A Study on Blade Performance of Transverse Axis Wind Turbine Mounted on a Rooftop

by

Rafflella Anak Deraman

Dissertation submitted in partial fulfilment of

the requirements for the

Bachelor of Engineering (Hons)

(Mechanical Engineering)

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CERTIFICATION OF APPROVAL

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Approved by,

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(Mr Mohd Syaifuddin b. Mohd)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

September 2013

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in the project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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(RAFFLELLA ANAK DERAMAN)

ABSTRACT

The idea of generating electricity using rooftop mounted wind turbine has raise over the last decade. It is due to rising energy costs and the global need to reduce the use of carbon and greenhouse emissions. The rooftop mounted wind turbine has the potential to replace the source of generating the electric power. This research paper presents about the modeling, analysis and study of the blade design that affect performance of transverse axis wind turbine mounted on a rooftop. It consists of background of study of the project, problem statement, objectives, scope of study, literature review for the relevance, methodology and final result, conclusion and recommendations to improvise the experiment. In this project, the author design and fabricate the transverse axis wind turbine based on relevant parameters and determine which turbine offer the best in term of speed that can be generated from the wind. At the end of this research, several recommendations have been made to improve the project that had been done.

ACKNOWLEDGEMENT

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Last but not least, the author wishes to express her love and gratitude to her beloved parents, for having so much faith and courage in her and never failed to support her in many ways.

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ABBREVIATIONS

CAE	Computer-Aided Engineering
CATIA	Computational Aided Three-dimensional Interactive Application
HAWT	Horizontal Axis Wind Turbine
PVC	Polyvinyl Chloride
RPM	Revolution Per Minute
UTP	Universiti Teknologi PETRONAS
VAWT	Vertical Axis Wind Turbine

NOMENCLATURES

P	Pressure
ρ	Density
A	Area
Cp	Coefficient of Power
V	Wind Speed / Velocity

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Use of wind power or wind turbine is growing fast, due to large improvement on technology, industry maturation and an increasing concern with greenhouse emissions linked with fossil fuels. The Association of Wind Energy Generation predicts that this trend will continue as there is significant opportunity to expand use internationally, particularly since only small portion of the wind potential is presently utilized [1].

Many different wind generators has evolved over the years, with many design modification introduced. Two basic classifications of the wind turbine exist are horizontal axis and vertical axis.

Horizontal axis wind turbines (HAWT) are considered more efficient in operating than vertical axis wind turbine (VAWT). Yaw is needed in operating HAWT which are costly higher and require high levels of maintenance, but naturally unnecessary for VAWT.

A deployment of small scale rooftop mounted wind turbine in urban environment has increased over the last decade due to sing energy costs, and the global need to reduce carbon and greenhouse emissions [2]. In order to improve the performance of the rooftop mounted axis, the present study will consider the improvement of the blade design of the wind turbine, which is the basic geometry, as a critical step to increase efficiency of the output power. Investigation is conducted to study effect of geometrical configuration on the performance of the rotor.

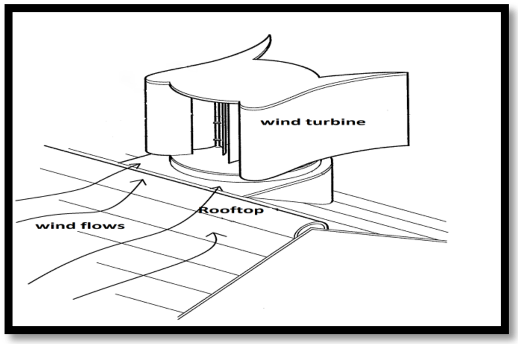

Figure 1.1: Wind flows on the mounted roof wind turbine [3]

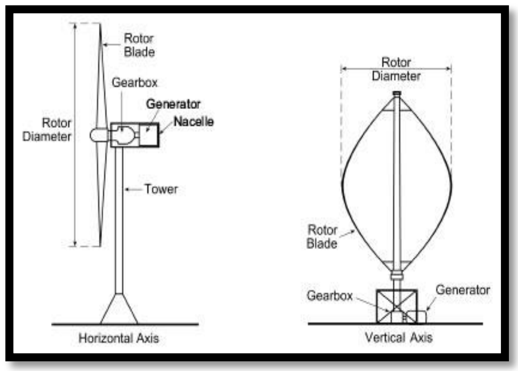

Figure 1.2: (right) Horizontal axis wind turbine and (left) vertical axis wind turbine [4]

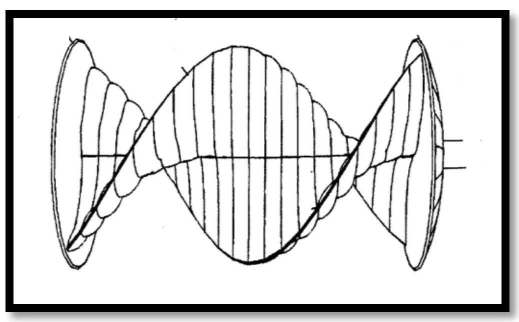

Figure1.3: Transverse axis turbine with twisted foil [5]

1.2 Problem Statement

A rooftop mounted wind turbine take advantage if accelerated wind velocity over the sloping roof. Blade design on the transverse axis mounted on a rooftop that can produce higher speed in term of RPM will be studied.

