and improving weak points, computing life and foreseeing probable problems are possible by 3D simulations in virtual environment.

1.2 Problem Statement

The rooftop turbine ventilator now is not only widely accepted as industrial ventilation, but also has become a common ventilation feature used in other types of buildings including institutional, commercial and residential as an alternative to air-conditioning systems. This device quality basically assessed by its performance on controlling temperature in a building by transmitting hot air from the attic. To be more specifically, its performance depends on the design of the wind ventilator turbine itself. Although it is often thought to be very effective even in the lightest wind conditions, but many scientific studies found that its actual performance in the real building is not very promising due to some outdoor climatic constraints and the weaknesses of the device's configuration itself. Based on this problem, this report aim is to design a better wind turbine ventilator in order to describe its full characteristics, reliability and limitations of the device. Future turbine ventilator criteria which is not only ventilate well in high-wind speed region, but also could be an effective multifunction device even in low wind velocity region is also considered.

1.3 Objective

The objective of this project are as follow:

i. To review the mechanical mechanism used on wind ventilator turbine.

ii. Design an improvement feature on wind ventilator turbine for domestic application based on the three different blades design.

iii. Compare the CFD analysis result of drag and lift coefficient of the three blades design.

1.4 Scope of Project

The scopes of this project are:

i. Calculation and analysis of wind ventilator turbine using CFD software (ANSYS).

ii. Indicate the different of drag and lift coefficient result and data based on three different blades with different number of tubercles.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

Literature review is focused on previous study in the related field which includes the current knowledge including substantive findings, as well as theoretical and methodological contributions to a particular topic. In this chapter, journal and technical report from other researchers are reviewed and summarize.

2.2 Analysis and Design of Roof Turbine Ventilator for Wind Energy Harvest by Yung Ting et al. (2010)

This study analyzed the effect of number of blade used and the blade angle on the performance of a vertical axis roof turbine ventilator. According to the previous studies, electroactive material had already been verified its capacity for energy harvest. Roof turbine ventilator with gear mechanism that attached on the bottom side is considered to achieve that purpose. The electroactive materials employed around the ventilator will be impacted and vibrated by the rotation of gear teeth

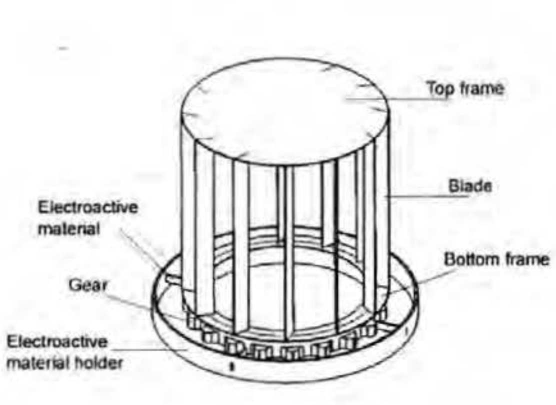


Figure 2.1.1: Roof Turbine Ventilator

2.2.1 Methodology

The experiment was carried out by testing 3 main aspect of roof turbine ventilator which are number of blade, blade angle and number of electroactive material attached. For better efficiency, straight type of blade was used in this experiment. 12 and 18 number of blade was chosen to examine the performance with various combinations of blade angle (β = 30°, 45°, 60°, and 90°). Diameter of the roof turbine used in this study is 250mm. Different number of pieces of electroactive materials (Nu=1, 2, 3, 6) are also assigned. In order to closely emulate the real environment, the wind speeds are assumed to be 3, 4 and 5m/sec.

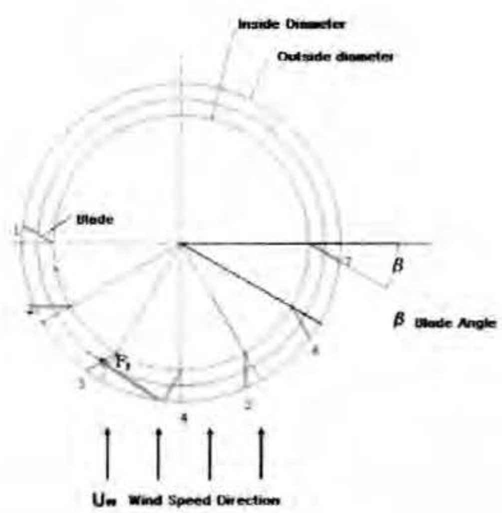


Figure 2.1.2: Top view of roof turbine and wind flow

2.2.2 Result and Discussion

i. Minimum Requirement Force for Rotation

Wind power should provide enough force to overcome the inertial of roof turbine ventilator and the deflection of electroactive material. Therefore, the minimum force to rotate the turbine blade was calculated as Table 2.1 below.

N_U (piece)	F_{min} (N)	
	N_b= 12	N_b= 18
1	0.44	0.46
2	0.84	0.86
3	1.24	1.26
6	2.44	2.46

Table 2.1: Fmin for different Nu

The force for 1 piece of electroactive material is about 0.04N and 0.06N for Nb=12 and 18 respectively. Number of electroactive material (Nu = 1, 2, 3 and 6) in this case study with 5mm vibration displacement generated in each of them. Therefore, the minimum force Fmin is calculated for Nb=12 and 18 respectively.

ii. Angle and Number of Blade Effect

From the result of experiment, its show that higher wind speed could generate more wind power so that larger driving force is obtained. At the same time the wider the blade angle, possibility to generate larger driving force is high based on Figure 2.1.3. For example, with Nu = 3 and blade angle of 90°, number of blade Nb=12 at wind speed 5m/sec is the only condition that can rotate the turbine and Nb=18 wind speed Vw=4 and 5m/sec can rotate the turbine.

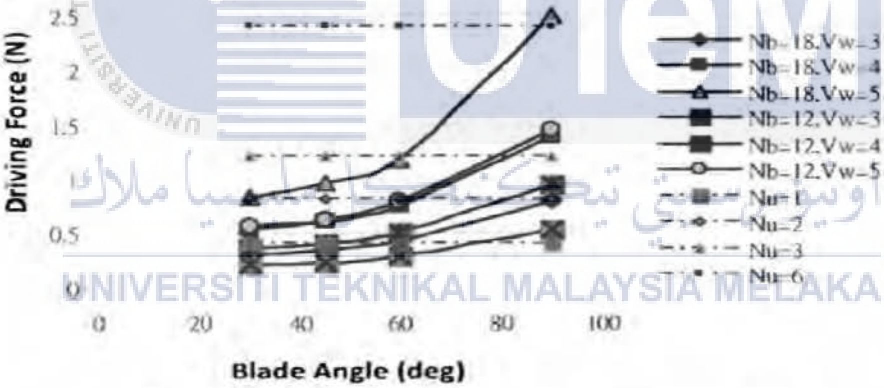


Figure 2.1.3: Graph of Driving Force against Blade Angle

Note that: Nb = number of blade

Nu = number of electroactive material

Vw = wind velocity

2.2.3 Conclusion

The roof turbine ventilator blade seem to be important for its better effectiveness in giving human comfort. It can be conclude that, the efficiency of the roof turbine can be improved by adding more blades and wider blade angle to ensure the turbine can rotate even with minimum wind speed.

2.3 Rooftop Turbine Ventilator: A Review and Update by Mazran Ismail & Abdul Malek Abdul Rahman (2012)

In order to describe rooftop turbine ventilator full characteristics, reliability, limitations and possible improvement of the device, this study discusses the current development and future prospects of the turbine ventilator by elaborating the results of some experimental and analytical work that have been done in various aspects of its application and performance. The analysis and summarized findings presented in this study also recommend some criteria that should be considered in designing future turbine ventilator which is not only ventilate well in high-wind speed region, but also could be an effective multifunction device even in low wind velocity region.

2.3.1 Methodology

Some important design aspect for a rooftop turbine ventilator have been focused in this study such as turbine diameter (size), blade height, blade configuration, openings and duct/throat diameter. The referred blade height in this study are 170, 250 and 340 mm at a fixed wind speed of 12 km/h. For blade design, 300mm straight vane turbine, 300mm curved vane turbine, 250mm straight vane turbine, 250mm straight vane turbine were tested. Besides that, throat diameter and opening of rooftop turbine ventilator also tested on 4 different design as shown on Figure 2.1.6.

