Vertical Axis Wind Turbine with H-Type Darrieus Rotor

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Abstract : The project focuses on Design, Fabrication and Testing of a VAWT (vertical Axis Wind Turbine). The project is an ongoing research project and the phase we carried out was concerned in shifting the design from Savonius type to Darrieus type, which created the necessity of freshly designing all the parts, increasing the torque and rpm of the VAWT by implementing gear system for transmitting the wind energy into mechanical energy. The whole structure is portable meanwhile maintaining the project within a very low cost range. The said objectives can be achieved by manipulating the knowledge of Design of Machine element, fluid dynamics, Energy Technology and CFD analyzing. A major concern was fashioning the design to enable the VAWT to operate with a maximum efficiency. Several parameters were analyzed with respect to wind speed to determine the best value for each parameter which would give the highest efficiency, thus ensuring the maximum ultimate performance of the VAWT. The parameters that were considered for analyzing are the number of blades the rotor should have, positioning of the blade. Above parameters were analyzed using ANSYS/Fluent software package and the ultimate design was produced in accordance with the obtained results. The final design was virtually created in 1:1 scale in Solid Works environment and tested for its strength and durability. The targets laid ahead of us at the beginning of the project were successfully achieved through careful and wise manipulation of theoretical and practical knowledge as well as hands on experience. Objectives were accomplished, not with ease but certainly.

KEY WORDS – Aerofoil, Wind power, NACA, CFD

1. INTRODUCTION

The rising concerns over global warming, environmental pollution, and energy security have increased interest in developing renewable and environmentally friendly energy sources such as wind, solar, hydropower, geothermal, hydrogen, and biomass as the replacements for fossil fuels. Wind energy can provide suitable solutions to the global climate change and energy crisis. The utilization of wind power essentially eliminates emissions of CO_2, SO_2, NO_x and other harmful wastes as in traditional coal-fuel power plants or radioactive wastes in nuclear power plants. By further diversifying the energy supply, wind energy dramatically reduces the dependence on fossil fuels that are subject to price and supply instability, thus strengthening global energy security. During the recent three decades, tremendous growth in wind power has been seen all over the world. In 2009, the global annual installed wind generation capacity reached a record-breaking 37 GW, bringing the world total wind capacity to 158 GW. As the most promising renewable, clean, and reliable energy source, wind power is highly expected to take a much higher portion in power generation in the coming decades.

Wind energy has a number of benefits and advantages. Wind power is a clean and environmentally friendly energy source. As an inexhaustible and free energy source, it is available and plentiful in most regions of the earth. In addition, more extensive use of wind power would help reduce the demands for fossil fuels, which may run out sometime in this century, according to their present consumptions. Furthermore, the cost per kWh of wind power is much lower than that of solar power.

Energy is a hot topic in the news today: increased consumption, increased cost, depleted natural resources, our dependence on foreign sources, and the impact on the environment and the danger of global warming. Something has to change.

Wind energy has great potential to lessen our dependence on traditional resources like oil, gas and coal and to do it without as much damage to the environment. Alternative energy sources, also called renewable resources, deliver power with minimal impact on the environment. These sources are typically more green/clean than traditional methods such as oil or coal. In addition, alternative resources are inexhaustible.

These benefits, as well as data that suggest the drop-off of conventional oil drilling will overtake the output of new drilling by 2014, make renewable energy a viable source to pursue.

Wind Turbines

A modern wind turbine is an energy-converting machine to convert the kinetic energy of wind into mechanical energy and in turn into electrical energy. Various wind turbine concepts have been developed and built for maximizing the wind energy output, minimizing the turbine cost, and increasing the turbine efficiency and reliability.

Types of Wind Turbines

Wind Turbines are broadly classified into two categories:- a) Vertical Axis Wind Turbines b) Horizontal Axis Wind Turbines These two types find their use cases appropriately. Both have their own advantages and disadvantages, but majorly fulfilling the needs of remote power generation.