1.3 Objectives

i. To investigate the different design parameters affecting the performance of the transverse axis wind turbine.
ii. To design and fabricate models of the transverse axis wind turbine blades mounted on a rooftop.

1.4 Scope of Study

i. This study will focus on the same geometry of the wind turbine with different configuration of blade that produce higher speed rotor.
ii. The type of wind turbine that will be used is transverse axis wind turbine.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Wind energy as a renewable energy sources is growing quicker nowadays. In the future of renewable energy derives from wind turbine is expected to play an important role as a tool in generating electric energy. Up to now, there are many different type of wind turbines have been utilized to generate power. Wind turbines can be classified into two major types, horizontal axis wind turbines and vertical axis wind turbines. In wind turbine industry today, it is been dominated by horizontal axis wind turbine with vertical axis wind turbine being less in common.

2.2 Types of Wind Turbine

Turbine can be divided into two types that are horizontal axis wind turbine (HAWT) and vertical axis wind turbine (VAWT). The different between the two types is based on the axis position. HAWT are already commonly used with plenty of manufacturer. VAWT is still very new implemented as commercial usage. VAWT also still been studied by various researchers using modern analysis technique. Unlike VAWT, HAWT is not omni-directional. As the wind direction change, HAWT must also change direction to enable continues functioning. VAWT has advantages that are attracting increasing such as suitability in urban areas, low noise at low tip speed ratio (TSRs), better aesthetics in terms of integrating in architectural structures, insensitivity to yaw direction and increase power output in skewed flow [6]. These advantages have led to a growing research interest in VAWTs, to bridge the gap of shortcomings with HAWTs.

2.3 Parameters Affecting the Performance of Wind Turbine

2.3.1 Size / Length of blades

Wind turbine design and development requires a detailed understanding of the physics of the interaction between moving air and rotor blades. Wind is consisting of a combination mean flow and turbulent fluctuations about it. There are a few characteristics of the wind turbine that past researchers believe affecting its performance. Bhattacharya (2010) found that size of blades affect the power coefficient of the wind turbines. A wind turbine has larger blades will produce a lower voltage. Since, the larger blades are heavier; it is more difficult to spin.

2.3.2 Number of Blades

The number of blades increases the weight to be turned by the turbine. In the other hand, more blades provide a greater surface area for the wind to push, so it will produce more turning power. Having fewer blades could be beneficial, but it will also be somewhat inefficient because it produces less turning power but some studies during the 80's demonstrates that the 2 bladed configurations have higher efficiency [5].

2.3.3 Roof Profiles

Types of roof also contributed into the parameter that affecting the performance if wind turbines. The wind characteristics that built up in environments is influenced by the shape of the building especially the shape of the roofs. There are only a few numbers were considered in previous study, the pitched roof, pyramidal roof, and flat roof (Gomis, 2011).

Figure 2.1: (left) pitched roof; (middle) flat roof; (right) pyramidal roof [10]

2.4 Equations for Power Coefficient of Wind Turbine

The coefficient of power of a wind turbine is a measurement of how efficiently the wind turbine converts the energy in the wind into electricity.

$$P = \frac{1}{2} C_p \rho A v^3$$

The amount of power, P that can be absorbed by wind turbine is calculated by above equations where;

Cp = power coefficient,

ρ = density of the air,

A = swept area of the turbine,

v = wind speed

CHAPTER 3

METHODOLOGY/PROJECT WORK

3.1 Overview

This project has been conducted experimentally by designing and fabricating three different type blade design of wind turbine. All the data obtained will be recorded. The results obtained were then to be discussed.

3.2 Computational Aided Three-dimensional Interactive Application (CATIA)

All the process involved in designing, modelling and assembly of parts of the wind turbines are using CATIA. Before job fabrication can be done, the drawings of the desired design are made. It is important to have those drawing where it can be as used as a reference.

3.3 Material Selection

The choice of the material is the most vital part before fabrication job started. Few design criteria are to be taken into consideration for the choice. Cost, weight and availability

Table 3.1 Material selection

Material	Used for	Reason
PVC Pipe	The turbine blade	▪ Light weight ▪ Low cost ▪ Easy to find ▪ Glueable

		▪ Good to aggressive environment ▪ factor
Perspex	End plate of the turbine blade	▪ Strong and light weight ▪ Available in UTP ▪ Good impact strength
Galvanized iron	Shaft	▪ Available in the lab ▪ Suitable with the loads condition

3.4 Equipment and tool components

Table 3.2: Equipment and tool components

Equipment's and tool components	Function
Turbine	- Main component - Transform air from the wind
Bearing	- Ball bearing were used - Lower cost - To reduce rotational friction and support radial and axial loads
Digital tachometer	- Instrument measuring the rotation speed of a shaft or disk as in a motor or other machine - Displays the revolution per minute (RPM) in numerical readings
Digital anemometer	- A device used for measuring the wind speed
Roof model	- A house with pitched roof has been used - With an angle of 45˚.