2.3.2 Result and Discussion

i. Turbine Diameter

Based on previous study, Lai (2003) confirmed the consumer beliefs that the bigger size of turbine ventilator would induce higher ventilation rate. However, it was found that the ventilation rate induced by more commonly used ventilators of 14" (360mm) and 20" (500mm) are more or less the same, meaning that the rate can be considered equal when it comes to the application in engineering.

ii. Blade Height

When turbine ventilator of different vane heights of 170, 250 and 340 mm shown in Figure 2.1.4 were tested at a fixed wind speed of 12 km/h. The study found that 13.5% improvement in flow rate could be achieved if the vane/blade height is increased by 50%. This percentage can be related by increasing airflow rates of 65, 70 and 75 l /s for all 3 model respectively.

Figure 2.1.4: Variable blade height

iii. Blade Design

In terms of vertical vane or blade design, it was found that for the same size of 300mm (12") turbine ventilator, the curved vane type of ventilator had about 25% larger flow rate than the straight vane ventilator at the same wind speeds. Besides, the study on the different types and forms of turbines ventilator as shown in Figure 2.1.5 also revealed that the fabrication material of the device also affect the ventilator's capacity to induce airflow.

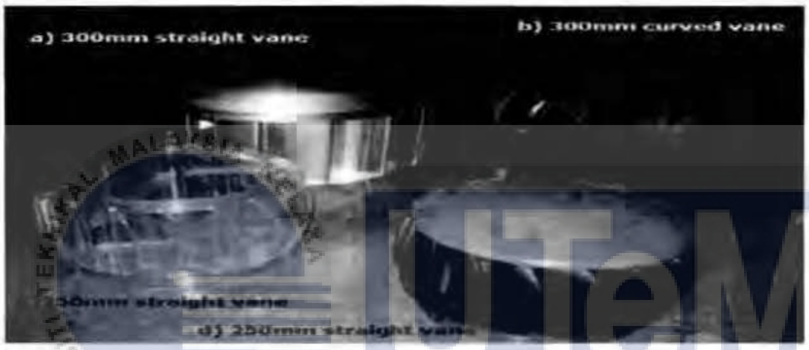


Figure 2.1.5: Different types of turbine ventilators under test

iv. Throat Diameter and Opening

The results of a single performance curve (embodying air extraction rates, wind speeds, throat size and pressure differentials across the devices) confirmed that the turbine ventilator with bigger throat of 300mm (12") is perform better than turbine ventilator with 250mm (10") diameter throat. The study also indicated that the simple open stub (without turbine ventilator) performed best in air extraction, thus recommended the type to be a base-line model for improving conventional turbine ventilator as shown in Figure 2.1.6.

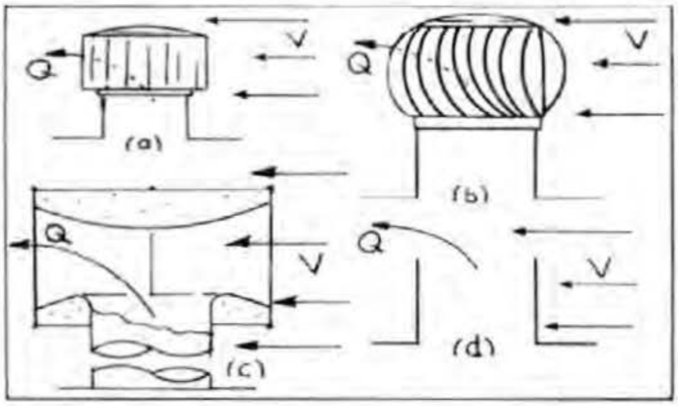


Figure 2.1.6: Various ventilator throat diameter

2.3.3 Conclusion

As can be conclude in this study, the performance of rooftop turbine ventilator depends on many factors. For future recommendation, this study have been elaborated the full characteristics, current status and also the possible development of the device. Based on the analyses and summarized findings, this study has also suggested some criteria, current limitations and future prospects of the device which need to be considered in developing future.

2.4 More Efficient Helicopter Blades Based on Whale Tubercles by Sam Weitzman and Ann Lambert (2013).

The main objective of this experiment was to study the effect of adding tubercles based off those of a humpback whale to the increase of efficiency of the helicopter blades on the Double Horse 9053 RC Helicopter. This study was inspired by the natural occurrence, which applied on helicopter blades for better performance that could save fuel and reduce emissions while being able to fly, and accelerate at the same, if not better, level and quality.

2.4.1 Methodology

i. Base construction

A base for the Double Horse 9053 RC Helicopter was built out of wood and screws. This base is needed to ensure that the helicopter remain static even when the blades start spinning. The skis of the helicopter were held to a thick piece of wood by a thinner piece of wood placed over the skis but under the body of the helicopter. Another long piece of wood was placed perpendicular to the main base and attached by screws to hold the anemometer. An anemometer is a device for measuring wind speed. For testing, the base was clamped to two desks and an anemometer was clamped to the area on the base designed to hold it shown in Figure 2.1.7 and Figure 2.1.8.

Figure 2.1.7: Clamped RC Helicopter

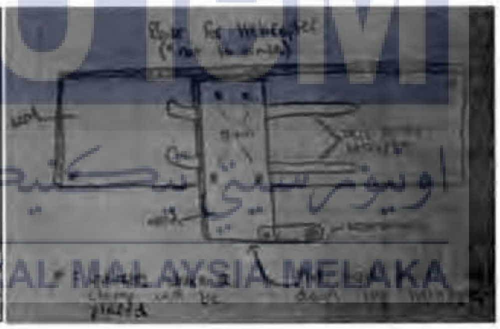


Figure 2.1.8: Base Drawing

ii. Tubercle construction

The tubercles were made out of yellow FIMO Soft clay (FIMO). There were two types of blades, the 8-tubercle and the 4-tubercle. The tubercle blades were a separate set from the control blades and were only used with the tubercles on each blade spaced 1.7 cm apart, so 16 in total (Figure 2.2). In total, the two 4-tubercle blades had 8 tubercles (Figure 2.1.9). The tubercles on the 4-tubercle blade were spaced 3.7 cm apart. The tubercles were about 1 cm long, 3 mm wide, and 2 mm tall. They were made slightly bigger toward the base of the wing and smaller toward the end. They took up about a third of the blade toward the inner part of the blade (around 3 cm wide) and about half the blade toward the outer end around 2.5 cm wide). In separate tests, the 8-tubercle and 4-tubercle blades were attached and the same process was completed as with the control blade. Three trials of each test were completed using new tubercles each time in order to ensure repeatability.

Figure 2.1.9: 4-tubercle blade

Figure 2.2: 8-tubercle blade

2.4.2 Result and Discussion

Table 2.2 : Average differences between blades and control for each blade type

8-Tubercle	Average difference in speed (mph)	Average percent change in speed
Speed 1	0.16666666666667	4.20
Speed 2	0.05555555555556	1.54
Speed 3	0.11111111111111	2.32
4-Tubercle	Average difference in speed (mph)	Average percent change in speed
Speed 1	-0.17777777777778	-3.38
Speed 2	-0.10555555555556	-1.65
Speed 3	-0.11111111111111	-1.44

According to the data above, All the 8-tubercle blades had an average increase in output while all the 4-tubercle blades had an average decrease in output. As seen in Table 2.2 the highest change in performance was Speed 1 with the 8-tubercle blades, which had an increase of about 0.167 mph. It is clear that the 8-tubercle made a change in the output. Speed 1 had a 4.2% increase. The 4-tubercle blade hindered the efficiency of the blade. For the 4-tubercle blade, all the speeds had an average percent decrease. It ranged from a 1.44% decrease in Speed 3 to a 3.38% decrease for Speed 1. These data show that there is a significant relationship between the number of tubercles and the efficiency that can be achieved. From the data, there are conclusive results that the 8-tubercle blade increases efficiency while the 4-tubercle blade decreases efficiency.

2.4.3 Conclusion

The closer the tubercles are together, the better the outcome. This correlation can be tied to the fluid dynamics physics that apply to tubercle-blades. If tubercles are too far apart, the vortices that create the differentiating air pressures on the blade become impossible to create. To create the vortices, there cannot be large amounts of space between tubercles. Because the 8-tubercle blades had much less space between tubercles, they were a closer model to real tubercles. Because they were a closer model, they had an overall increase in output.

2.5 Effect of Inclined Roof on the Airflow Associated with a Wind Driven Turbine Ventilator by Shao Ting J. Lien & Noor A. Ahmed (2010).

