

A REVIEW: AERODYNAMIC ANALYSIS ON VERTICAL AXIS WIND TURBINE BLADE

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Abstract - This review contains a various work was done on wind blade carried out by different authors around the world wide. It will give the information about different techniques used to enhance the performance of wind mill blade. From the early stage of the project, various literature studies have been done. Use some of the information from the literature review to achieve our target. There are many research are performed on wind turbine all research are concentrated on blade profile in some research on 2D and 3D profile CFD simulation is done. This review paper aims at to move forward in this research on blade profile have critically analyzed some paper. The aim of this literature is angle of attack, wind blade material, twisting of blade airfoil, Vibration on blade and selection of Blade airfoil. 'Wind Power' When evaluating any change to the design of a wind turbine, it is critical that the designer evaluate the impact of the design change on the system cost and performance.

Keywords- VAWT, CFD simulation

I. INTRODUCTION

Wind turbines can be classified into two general types: drag machines (Figure 1.1a) and lift machines (Figure 1.1b & c). Drag machines generate forces through the creation of large separated flows and move slower than the wind. The most common application of these devices is in water pumping. In lift machines, the wind is made to follow a curved path as it passes about a rounded object. The turning of the fluid generates forces on the object, typically of an aerofoil profile, thus producing the required thrust. Blade speeds are most often greater than the wind speed and far exceeds what is possible in drag machines. Lift machines are thus more favorable from an energy production view point due to a greater potential for energy extraction.

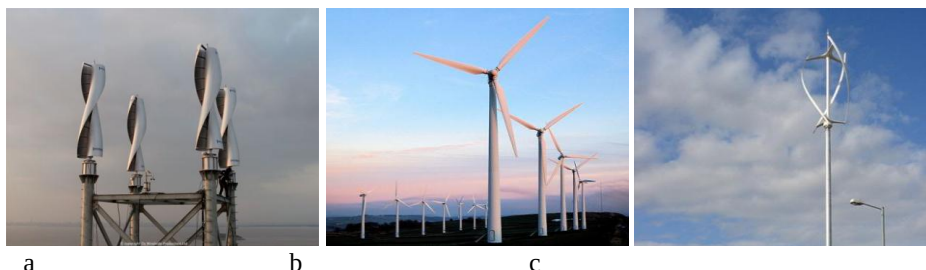


Fig 1.1 Examples of wind turbines: a) drag VAWT, b) lift HAWT, c) lift- VAWT.

There are two main methods of extracting energy utilizing the lift concept: horizontal axis wind turbines or HAWT (Figure 1.1b) and vertical axis wind turbines or VAWT (Figure 1.1c). HAWTs have received significant research and development work over the decades giving them a well-established and mature technology base that makes them the preferred configuration in all large scale wind farm installations. VAWTs on the other hand have not been given the same attention. The complex aerodynamic and structural aspects of VAWT operation make their understanding and optimization difficult which is one of the reasons why they are less favored than their horizontal counterparts.

There are several points of contention on the use of VAWTs over HAWTs. The key point that prevails is the generally perceived superior performance of HAWTs over VAWTs. Nevertheless, VAWTs present a number of potential advantages over HAWTs when it comes to applications in the built environment:

- Easier maintenance because of the rotor's proximity to the ground. VAWTs are typically smaller in scale and mounted on masts that are many times shorter than conventional HAWT installations. Additionally, the rotor sits on a bearing and drives the generator below it.
- No need to yaw to the wind thus reducing the efficiency loss when tracking changes in wind direction.
- Sound emissions are usually lower as they operate at lower tip speed ratios. This can also reduce structural issues such as vibration that result from high centrifugal forces.
- Potentially lower manufacturing costs due to the simplicity of the straight blade shape.
- better performance in skewed flow

VAWTs are not without their disadvantages when compared to HAWTs. The most common are:

- Lower efficiency due to the additional drag of blades moving against the wind. Moreover, HAWTs are presumably more optimized in their design as a consequence of greater efforts made in research and development.
- Less access to stronger winds in higher elevations.
- Complex aerodynamics resulting in continuously fluctuating blade loading during operation and therefore a lower fatigue life cycle.

II. LITERATURE REVIEW

Dr. Abdullateef A. Jadallaha et al [1] has give that the major point in wind turbine performance is Blade Element Method and Momentum theory Which gives some important parameter like tip speed Ratio, Pitch angle, Number of blade and wind speed. For low power wind turbine above parameter acts as a basis fundamental on blade design. The Opt imization of wind turbine performance calculation based on Low wind speed to high wind speed by the changing of Pitch angle , angle of attack and tip speed Ratio.

Carrigan et al. [2] successfully demonstrated a fully automated process for optimizing the airfoil cross-section of a VAWT. The generation of NACA airfoil geometries, hybrid mesh generation, and unsteady CFD were coupled with the DE algorithm subject to tip speed ratio, solidity, and blade profile design constraints. The optimization system was then used to obtain an optimized blade cross-section for 2 test cases, resulting in designs that achieved higher efficiency than the baseline geometry. The optimized design for the 1st test case achieved efficiency 2.4% higher than the baseline geometry. The increase in efficiency of the optimized geometry was attributed to the elimination of a leading edge separation bubble that was causing a reduction in efficiency and an increase in cyclic loading. For the 2nd test case, the VAWT was given complete geometric flexibility as both the blade shape and rotor solidity was allowed to change during the optimization process. This resulted in a geometry that achieved efficiency 6% higher than the baseline NACA 0015 geometry. This increase in efficiency was a result of the 40% decrease in solidity coupled with the 58% increase in thickness, leading to a slight phase shift in the torque and higher overall peak performance.