3.5 Project Activities

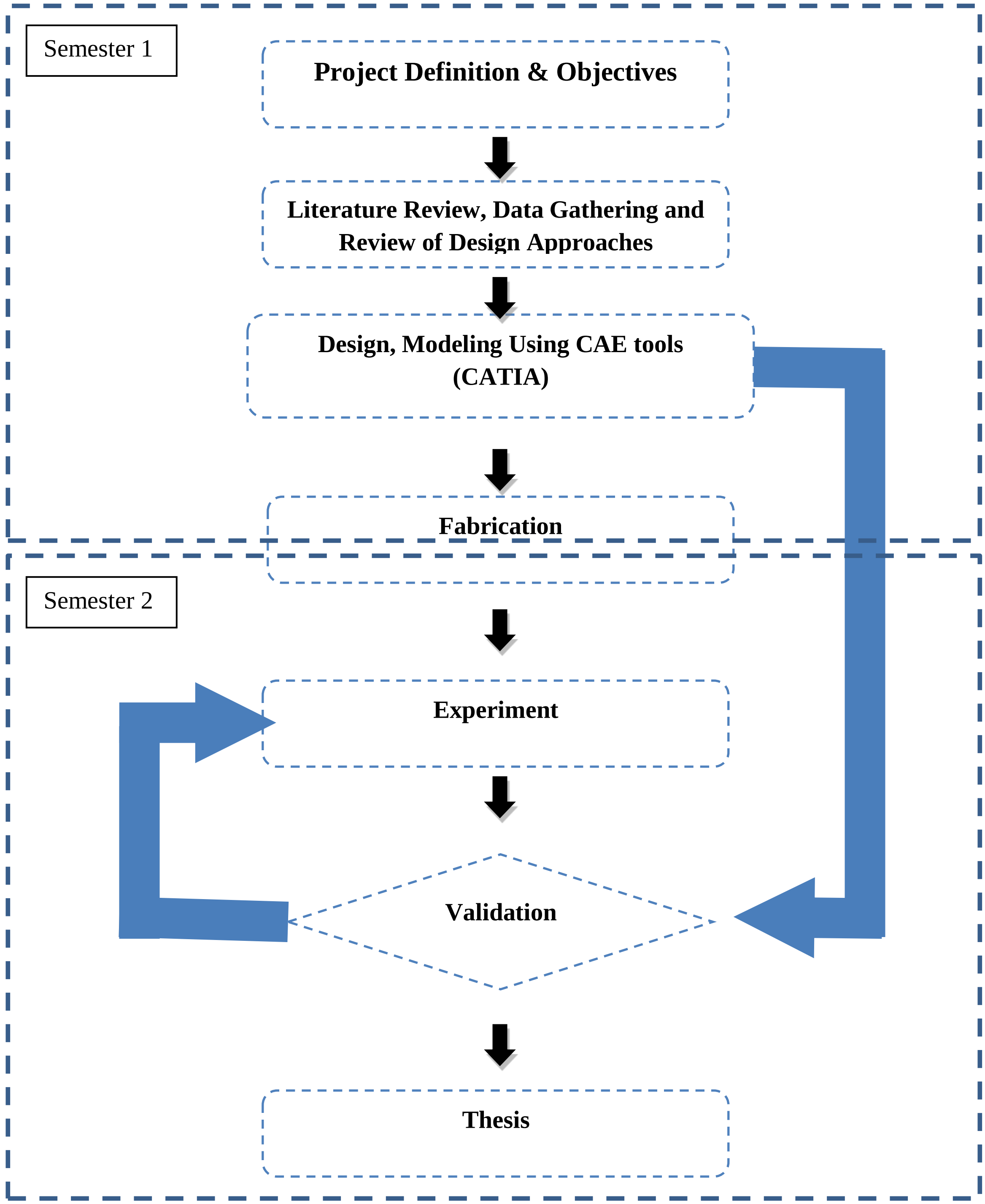

Figure 3.1: Project activities flows

The project activities shown in Figure 3.1 are a brief overview of the work flow for this project. It started with defining the problem and objectives of the project before carry out the literature review, data gathering and review of the design approaches.

After the design approaches has been decided, the process of modeling of the wind turbine blade using CAE tools (CATIA) will be started. The construction of the wind turbine blades, the roof model and how the turbine will be mounted decided on this design. The fabrication and assembly process then started after the completed modeling of the turbine blade and roof model design.

The project continues in the next semester which in FYP 2 with experimentation of the blade performance. Required experiment will be conducted to verify the hypothesis. If the experiment unsuccessful or not meet the requirement, the experiment will be done again. The validation of the parameters that affected the performance of the transverse axis wind turbine rooftop mounted will be made soon after the experiment done. The final stages of the project are the thesis writing.