This study analyzed the effect of the inclination on rooftop to the performance of turbine ventilator. The characteristic of a wake far downstream of the body depend mainly on the viscous forces and not on the pressure forces and the skin friction in the boundary layer downstream of the bluff bodies reduces due to the effect of turbulence and mixing generated by the rotating bluff bodies was examine in this study .

2.5.1 Methodology

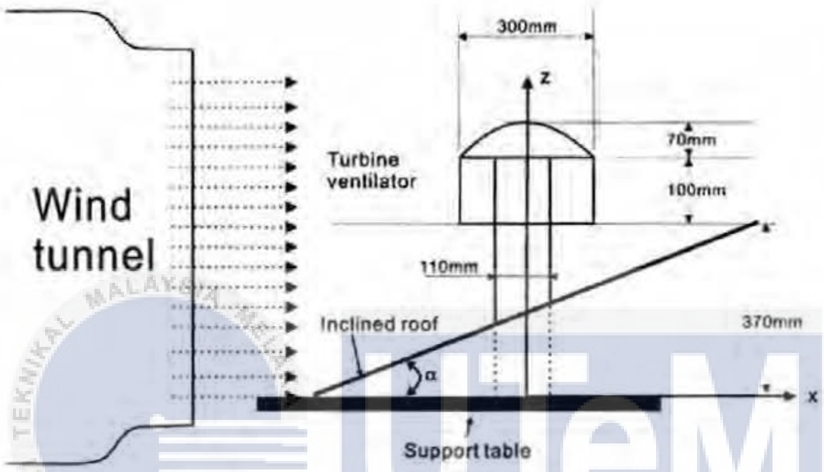


Figure 2.2.1: Top view of the measuring plane

The experiment were conducted in a 76 mm diameter open return, 0.2% turbulence intensity open test section wind tunnel. Wind speeds that ranged between 4 m/s and 15 m/s were considered sufficient for this experiment. The roughness effect of the tiles was ignored and a rooftop was represented by an inclined flat plate. Inclination angles of 0°, 15°, 30° are used in the current investigation. The rotational speed of the ventilator was measured using a CDT-2000 digital tachometer with an accuracy ±0.01% with a resolution of 0.01 RPM. The manometer and the pressure transducers provided measurement in the range that varied from −2000 Pa to 2000 Pa with an accuracy of ±0.1 Pa. The experimental setup is shown in Figure 2.2.1 above.

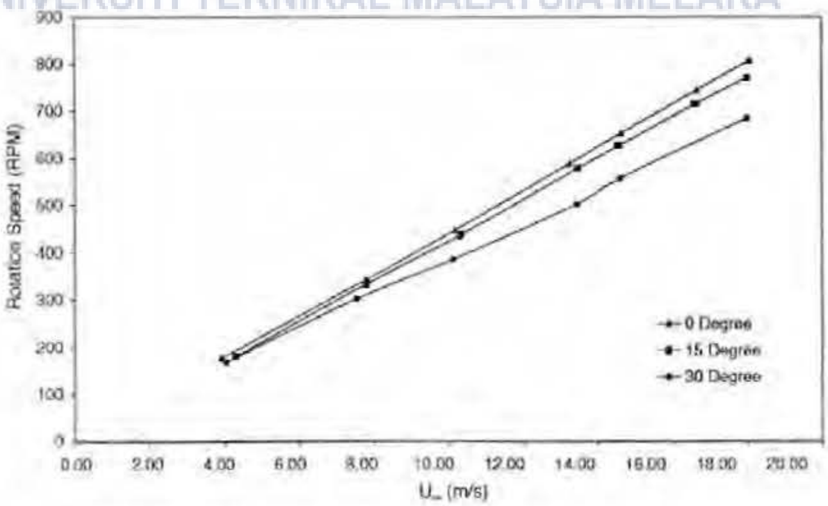
2.5.2 Result and Discussion

i. Effect of inclination angle on forces on a ventilator

Based on coefficient of force at various inclination angles experiment result, it shows that the inclination angle give minimum effect on the coefficient of force values. Consequently, the total force coefficient acting on the ventilator reduced with increases in inclination angle.

ii. Effect of inclination angle on rotational speed of a ventilator

The rotation speed of the turbine ventilator showed a linear relationship with the free stream velocity as shown in Figure 2.2.2. This is also a significant observation since the operation of these ventilators are designed for low wind speeds and as such will not suffer greatly from adverse effect of the high inclination angle. Thus, the lowering of rotation due to increasing inclination angle of roof may thus be usefully exploited to reduce wind loads and hence extend the safety margin.



Graph 2.2.2: Graph Rotation Speed against Velocity

iii. Normalized static pressure distribution on the roof

On the inclined plane, the addition of the ventilator imposed further pressure gradient that slowed the incoming flow even further. The presence of the ventilator while maintaining symmetrical distribution for the upstream flow as expected increase the Coefficient of force. Similar trends were also observed for flows at 5 m/s suggesting that the Reynolds number appeared to have negligible effect on the overall pressure distribution.

iv. Skin friction distribution on the roof

From tests conducted at the two wind tunnel speeds of 5 m/s and 10 m/s and at the three different inclination angles of 0°, 15°, and 30°, the skin friction distributions were found to become progressively lower downstream of the ventilator. This reduction in skin friction values appears to be a consequence of reduced free stream velocity due to the momentum deficit occurring behind a bluff body. With the ventilator placed on the roof, the skin friction distribution on the roof increased significantly with increases in the roof inclination angle.

2.5.3 Conclusion

As the conclusion, the forces acting on the ventilator and its rotational speed were found to have a linear increasing trend with the free stream velocity that agrees well with published data. The total force acting on the ventilator as well as its rotational speed decrease with the increase in inclination angle and the effect is more pronounced at higher wind speeds.

2.6 Experiments on the Ventilation Efficiency of Turbine Ventilators Used for Building and Factory by Chi-Ming Lai (2003)

This study focused on method or design to improve the performance of turbine ventilator for better indoor air quality in future. Building and factory ventilation in Taiwan was referred in this journal in order decrease the reliance on air-conditioning. The data of the experiment were discussed in this study.

2.6.1 Methodology

Low-speed wind tunnel experiment was conducted to investigate the flow structure and induced flow rates. The speed of outdoor wind is set at 10, 15, 20, 25, 30 m/s. TESTO 445 Multi-functional ventilation/air-conditioning detector, which is equipped with sensors used to detect the environmental factors such as the wind speed, temperature and humidity.

i. Experiment 1 : Installation enhancement of turbine ventilators

To understand the effects of ventilator-installation on the ventilation, 3 different condition was imposed.

a. Blank experiment (in which no ventilators are being installed)

b. 0.5 m ventilator is being stalled yet it is not in rotation

c. 0.5 m ventilator rotates freely

ii. Experiment 2 : Size effect of turbine ventilators

Ventilators of three sizes (all without inner vanes) are used in the measurements to get hold of the impact the sizes have on the ventilation they induce.

iii. Experiment 3 : Inner vane enhancement of turbine ventilators

To understand what impacts inner vanes have on the ventilation induced, two ventilators with diameter of 0.5m were used in the experiment, one with inner vanes and the other one without. Lastly, compare the actual results of the ventilation measurement with those regulated in domestic and abroad regulations to better understand the efficiency of ventilation with the installation of one single ventilator.

2.6.2 Result and Discussion

i. Experiment 1

Figure 2.2.3 shows that the installation of ventilators is indeed helpful in inducing airflow. However, when the ventilator was failed to move, the ventilator block the airflow in the connecting pipeline, and resulting an even lower ventilation rate compared to when there was not the ventilator.

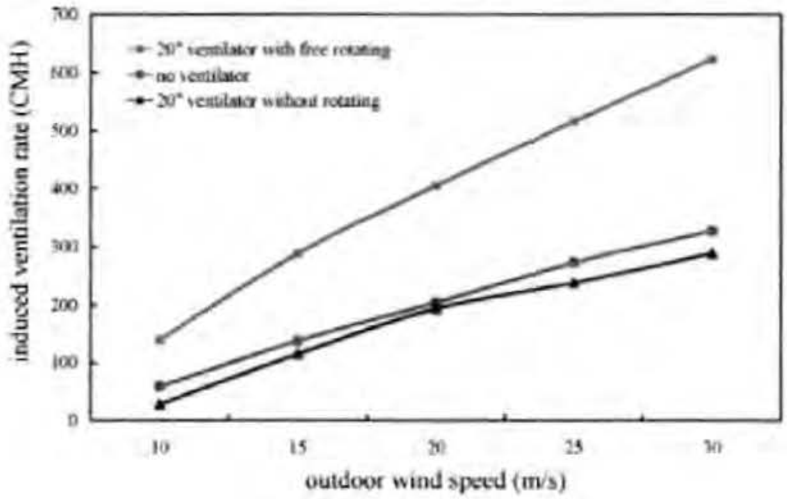


Figure 2.2.3: Experiment 1

ii. Experiment 2

The size of turbine ventilator are not really affected its performance. Figure 2.2.4 shows that the rate of ventilation rate induces are not really impacted by the different of ventilator sizes. When it comes to the application in engineering the rate can be considered equal.