Horizontal Axis Wind Turbines

The HAWT is the most common turbine configuration. The propellers and turbine mechanisms are mounted high above the ground on a huge pedestal. It is a matter of taste as to whether they enhance the landscape. However, there is no denying that the height at which their mechanisms are located is a disadvantage when servicing is required. Also, they require a mechanical ya w system to orient them such that their horizontal axis is perpendicular to and facing the wind. As potential power generation is related to the swept area (diameter) of the rotor, more power requires a larger diameter. The blades experience large thrust and torque forces, so size is limited by blade strength. Horizontal axis wind turbines are the conventional source of major wind power generation throughout the world majorly because of their higher efficiency.

Figure 1.1Horizontal Axis Wind Turbine

Vertical Axis Wind Turbines

Vertical axis wind turbines are the turbine which have the rotor shaft mounted parallel to the main tower. These are suitable for places with low wind speed ranges while the horizontal axis wind turbine is used for high wind speed. Besides that, there is also a slight difference in the components of both turbines. The horizontal wind turbines contain yawing mechanism which helps them to point in the direction of the wind at all times, by means of a deflector plate. Whereas a Vertical axis wind turbine is capable of harnessing wind from all direction to produce electricity. Besides that, VAWT also suitable to be installed in urban area since they are easy to transport from one place to another and also easy to install as compared to HAWT. VAWT’s come in a small form factor which make them fit for versatile and remote power generation, capable of powering individual households.