3.6 Design and Fabrication of the Wind Turbine

There are three type of wind turbine that is used to investigate their performances. The entire turbine has different types of blades design. Drawing construction of the wind turbine was model in CATIA. The blade of the wind turbine are using Polyvinyl Chloride (PVC) pipe with diameter of 55 mm which are cut into half. The thicknesses of the PVC pipe are 2.2 mm. The end plates of the wind turbine are made of Perspex. The Perspex cuttings are done by the technician of Design and Prototyping Centre (DPC). The blade end plates set was cut exactly as per requested in CATIA drawing using CNC machine. The PVC then inserted into the slot in the Perspex and glued by the silicone. As for the shaft, galvanized iron was being used. Ball bearing were installed both in the end of the shaft. Then it was installed on a rooftop house model.

Figure 3.2: One of the technicians does the PVC pipe cutting process using cutter. The PVC pipe is cut into half.

Figure 3.3: End plate of the wind turbine

3.7 Experimental process

Experimental process was done to test which type of turbine rotor can generate most speed form the wind. In this process, the turbine is installed on the rooftop. Two portable fans are used as a source of wind for this analysis. The fan consists of three different speeds. Five different angle readings are measured and recorded for each turbine rotor speed. RPM of the turbine are taken once the wind speeds are stable. The experiments processes are then to be repeated with different type of turbine blades. Below are points that the wind speeds are measured. This has been done to see the roof effect from wind that flow to the roof. The distance of fan from the roof is 1.5 meter.