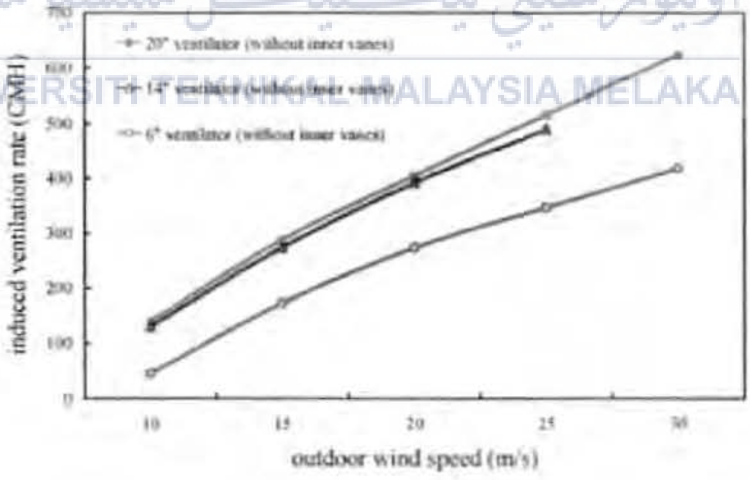


Figure 2.2.4: Experiment 2

iii. Experiment 3

The results in Figure 2.2.5 show that the efficiency is better for ventilators with inner vanes. However, the difference was not significant. The differences on the two turbine we measured are not that significant in the application of engineering, which could result from structural factors in the flow and the imperfect shapes of the inner rotating vanes.

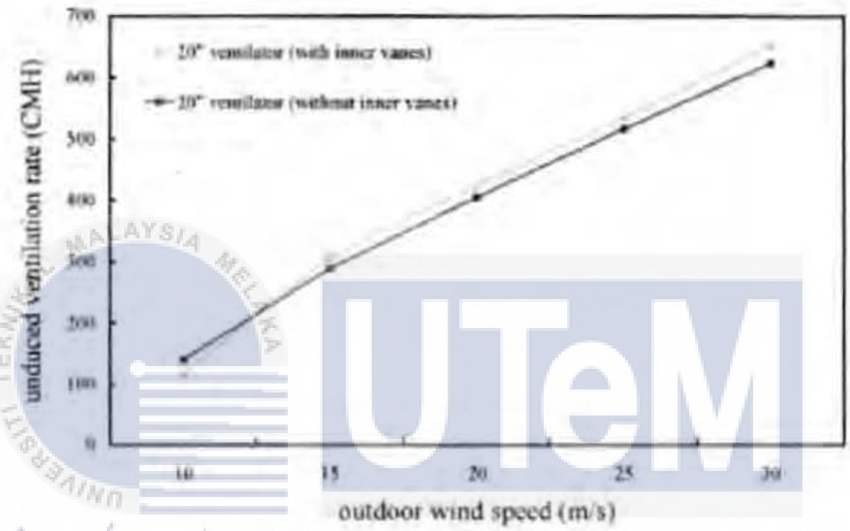


Figure 2.2.5: Experiment 3

2.6.3 Conclusion

The bigger the size of the turbine ventilator is, the bigger ventilation rate is achieved. In other words, a ventilator with the diameter of 0.5 m induces bigger ventilation rate than the one with a diameter of 0.36 or 0.15 m. However, the difference between both ventilation rates is not significant. Turbine ventilator with inner vanes exhausts better than the one without. However, the difference between the two is not significant. Generally speaking, the size (0.5 m/0.36 m) of the turbine ventilators and the availability of inner vanes do not mark significant differences in the ventilation rate induced.

CHAPTER 3

METHODOLOGY

3.1 Overview

This section will focus on the stages for designing and analysis of three different types wind turbine ventilator blade. The procedures to carry out analysis measurement, step for settings and software used for testing the wind turbine ventilator blade were discussed in this chapter.

3.2 Introduction

To design a well functional wind turbine ventilator for commercial use, the device need to be tested and well fabricated to maximize its full potential and minimize maintenance cost. By using ANSYS software that can be easily get from the internet, a better result of testing the designed wind turbine ventilator could be performed. This is due to the ability of the software to run the simulation with a minimum error occur. All the process and step to run the simulation were stated in detail.

3.3 Flow Chart

The flow of the methodology process of designing and testing a wind turbine ventilator briefly showed step by step in Figure 3.1.

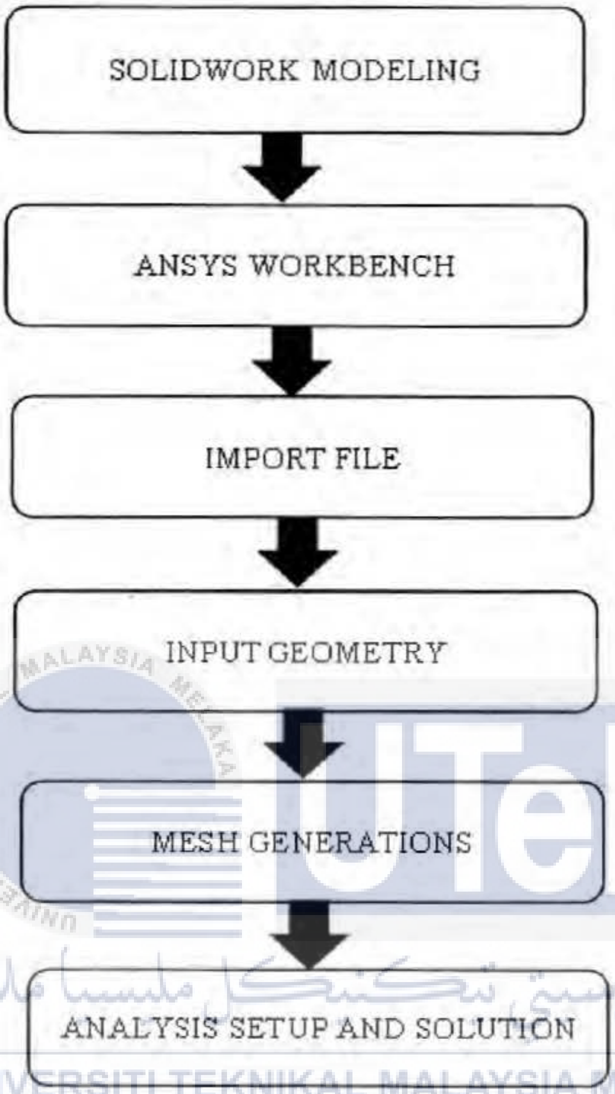


Figure 3.1: Design Process Flow Chart

3.3.1 SOLIDWORK Modeling

This step explain the modeling stage of a wind ventilator turbine use for this project. We can either use SOLIDWORK or ANSYS software to design part or model we wanted to but for amateur user, SOLIDWORK software are more ease to work with when dealing with a complex design. Since the design of this device are quite complicated, it actually minimize the time used for modeling stage as the software were basically developed to focus on modeling ability compare to ANSYS software which is more to device simulation and analysis. Figure below shows the final design of wind ventilator turbine. Three different blades design with different numbers of tubercle was put on a test. Features used for this model including boss extrude, extrude cut, circular pattern, linear pattern, and flex. All the detail of drawing were stated with negative fifty degree (-50°) of blades twist and 300 mm height.

Figure 3.2.1 : Blade with 15 Tubercles

Figure 3.2.2: Blade with 8 Tubercles

Figure 3.2.3 : Blade without Tubercles

Figure 3.5 shows the dimension used for the blade tubercles in this project. Each tubercle have 12mm open diameter, 10.99mm height and 5mm fillet radius. After a single tubercle was measured well, the linear pattern operation from the sketch section was selected to produce repeated drawing along Y-axis. Extrude cut operation which functional as the part removing option have been include in this model drawing's step to cut the body into required shape.