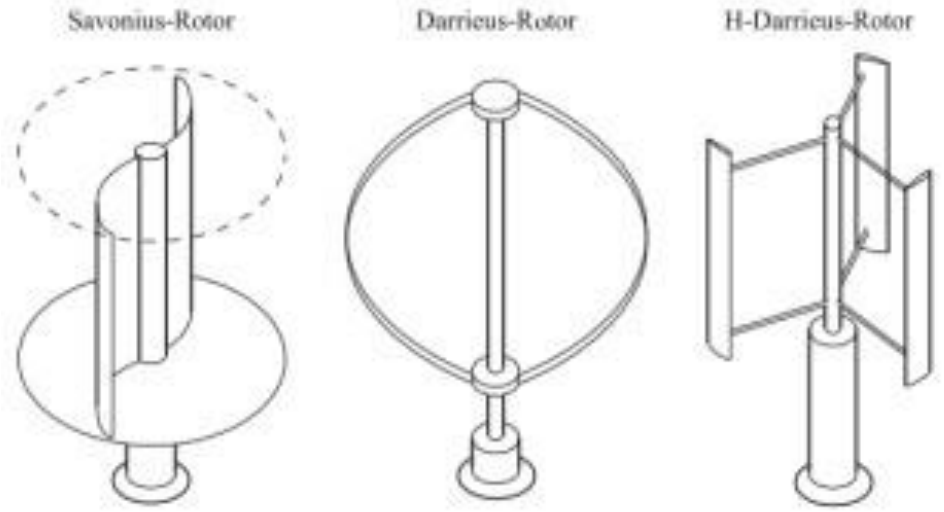


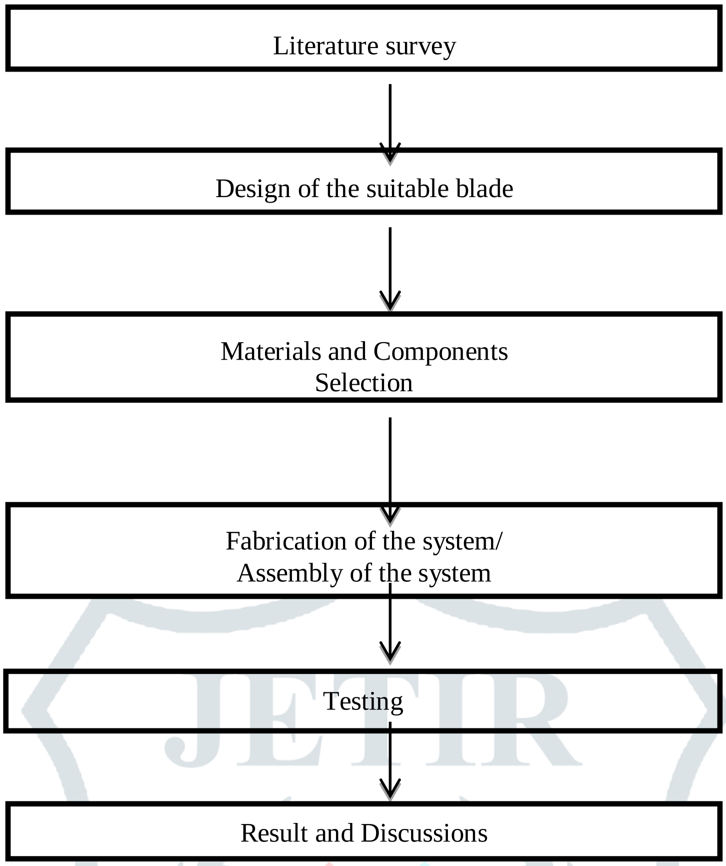
Figure 1.2 Types of vertical axis wind turbines

2. OBJECTIVES

There are few objectives set in this project to ensure that the out coming product is fulfilling the requirement. Staring a project with a clear objectives and specific direction are important to structure the project along the given time and validate the success.

1. To propose unique and innovative designs of a Vertical Axis Wind Turbine using gear arrangement.
2. To propose suitable design of rotor blades for maximum efficiency.
3. To design all the necessary component of the Wind Turbine adhering to suitable standards and codes.
4. To model the Wind Turbine on SOLIDWORKS or ANSYS software, and conduct stress and deformation analysis for the major parts of the turbine.
5. To design and fabricate a working model to be used for domestic purposes with a suitable scale.
6. To conduct performance and cost analysis of the design.

3. METHODOLOGY



4. EXPERIMENTAL WORK

The steps involved in the making of turbine starts from the design of VAWT along with the framework, then the selection of the type of blades to harness maximum efficiency from the turbine followed by the analysis of the setup in CFD to study the air flow patterns across the blades and the assembled setup. This was followed by a test run in the actual scenarios.

The crux of the project was to improvise the existing efficiency of vertical axis wind turbines and to provide useful work output from the wind energy. This was achieved by implementing a blade design such that it produced maximum lift from the available wind energy. Following the literature survey, we could come to a conclusion that Darrieus type rotors are much more efficient in producing energy compared to Savonius rotors. For this we had to undergo a study session on the types of existing rotors available for Vertical Axis Wind Turbines.

The Darrieus type rotors further come in various types of configurations such as H-Type, D-Type, Helical Type, etc. and the one we chose to implement was the H-Type Darrieus Rotor based on its ease of manufacturing and design. The Darrieus Type rotors make use of Aerofoil blade structures to generate lift force in each blade which together generate rotational motion in the rotor shaft. Hence, further study on airfoils was done to choose the best suited Aerofoil blade according to the National Advisory Committee for Aeronautics (NACA).

We chose the NACA4412 Aerofoil structure for the blades. This was done after a thorough review of our use case. There are numerous Aerofoil structures out there but the one which serves our purpose requires to be able to generate maximum lift at nominal angle of attacks and the cross section needs to have less maximum thickness of the Aerofoil so that the complete blade will be of low weight.

Then came the selection of the raw materials for the blade. Light weight blade is one of the most important factors in making the turbine sensitive to even low wind speeds, hence going by the range of materials, a survey was done to choose the optimum material best suited for our use.