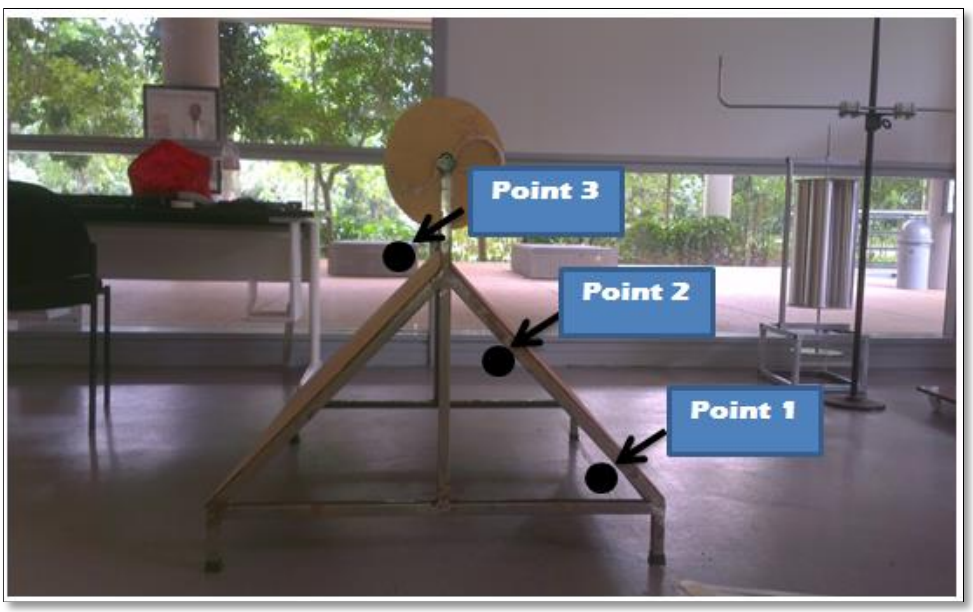

Figure 3.4: Point on the roof that been measured for the roof effect

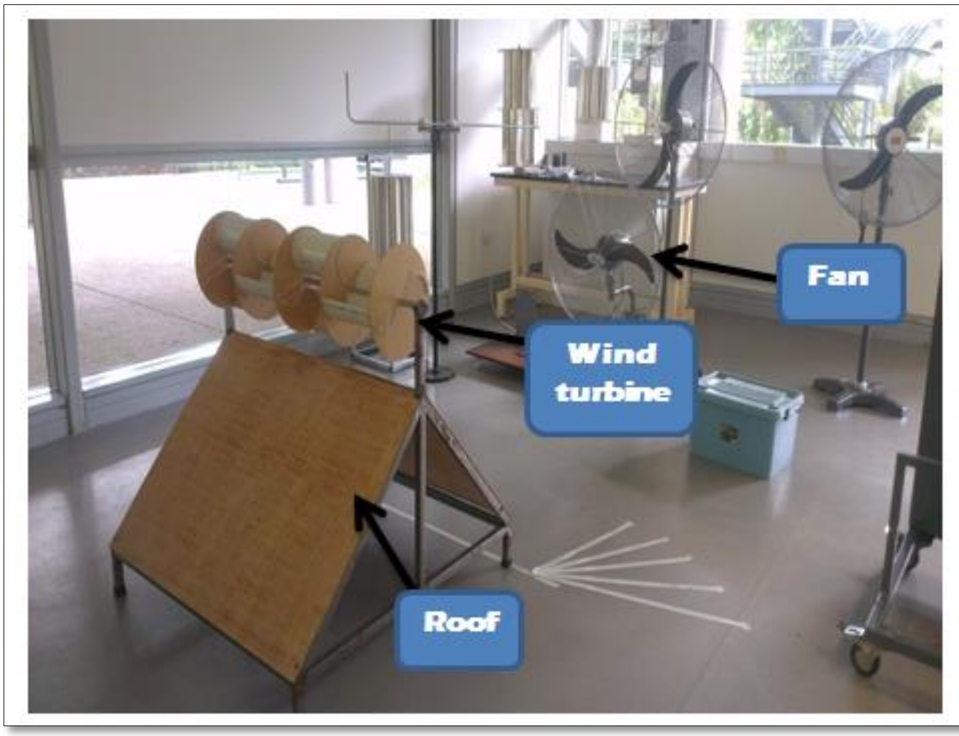

Figure 3.5: The set-up of experimental process

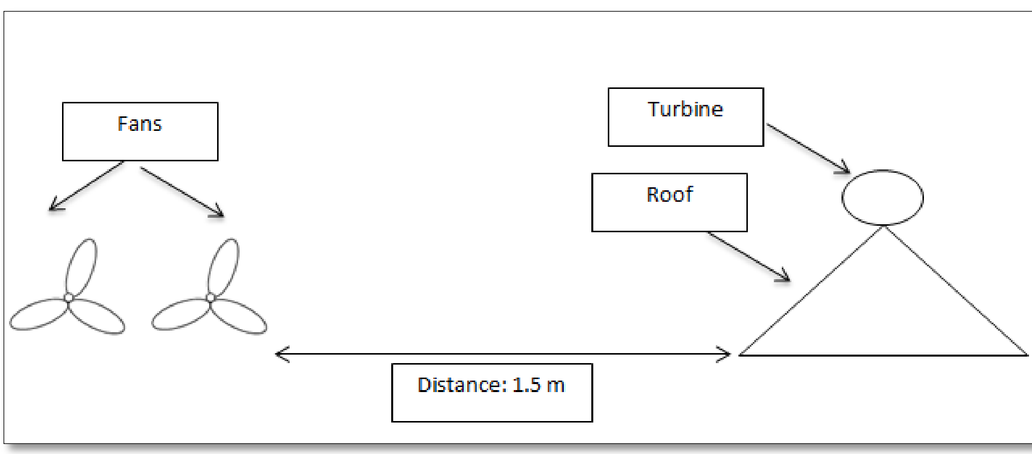

Figure 3.6: Schematic diagram of the experimental process set-up

3.8 Flow visualization

Flow visualization is used to make the flow patterns of the wind visible. Flow visualization of the turbine was done by using dry ice and cold water. The turbine and the roof had to be painted black in order to get the better visualization the wind flow.

3.9 Project Gantt chart and Project Milestones

Refer to the Appendices one (1) and two (2)

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Data gathering and analysis

The experiment were conducted in Block 18 lab. The results are based on the three types of the wind turbine blades.

Table 4.1: Wind speed at different point and different fan speed

	Location		
	Point 1	Point 2	Point 3
Speed 1	0.8 m/s	2 m/s	4.5 m/s
Speed 2	1.1 m/s	2.7 m/s	5.3 m/s
Speed 3	1.3 m/s	2.9 m/s	6 m/s

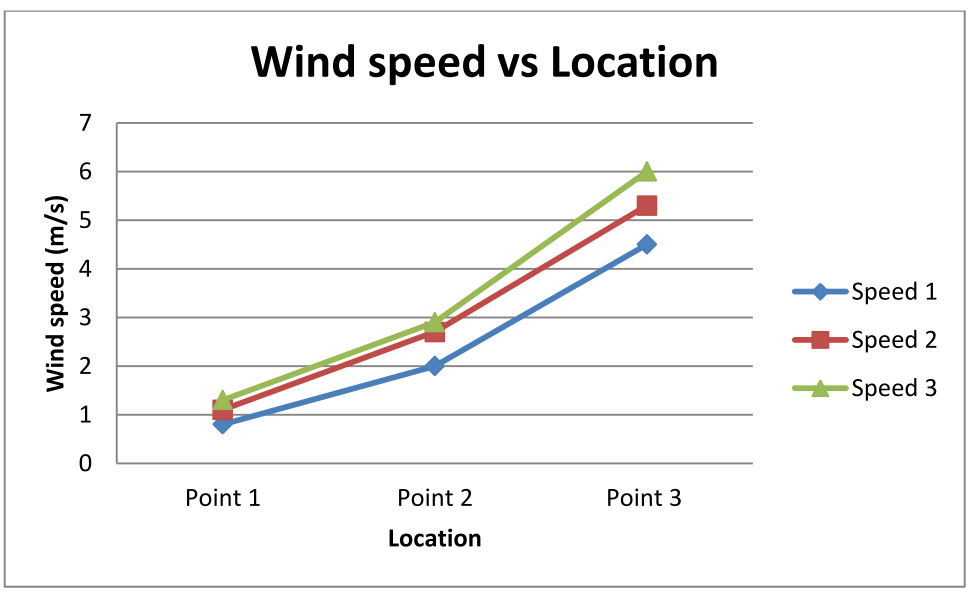

Figure 4.1: Wind speed (m/s) vs location

As can we see from figure 4.1, from Point 1 to Point 3 of each speed of fan had shown increase in velocity of the wind. It proof that the roof effect help increase the velocity of the wind on top of roof.