Figure 3.2.4 : Dimension of Tubercles

3.3.2 ANSYS Workbench

This is a project management tool. It can be considered as the top-level interface linking all our software tools. Workbench handles the passing of data between ANSYS Geometry, Mesh, Solver, Post-processing tools. This is a step in ANSYS workbench:

i. First, drag an analysis system (Fluid Flow (Fluent)) on the Project Schematic lays out a work flow, comprising all the steps needed for a typical analysis.

ii. Next, double click the icon geometry to the next step.

Figure 3.3: ANSYS Workbench

3.3.3 Import File

Two common format file used to transfer a SOLIDWORK model to ANSYS are STEP,and IGES. Though this step seem not really important for some user, but it is crucial to choose the right file format since every format has it's own function and use. For this project, IGES format file is more preferable as advised by professional instructor. Besides that all learning process of Computational Fluid Dynamic(CFD) at UTEM also use the same type of format file. The user also can change the format file anytime they wish as shown in Figure 3.6.

The Initial Graphics Exchange Specification (IGES) allows digital exchange of information among computer-aided design (CAD) systems. This type of format file capable of exchanging only geometry and topolog information between different CAD systems.

Figure 3.4: Changing File Format

3.3.4 Input Geometry

Analysis of this project focus on the the wind ventilator turbine. Therefore, a test section need to be create and treat as free moving air or atmosphere around the test subject. The step to generate the geometry of this condition was listed below.

i. The first step is to drag an analysis system from the toolbox in ANSYS workbench. Geometry from component systems section was chosen.

ii. The existing SOLIDWORK model in IGES format file was imported to the geometry.

iii. A warning appeared on the monitor which mention the limitation of the unit used. The unit meter used for this project.

iv. Enclosure was generated around the wind ventilator as a test section. The box which act as atmosphere have a dimension of (3500×2000×1000)mm, meanwhile the sphere is 440mm in diameter.

v. The solid bodies were renamed and the type of material of the body was selected either in solid or fluid form to avoid any error occur in further analysis.

vi. Boolean operation selected to subtract the body of wind ventilator turbine and the atmosphere. The body operation can be find under the create heading.

vii. The geometry was closed and proceed to the next step named mesh.

Figure 3.5: Wind Ventilator Turbine Geometry

3.3.5 Mesh Generations

Meshing is the initial step in doing analysis of any geometry. The mesh defines the model for the analysis. Meshing also will create a mesh of some grid-points called nodes. It is done with a variety of tool and options available in the software. The size of the mesh influence the accuracy of the result. Small mesh sizing will give a better data compare to the bigger size. The setting of mesh were shown below including sizing, inflation and the statistic of the mesh.

Sizing	
Size Function	Curvature
Relevance Center	Fine
Initial Size Seed	Active Assembly
Smoothing	High
Transition	Slow
Span Angle Center	Fine
Curvature Normal A...	Default (18.0 °)
Min Size	Default (0.606320 mm)
Max Face Size	Default (60.6320 mm)
Max Tet Size	Default (121.260 mm)
Growth Rate	Default (1.20)
Automatic Mesh Based...	On
Defeaturing Tolera...	Default (0.303160 mm)
Max Dual Layers in Thi...	No
Minimum Edge Length	8.53720 mm

Figure 3.6.1: Sizing Selection

Inflation of the mesh used in this project was shown in **Figure3.** smooth transition was set with transition ratio of 0.272. Maximum layers was increase from 5 to 10 and the growth rate is 1.2.

Details of "Mesh"

+ Sizing	
Inflation	
Use Automatic Inflation	Program Controlled
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Layers	10
Growth Rate	1.2
Inflation Algorithm	Pre
View Advanced Options	No

Figure 3.6.2: Inflation Selection

The result of generated mesh for the test were shown below. Based on the statistic, the nodes and elements generated from the model are 104,593 and 356,145. We need to alert on the elements generated since the limit of element allowed of this software cannot exceed more than 500,000.

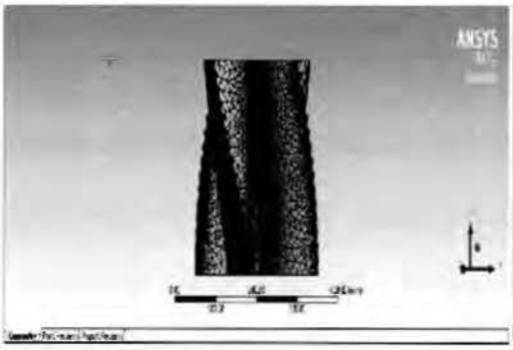


Figure 3.6.3: Blade Mesh

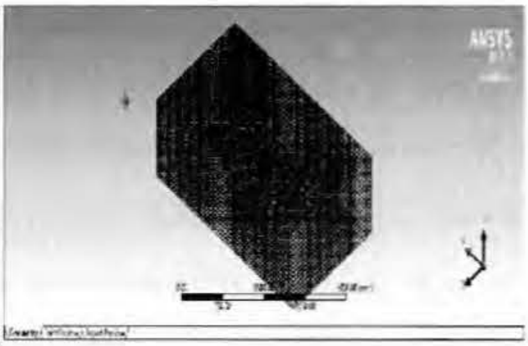


Figure 3.6.4: Inflation Selection

Statistics	
Nodes	104593
Elements	356145
Mesh Metric	None

Figure 3.6.5: Mesh Statistic

Before proceed to setup and solution, the boundary layer of the testing model were declared as inlet, outlet, wall and turbine wall. The named selection mostly depend on the case studied. The mesh was then updated and the next step can already be started.

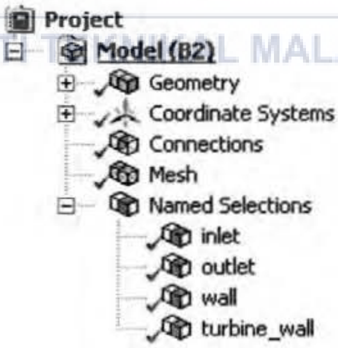


Figure 3.6.6: Name Selection of Ventilator

3.3.6 Analysis Setup and Solution

Double precision with serial processing was chosen. The test was conducted under standard k-epsilon model with standard wall function. Material used was air that have a constant density and viscosity of 1.225 kg/m³ and 1.789e-05. Boundary condition was set at the inlet and the turbine wall. The solution methods used is "SIMPLE" scheme for pressure-velocity coupling. As for spatial discretization, the details shown in **Figure3.**

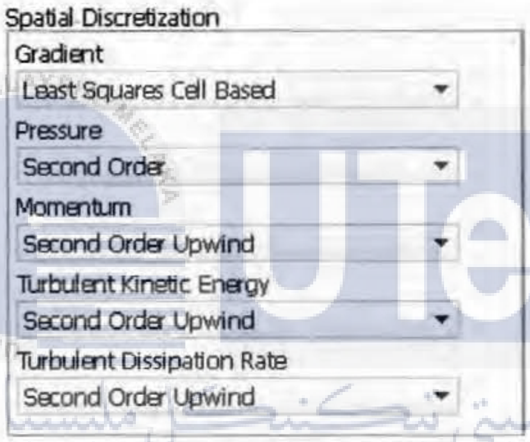


Figure 3.7: Setting for Spatial Discretization

At the monitor section, the residual for all axis was fixed to 0.001 absolute criteria. The drag and lift were also set to make sure the data was set during the solution stage. Hybrid initialization preferred for this case and the number of iteration was increase to 20. It is crucial to check the number of iteration for initialization since it may effect the calculation of the model. Finally the calculation was run with maximum number of iterations which is 1000 to ensure the calculation of the solution converged at the exact number of iterations.

CHAPTER 4

RESULT

4.1 Overview

In this study, the data and results of lift coefficient and drag coefficient of the wind ventilator turbine blade with different number of tubercles was obtained. Three cases condition with 15 and 8 tubercles and a blade without tubercle are tabulated and analyzed. The data and result simulate from the ANSYS software are compared to identify the best design for future development.

4.2 ANSYS Simulation Result and Analysis

Computational simulation was conducted on a wind ventilator turbine blade with variety number of tubercle. Each blade will be simulated for different inlet velocity from minimum of 1 m/s to the maximum of 9 m/s. The values of inlet velocity were aligned for the other two blades. Besides that, the rotational speed of the wind ventilator turbine was fixed to 1.6 rad/s. Table 4.1 shows the constant variables used for three different types of blade.