A comparison on density, cost per unit kg, and ease of machinability were done to consider and reject several materials such as Carbon Fibers, Glass Fibers, Galvanized Iron and Aluminum alloy. As we intended to keep the weight low as well as maintain the structure of the Aerofoil to our desired dimensions, we initially considered the use of glass and carbon fibers as they are both known for their impeccably low density and high strength, the cost of material is equally high and thus rendered noon feasible. Thus we had to go with metallic sheets of Galvanized Iron and Aluminum Alloys. The latter being lower in density, and with ease of machinability, we chose sheet metals of Aluminum 6061 to manufacture the blades according to the given dimensions by the help of plasma cutting.

Once the blades have been prepared, and because these are sheet metals we are using, we chose to go with three blades instead of four to keep the rotor shaft as light as possible while keeping the mechanism working. Suitable supports were given at the Bessel points of the Blades to prevent the elongation of the blades while rotation over a period of time.

The Framework was made in hollow pipes of Mild steel and were joined using arc welding process. Following the framework, we had to implement Jig boring Technique to create holes in the framework plates, of the same size as that of the outer diameter of the ball bearings we used to keep the shaft rotations frictionless.

We ran a CFD analysis of the cross section of NACA4412 blade from which we could evidently spot the pressure differences in the regions near the blade surface which are responsible for generating lift. Following this we ran the analysis with the tri-blade setup to understand the wind flow patterns across the turbine.

Manufacturing the NACA 4412 Aerofoil blades were done using sheet metals of Aluminum 6061 and were bonded using the process of plasma welding. The main rotor shaft along with the prepared framework were assembled and the shaft was directly coupled with a gear train to increase the rpm and then connected to a low capacity dynamo to extract DC current from the rotations. The Wind speeds were tested using an Anemometer and the extracted current was tested for its voltage using a Multimeter.

5. COMPONENTS USED

- Aerofoil NACA 4412 (AL)
- Angular contact Bearing SKF7204
- Alternator/ Dynamo
- Base plate (MS)
- Connecting Beam (AL)
- Formed Hex. Screw arm M5 X 0.8 X 14
- Formed Hex. Screw arm M5 X 0.8 X 20
- Flange Hex Nut M5 X 0.8
- Inventor
- Rotor Beam (AL)
- Main Shaft (AL)
- Spur gear arm 1M 25T 20 PA 12 FW (CAST IRON)
- Spur gear arm 1M 60T 20 PA 12 FW (CAST IRON)
- Step-up transformer (12-0-12)

6. ANALYSIS

Following the finalization of the blade dimensions, the CFD analysis of NACA4412 blade structure was done in ANSYS FLUENT where the velocity and pressure contours were plotted with respect to the aerofoil structure.

The spline co-ordinates were imported from the Aerofoil tools website, into an excel sheet and then to ANSYS to form the geometric constrains. This was followed by specifying the boundary conditions such as the fluid type, velocity, direction, leading edge, trailing edge.

Then the spline was meshed followed by which the simulation was run giving us the following contours.