Table 4.2: Speed (RPM) of different configuration of blade

Blade type / Speed(m/s)	2 blades	3 blades	Savonius 4 section blades
0.8	214.9	287.3	184.9
1.1	225.19	320.3	225.4
1.3	273.3	346	245.4

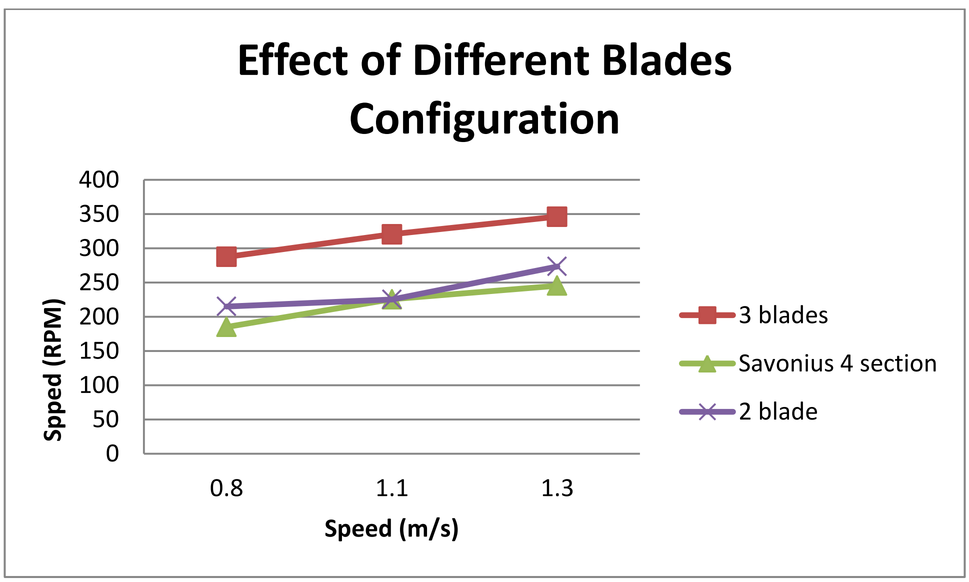

Figure 4.2: Effect of different blades configuration

Figure 4.2 shows the effect of different blades configuration on the rotor speed. As the velocity of the wind increase, the speed of the rotor also increases. Based from the result obtained, the 3 blade offered the best performance in term of speed (RPM) compare to the other three types of turbine which is 2 blade and Savonius 4 section turbine.

Table 4.3: Speed of all three configuration of turbine with different angle

	Type of blade		
Angle(˚)	2 blades	3 blades	Savonius 4 section blades
0	237.5	346	245.4
15	212.5	278.6	211.6
30	175.7	236.9	151.6
45	130.6	159.1	124.8
60	109.4	125.9	110.7

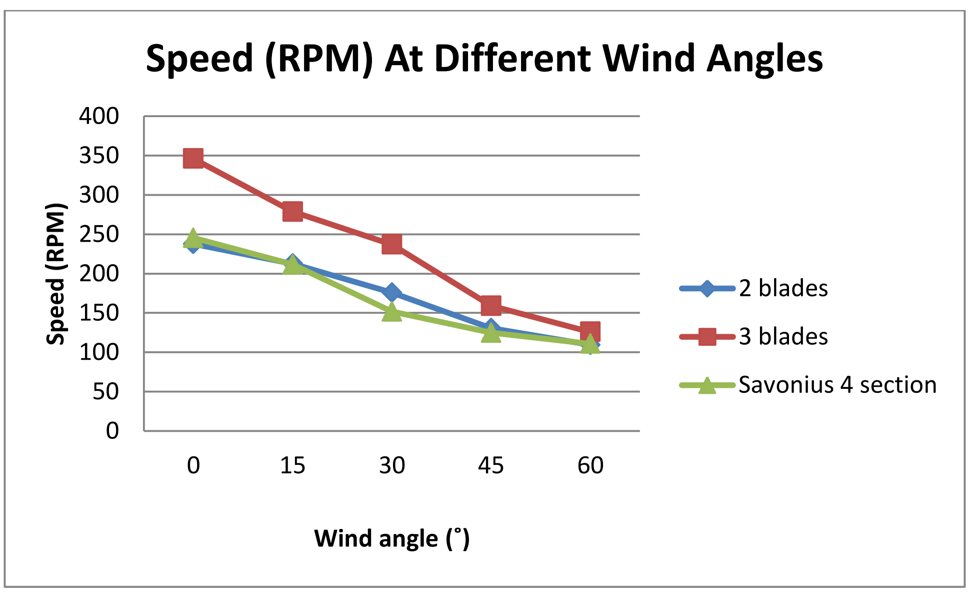

Figure 4.3: Speed (RPM) at different wind angles

Figure 4.3 shows the speed versus different wind angles. The wind angle do contributed to the effect of the rotor speed of the wind turbine. 0˚angle where the turbine faces directly to the wind produce higher speed compare to the other angle. The speeds of the turbine are supposed to reduce gradually but due to wind concentration at the end plate of the turbine, it still turns the turbine.

Figure 4.4: Flow visualization using dry ice

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

As for the conclusion, from the result obtained in the experiment, the 3 blade configuration turbine gave the best performance in term of speed. The speed of the turbine rotor are closely depends to the velocity of the wind, and the roof profile. Proper selections of the turbine type are very important as to produce much speed of the rotor as possible.