Table 4.1: List of Constant Variables

Variable	Value
Air density	1.225 (kg/m³)
Air viscosity	1.7894e-05 (kg/m.s)
Rotational speed	1.6 (rad/s)
Temperature	288.16 (k)
Ratio of specific heat	1.4

4.2.1 Simulation 1 Result

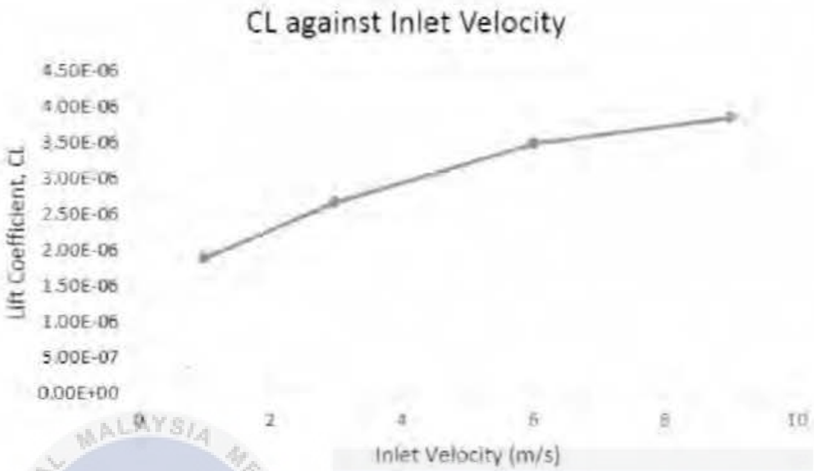
This computational analysis study the effect of a wind ventilator turbine blade with 15 number of tubercles. The material used was aluminum since it was light and following the real situation standard. The data and result of lift and drag coefficient of the blade from ANSYS solution was tabulated in Table 4.2. The solution take a minimum of 35 and maximum of 47 iterations before converged.

Table 4.2: 15 Tubercles Data

Inlet Velocity (m/s)	CL	CD	CL/CD Ratio
1	1.8937e-06	1.8937e-06	1.00
3	2.6761e-06	2.6761e-06	1.00
6	3.4933e-06	3.4933e-06	1.00
9	3.8465e-06	6.8472e-06	0.57

4.2.1.1 Coefficient of Lift

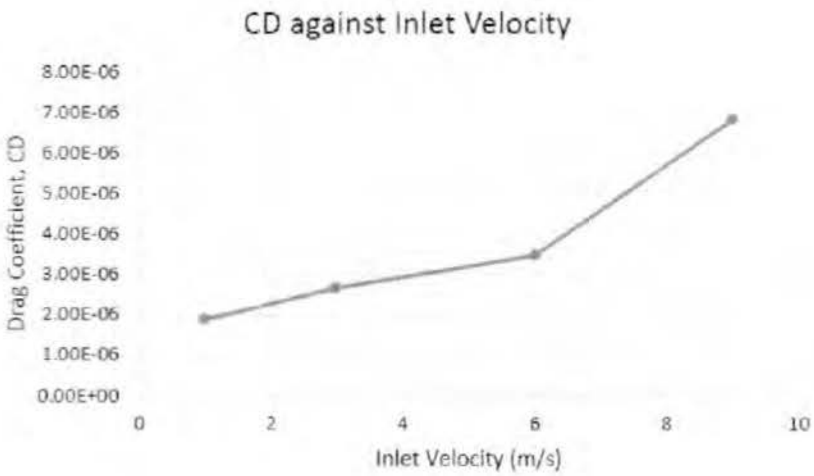
Graph 4.1 shows the relationship between lift coefficient and inlet velocity for blade with 15 tubercles. It can be seen that the graph experienced a slightly increases pattern. With the increase in inlet velocity during the simulation, the lift coefficient also increase which cause the blade work efficiently. Based on the graph, the highest lift coefficient of blade with 15 tubercles is 3.8465e-6 which recorded at 9 m/s wind velocity. Meanwhile, the lowest is at 1 m/s with just 1.8937e-06 CL.



Graph 4.1: Graph of CL against Inlet Velocity (15 tubercles)

4.2.1.2 Coefficient of Drag

Detail identification of drag coefficient for simulation 1 was performed in term of graph. Drag coefficient against inlet velocity graph shows a rise pattern of the data. The increasing result can be seen from the beginning until the end. The drag coefficient data look similar to lift coefficient except at velocity of 9 m/s which produced 6.8472e-06 drag.



Graph 4.2: Graph of CD against Inlet Velocity (15 tubercles)

4.2.1.3 ANSYS Result

Figures below shows the ANSYS result of velocity contour for blade with 15 tubercles. For Figure 4.1, the velocity inlet was fixed to 1 m/s which resulting a different pattern of contour on the blade. As can be seen, the wind velocity increase as it flow down on the upper part of the blade with maximum and minimum of 4.944e-01 and 6.194e-02.

Figure 4.1: Velocity Contour for 1m/s (15 tubercles)

While for velocity inlet of 9 m/s, the velocity contour was almost constant at all of the blade surface. This situation shows that the needed velocity of wind to operate this device is as minimum as 5.574e-01.

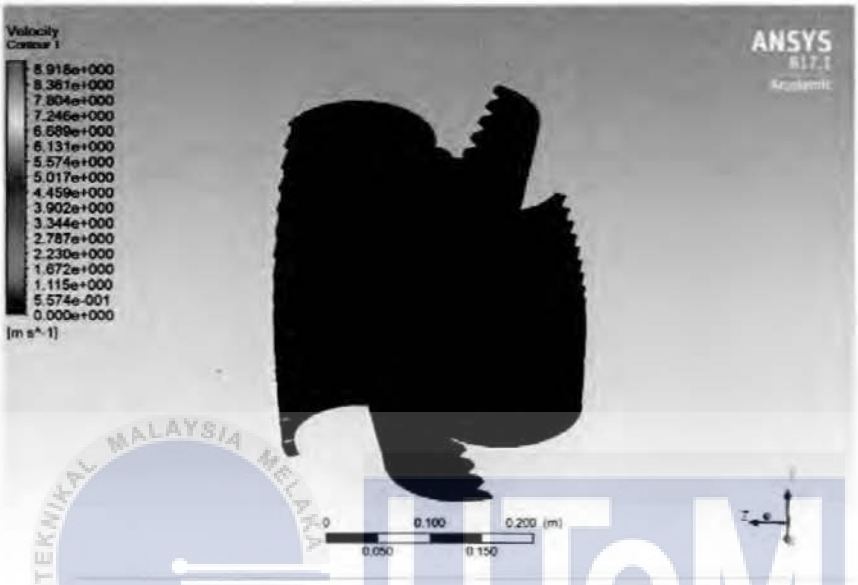


Figure 4.2: Velocity Contour for 9 m/s (15 Tubercles)

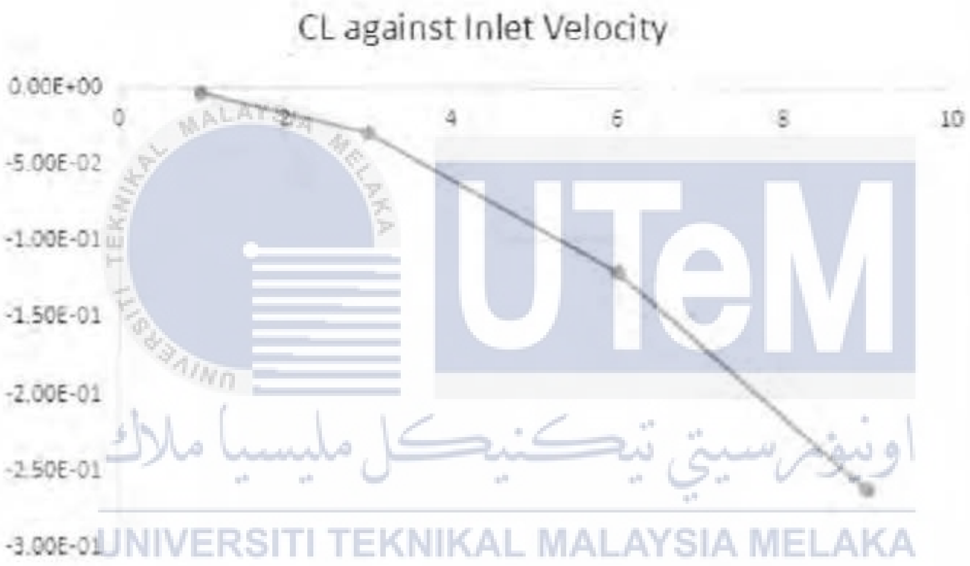
4.2.2 Simulation 2 Result

Second analysis was made by simulate the wind ventilator turbine blade with 8 tubercles. The dimension of tubercle used are still the same as blade with 15 tubercles, but the position of the tubercles designed gave a little different in result obtain from the ANSYS simulation. Maximum and minimum iterations occur was 465 and 264 before converged.