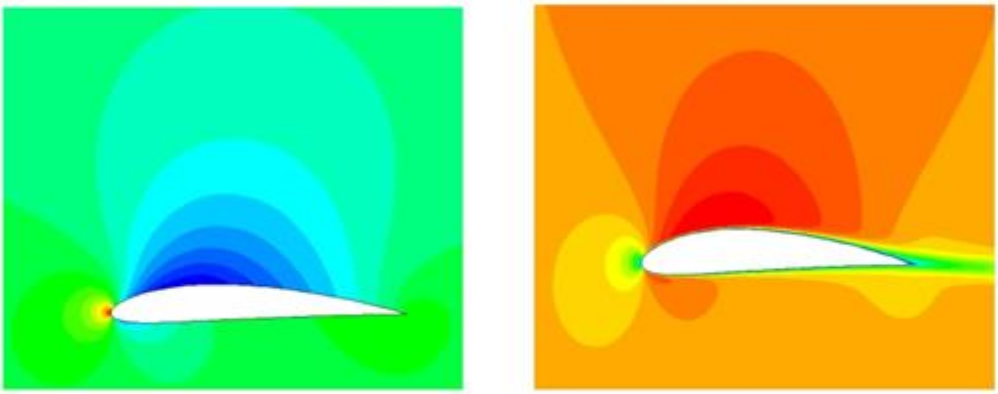


Figure 6.1 Static pressure and velocity plot at 0 degree Angle of attack

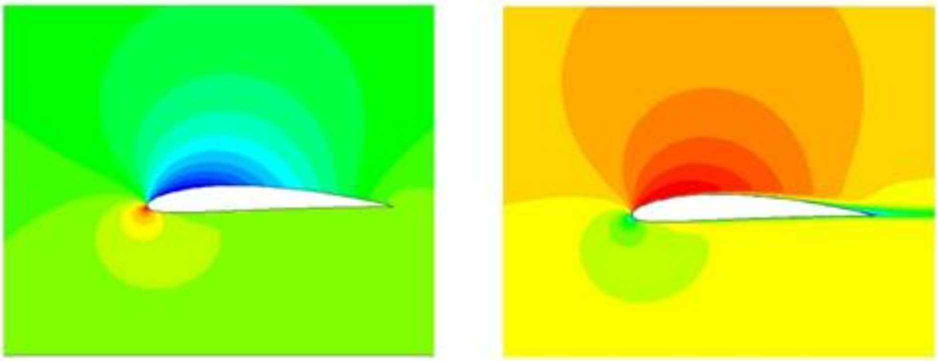


Figure 6.2 Static Pressure and velocity plot at 4 degree Angle of attack

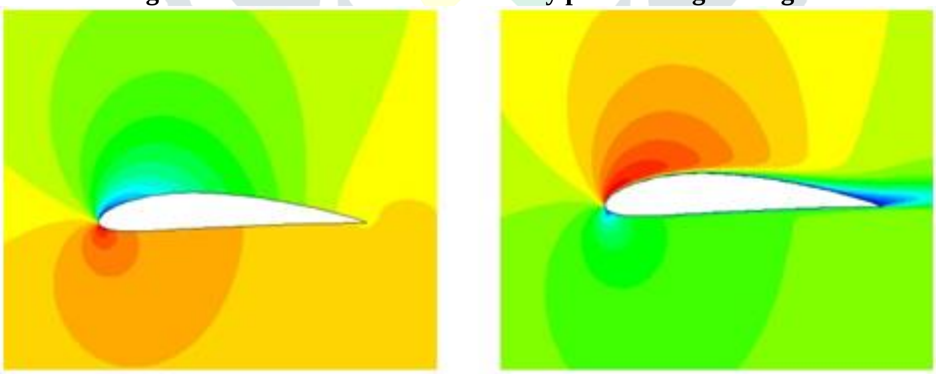


Figure 6.3 Static Pressure and velocity plot at 8 degree Angle of attack

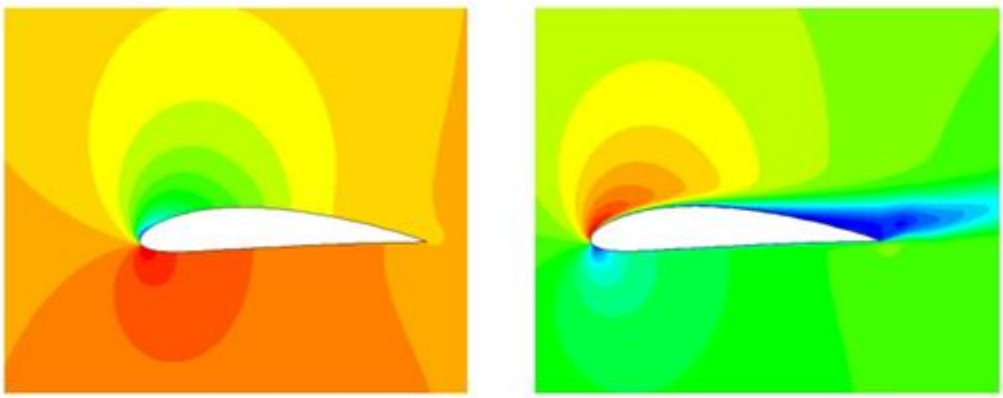


Figure 6.4 Static pressure and velocity plot at 12 degree Angle of attack

Simulation Inputs are:

Type of Solver	Pressure based Steady State
Viscous Model	Spalart-allmaras
Density (kg/m^3)	1.225
Viscosity (kg/m-s)	1.7894
Turbulent Viscosity Ratio	10
Inlet Velocity	15 m/s
Chord length	0.2 m
Reynolds Number	1 × 10^5

Table 6.1 Input parameters for simulation

The above mentioned parameters were inserted as the input for the simulation of the NACA4412 airflow pattern.

As evident from the pressure and velocity contours, the flow of wind is no longer streamlined beyond 8 degrees angle of attack. When at 12 degrees, the wind is no more adhered to the surface of the aerofoil and gets disrupted well before reaching the trailing edge. This phenomenon is known as Stalling. Stalling causes a reduction in the lift force generated and hence is non desirable in aerodynamics.

7. FABRICATION WORK

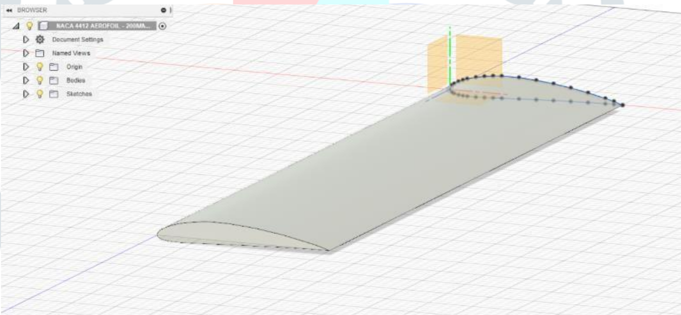


Figure 7.1 Design of NACA4412 Blade in Fusion

Figure 7.2 Fabrication of Framework and rotor beam holder

Figure 7.3 Fabrication of Aerofoil and Gear Blank

Figure 7.4 Assembled model of the proposed VAWT

RESULTS

The said objectives were accomplished right from the design and analysis to fabrication by means of various manufacturing techniques. The CFD analysis was completed to understand the fluid flow patter across the cross section of the aerofoil. The setup was tested in a condition with wind speeds of 15 m/s ranging up to 20 m/s using a blower which worked at a rate of 40-60 RPM respectively. The low capacity dynamo used, rendered a voltage ranging from 5-30 volts which was tested using a multimeter.

REFERENCES

[1] Dr. Hettiarachchi N.K., Jayathilake R.M., Sanath J.A. “Performance Simulation of a Small Scale Vertical Axis Wind Turbine (VAWT) with the Integration of a Wind Deflector System”, Department of Mechanical and Manufacturing Engineering, Faculty of Engineering, University of Ruhuna, Mar 19, 2014

[2] The-Importance-Of-Wind-Energy [Online]. Viewed 2014 June 04. Available:http://ezinearticles.com

[3] J.P.Baird, S.F Pender, “Optimization of a vertical axis wind turbine for small scale applications”, 7th Australian Hydraulics and Fluid Mechanics Conference, Brisbane, 18-22 August 1980.

[4] Website to import the spline co-ordinates http://airfoiltools.com/airfoil/details?airfoil=naca4412-il

[5] S.Kandwal, Dr. S. Singh, “Computational Fluid Dynamics Study of Fluid Flow and Aerodynamic Forces on an Airfoil”, IJERT, Vol. 1 Issue 7, September – 2012.