5.2 Recommendation

i. Fabricate different size/diameter of blades
   - Different size and diameter of blades should fabricate to see either it can produce higher speed of the rotor.

ii. Fabrication job and process must be done neatly without any mistakes to reduce any potential error in the experiment. Installation of the bearing was using force, so the bearing might be damaged during the experimental process and gave irrelevant result thus proper installation should be done.

iii. Shaft design should be considered

   - Due to the load of the turbine blades, the shaft will encounter the bending moment. So before construct the blade, shaft design need to take into account because it is important.

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APPENDICES

Project Gantt Chart and Milestones (a)

No.	Detail/Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14
1.	Selection of Project Topic								MIDSEM BREAK							
2.	Preliminary research work (understand the Concept, find requirement design)															
3	Submission of extended proposal															
4	Proposal defences															
5	Project work continues (start design, use software such CATIA)															
6	Submission of Interim draft report															
7	Submission of Interim report															

Timeline for FYP 1

= Suggested milestones = Progress

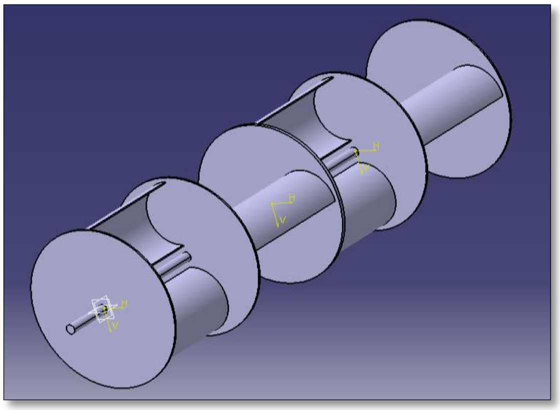
Project Gantt Chart and Milestones (b)

No.	Detail/Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14	15
1.	Project work continues								MIDSEM BREAK								
2.	Submission work progress report																
3.	Project work continues (fabricating, testing)																
4.	Pre-SEDEX																
5.	Submission of draft report																
6.	Submission of dissertation (soft bound) & technical paper																
7.	Oral presentation																
8.	Submission of project dissertation (hard bound)																