Table 4.3: 8 Tubercles Data

Inlet Velocity (m/s)	CL	CD	CL/CD Ratio
1	-4.0542e-03	-4.0542e-03	1.00
3	-2.9630e-02	8.5785e-01	-0.03
6	-1.2093e-01	3.442e+00	-0.04
9	-2.6332e-01	7.6969e+00	-0.003

4.2.2.1 Coefficient of Lift

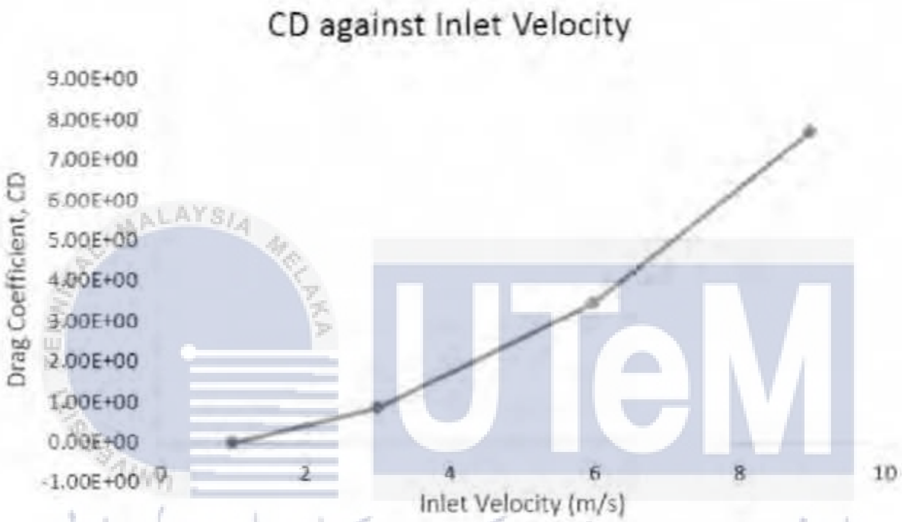


Graph 4.3: Graph of CL against Inlet Velocity (8 tubercles)

By referring the Graph 4.3 above, it can conclude that the coefficient of lift for the blade having 8 number tubercles. The data steeply plunged from the minimum wind velocity of 1m/s to the peak inlet velocity of 9 m/s. This situation maybe affected by an error since it does not following the engineering principle.

4.2.2.2 Coefficient of Drag

According to the data plotted in Graph 4.4, the drag coefficient seem to grow up as the inlet velocity surged. The maximum drag coefficient produced was 7.6969e+00 at maximum inlet velocity. The starting point of the graph was -9.844e-03 of drag coefficient at 1 m/s inlet velocity.



Graph 4.4: Graph of CD against Inlet Velocity (8 tubercles)

4.2.2.3 ANSYS Result

Figure 4.3 and 4.4 shows the velocity streamline on blade with 8 tubercles at different inlet velocity which is 1 m/s and 9 m/s. At 1 m/s inlet wind velocity, the maximum needed to rotate the blade was 7.284e-001. As can be observed, the wind mostly hit the outer part of the blade which resulted a reverse rotation of the blade. At the other hand, at 9 m/s inlet wind velocity, the 3.373e+00 of wind velocity mostly hit the inlet surface of the blade.

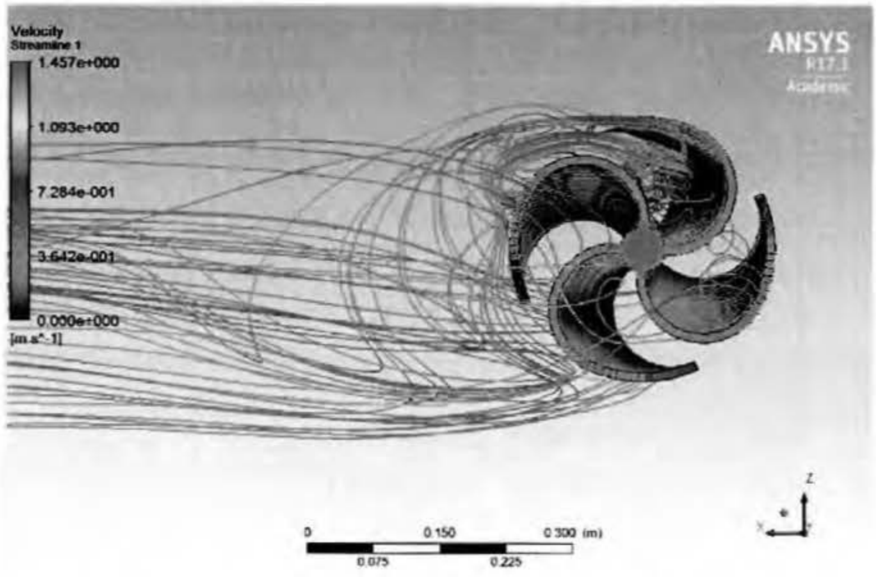


Figure 4.3: Velocity Streamline for 1 m/s (8 Tubercles)

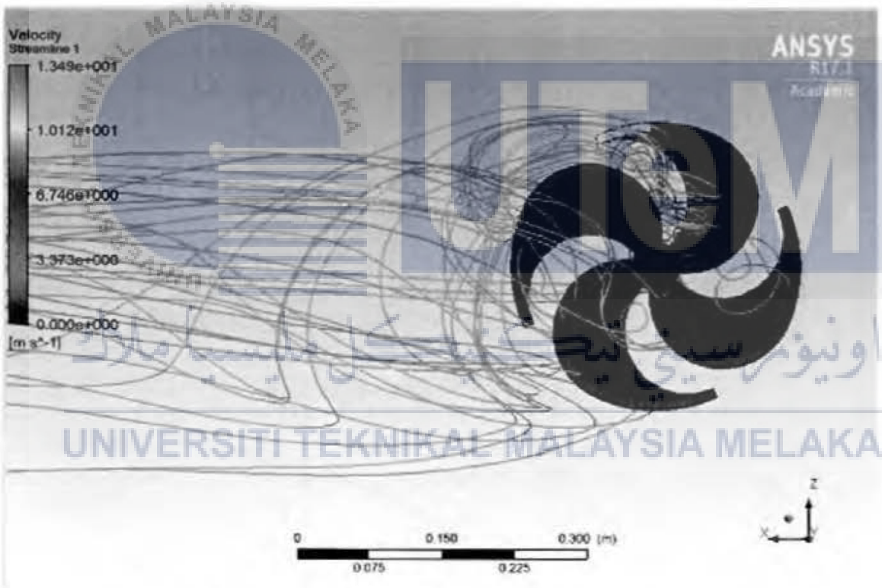


Figure 4.4: Velocity Streamline for 9 m/s (8 Tubercles)

4.2.3 Simulation 3 Result

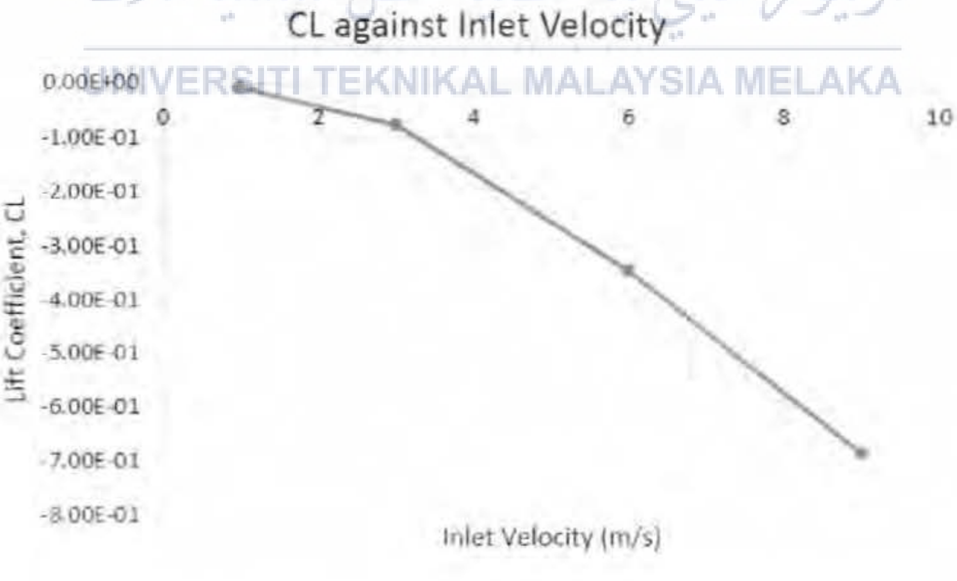
The last blade of wind ventilator turbine without a tubercles was put on a test. The result of the simulation was record according to the ANSYS solution data. The solution need 73 to 109 iterations to converge the solution. The time taken to converge the result depends on RAM of the computer.