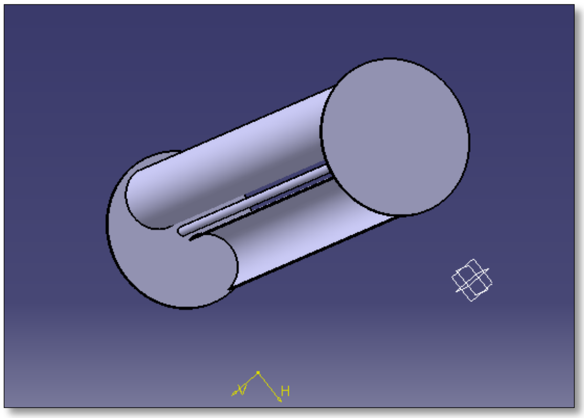
Timeline for FYP

= Suggested milestones   =Progress

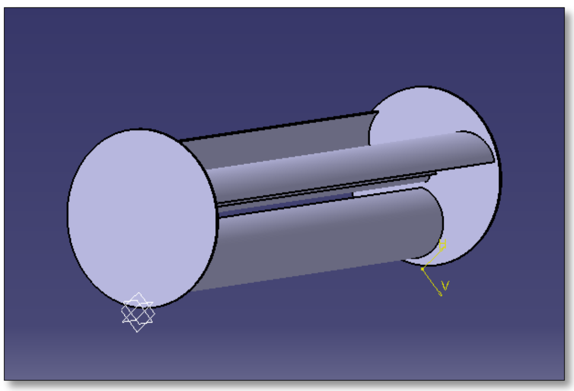
Blade design in CATIA



Savonius 4 section blade

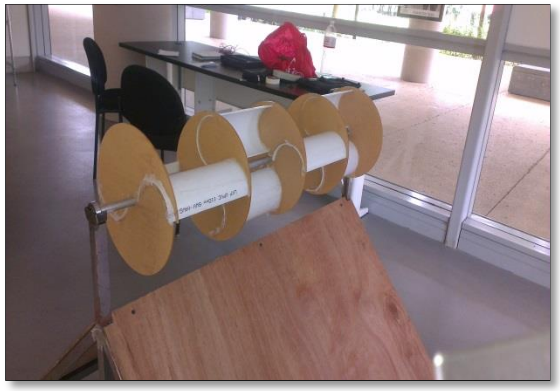


2 blades

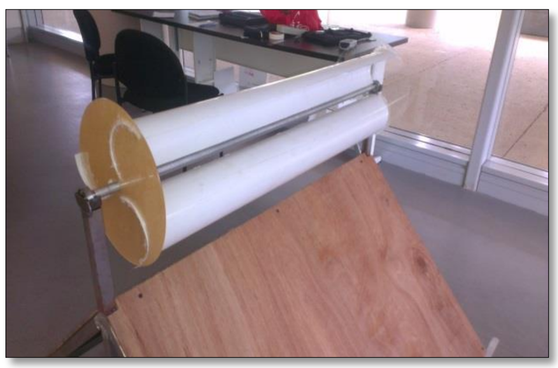


3 blades

Blade configuration



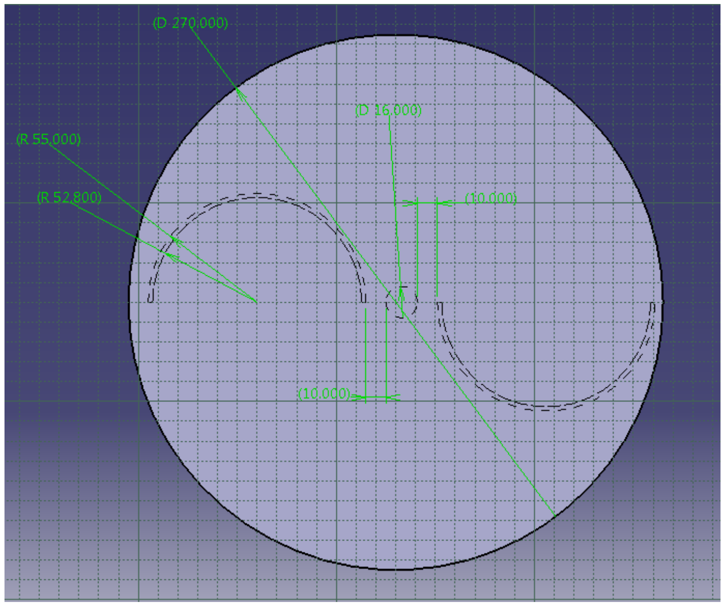
Savonius 4 section



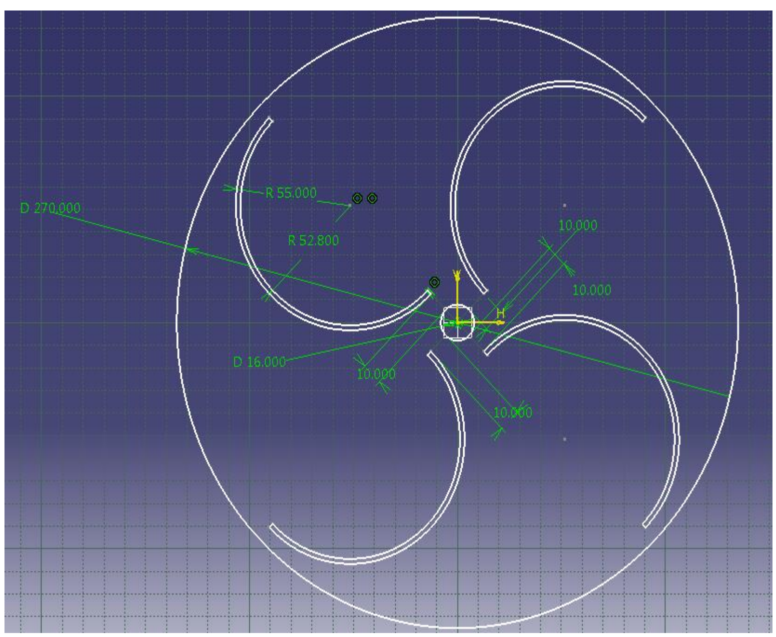
3 blades

2 Blades

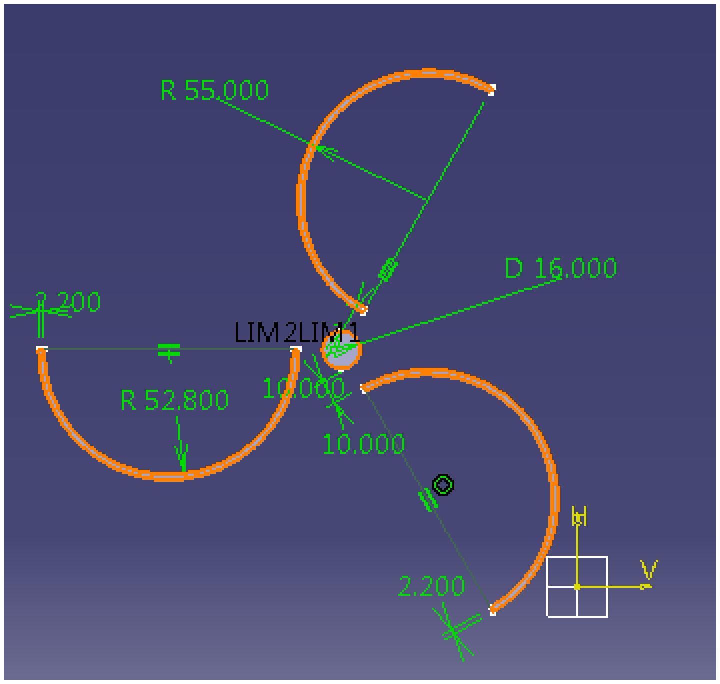
Dimension for the entire turbine configuration



2 blades



Savonius 4 section



3 blades