Table 4.4: Without Tubercles Data

Inlet Velocity (m/s)	CL	CD	CL/CD Ratio
1	-7.9927e-03	1.0544e-01	-0.08
3	-7.4862e-02	9.3861e-01	-0.08
6	-3.4731e-01	3.7262e+00	-0.09
9	-6.8543e-01	8.3710e+00	-0.08

4.2.3.1 Coefficient of Lift

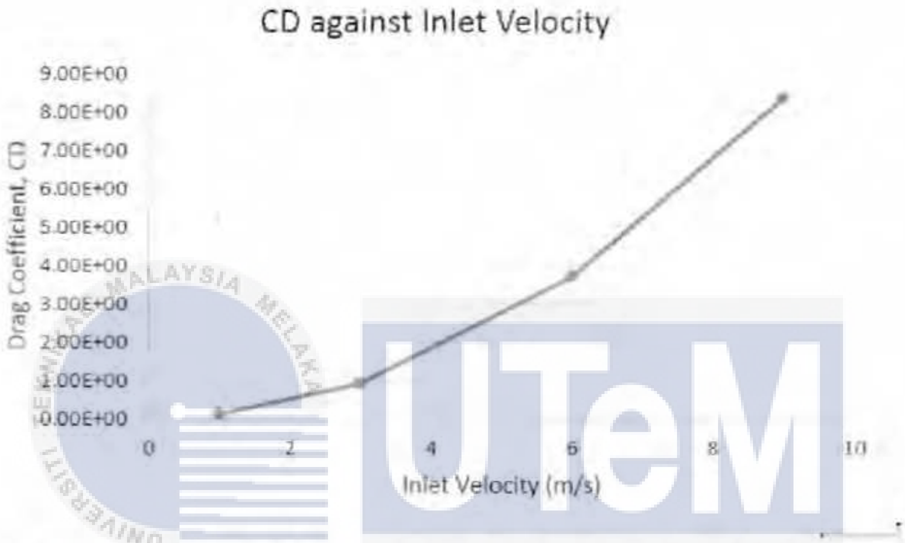
For the blade without tubercle, the graph of lift coefficient plotted was gradually dropped from -7.9927e-03 to -6.8543e-01. The negative sign of the lift coefficient represent the direction of air separation when hitting the edge of the blade.



Graph 4.5: Graph of CL against Inlet Velocity (without tubercles)

4.2.3.2 Coefficient of Drag

The relationship between drag coefficient and inlet velocity for simulation of blade without tubercles slightly rose. The greater drag force produced with higher inlet velocity provided which mean the device having difficulty to rotate.



Graph 4.6: Graph of CD against Inlet Velocity (without tubercles)

4.2.3.3 ANSYS Result

Based on observation that can be made from Figure 4.5, the maximum and minimum of forces that was experienced by the blade were 9.497e-001 and 3.166e-001 for 1 m/s wind inlet velocity. Meanwhile for 9 m/s inlet velocity, the maximum and minimum forces recorded were 5.759e+00 and 2.879e+00.

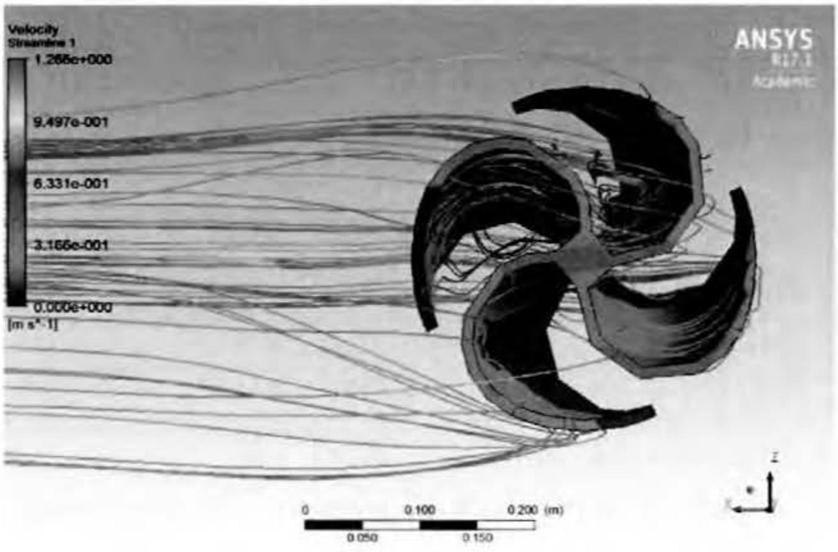


Figure 4.5: Velocity Streamline for 1 m/s (blade without tubercle)

Figure 4.6: Velocity Streamline for 9 m/s (blade without tubercle)

4.3 Analysis

The analysis of this project was made based on the result of three different blades simulation. All important data was listed in detail to ease the analysis for all the simulation result. A slight differences can be obtained from Table 4.4 below.

Table 4.5: Data for Three Different Blade

Inlet Velocity (m/s)	15 Tubercles		8 Tubercles		Without Tubercles	
	CL	CD	CL	CD	CL	CD
1	1.8937e-06	1.8937e-06	-4.0542e-03	-4.0542e-03	-7.9927e-03	1.0544e-01
3	2.6761e-06	2.6761e-06	-2.9630e-02	8.5785e-01	-7.4862e-02	9.3861e-01
6	3.4933e-06	3.4933e-06	-1.2093e-01	3.442e+00	-3.4731e-01	3.7262e+00
9	3.8465e-06	6.8472e-06	-2.6332e-01	7.6969e+00	-6.8543e-01	8.3710e+00

Rough observation can be made upon the data recorded. In term of coefficient of lift for three type of blade, the pattern for 15 tubercles blade shows an impressive rise along with the increase of inlet velocity. In the other hand, the graph of blade with 8 tubercles and without tubercles seem to be in opposite result. This phenomena can be related to the reverse direction of the wind.

For the coefficient of drag, all of the three simulation experiencing a greater drag at the highest inlet velocity based on the graphs shown before. The peak drag coefficient of blade 15, 8, and without tubercles are 6.8472e-06, 7.6969e+00 and 8.3710e+00. This may be affected by the geometry of the wind ventilator turbine itself as the cross-sectional shape of an object determines the form drag created by the pressure variation around the object.

The ratio of lift and drag coefficient also need to be considered. As can be seen the highest ratio was 1.00 while the lowest was -0.003. Based on calculation made, blade with 15 tubercles shows a quite consistent result compare to the other two cases.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

The development of a wind ventilator turbine should be more emphasized on its design and geometry in order to maximize its full potential even in low wind speed. It is crucial for the device to have a great blade design which can easily adapt with the natural conditions. The number of tubercles on the blade give a great impact in term of drag and lift coefficient. The more the tubercles along the blade edge, the better the outcome of drag and lift force produced. This correlation can be tied to the fluid dynamics physics that apply to tubercle-blade. The present of the tubercle actually help to generate more lift and less drag before stalling occurred. Since the 15 tubercles blade had much more tubercles, they were a closer model to real tubercles. Therefore it had an overall increase in output compare to blade with 8 tubercles and without tubercle.

When a solid body is moved through a fluid, the fluid resists the motion. The object is subjected to an aerodynamic force in a direction opposed to the motion which called drag. There are many factor that may lead to the increase of drag including the object geometry, motion of the air and properties of the air. As the wind velocity increase, the drag also increase. The drag occurred can be reduced by controlling the air viscosity and its compressibility during the simulation made by ANSYS software for all model.

The effectiveness of a blade also measured based on the ratio of lift and drag coefficient. The ratio is the amount of lift generated by the blade, divided by the aerodynamic drag it creates by moving through the air. The higher value of this ratio indicate the better performance of the blade. Therefore, it was proven that the higher the number of tubercles on the blade, the better its performance since the data for simulation 1 give an consistent value of lift and drag ratio.

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