Abdulkadir Ali et al [3] studied the VAWT configuration for two different set of blades (steel made and cardboard made) using partially and fully cowled configuration this analysis resulted in high rotational motion for the partially cowled configuration of the of cardboard made turbine this also resulted in heavier the turbine higher the wind speed will required to generate the rotational motion, the lighter turbine resulted a better performance at all the speeds.

W. T. Chang et al. [4] introduced a innovative devise called as Omni-Directional –Guide-Vane (ODGV) integrated with VAWT ODGV effectively improved the self-starting behavior of the VAWT. At 6 m/s, the rotor rotational speed was increased by 125% at free-running condition and the power output at maximum torque was 3.48 times higher for the ODGV integrated VAWT compared to the bare VAWT.

Huimin Wang et al. [5] this paper presented the numerical simulation of Vertical Axis Wind Turbine with Reynolds Average Navier-Stokes equations and Realizable $k - \epsilon$ turbulence model at different wind velocity. It used FLUENT software for performed CFD analysis. They use NACA 0018 airfoil series for created the blade 2D model where the dimensions of blades are: Chord length of the blade = 0.1, Diameter of rotor = 0.9m, Rotational speed = 100 rpm and also created the C-H type domain for CFD analysis whose dimension are: C is a half semicircle shape whose radius = 16m, H is a rectangle whose size are = 32m * 30m. They obtained three different results at four different velocities are:

Results	Velocity
Contours of Velocity	10m/s, 15m/s, 20m/s, 25m/s
Distribution of Eddy	
Change of Torque	

Results shows wind velocities increases eddy existed in downstream region, total torque coefficients tend to smooth, velocity distribution at upstream is large.

Ji Yao et al. [6] studied A two dimensional model of three blade H type vertical axis wind turbine was established in this paper, then the two dimensional unsteady flow field of the vertical axis wind turbine was simulated numerically for Standard $k - \epsilon$ turbulence models and RNG $k - \epsilon$ turbulence models. The results showed that the influence of different turbulence models on the velocity field is less, on the pressure field is relatively large, and on the value of the total torque is much larger. The gradient of the velocity and pressure around the wind turbines blade was apparent. The velocity field

and pressure field of the computational domain changed at different time. There would be a narrow region of the velocity wake within the certain range between the wind turbines rotation part and the down stream's static part. At the constant speed of the wind and rotation, the total torque of the vertical axis wind turbine would change periodically.

Seung Yong Min et al. [7] studied a research for the performance improvement of the straight-bladed vertical axis wind turbine aerodynamic analysis; control mechanism design and its realization of 1kw class model are carried out. 4 straight blades of 1m span length are used and rotor radius is fixed to 1m. The aerodynamic analysis shows that the cycloid wind turbine is possible to generate more power than fixed pitch type VAWT by changing its pitch angle and phase angle according to wind direction and wind speed. By maximizing the tangential force in each rotating blade at the specific rotating position, optimal pitch angle variation is obtained. And several airfoil shapes of NACA 4-digit and NACA 6-series are studied. Aerodynamic analysis shows performance improvement of 60%.

Farooq Ahmad Najar et al. [8] have investigated wind turbine blade geometric design and optimization, aerodynamics analysis, wind turbine blade structural design and dynamics analysis. Blade geometric design addresses the design parameters, including airfoils and their aerodynamic coefficients, attack angles, design tip speed ratio, design and/or rated wind speed, rotor diameter, blade aerodynamic shape with chord length and twist distributions, so that the blade achieves an optimum power performance. The geometry of the blade is S809 an aerodynamic shape can be obtained based on the BEM theory with respect to given aerofoil with known aerodynamic coefficients. Computational fluid dynamics (CFD) model has been used to calculate the aerodynamic effect on the blade airfoil. Critical Reynolds number and constant wind speed has been considered during analysis under different turbulence models via, spallart-almaras, k-epsilon, flow. During investigation it is observed that only k-epsilon showed efficient results than others and 14 degree angle of attack (AOA) is the optimum value at which there is much lift coefficient and minimum drag.

Chris Kaminsky et al. [9] have been carried out the research of a VAWT using the NACA0012-34 airfoil. The system was modeled in Solid Works. They are use of the STAR CCM software to CFD analyzes the air flow around a vertical axis wind turbine to perform. Analysis has been done in three ways as show:

1. To determine CFD analysis analyzed the 2D flow over the chosen airfoil.
 2. Determine the analysis looked at the flow over a 3D representation of the airfoil.
 3. Finally, a full VAWT assembly was created and analyzed at various wind directions at the same wind speeds.
- The airfoil then the 2D and 3D simulations used different angles of attack (0 to 15 degrees) and speeds (15 & 30 mph) to determine. The full assembly included 3 airfoils that were attached into a 5ft high, 3 ft diameter structure. The results of this research on the NACA 001234 airfoil showed it could be a very viable choice for a residential VAWT. The 2D analysis gave a stall angle of about 8 degrees, however, the 3D analysis, it being more accurate, did not provide us with a stall angle. The results for the 3D full assembly analysis of vertical axis wind turbine were incomplete.

Jon DeCoste et al. [10] have objective of this project was to design and build a self-starting vertical axis wind turbine. This report outlines the first term efforts in the design of our full-scale VAWT. The self-starting issues surrounding VAWT will be tackled by the use of alternative blade profiles and pitching mechanisms. A model that carries out turbine theory calculations was created to aid in the design of the full-scale turbine. The model inputs include NACA 0012 airfoil lift and drag coefficients, angles of attack and relative wind speeds as determined from a MATLAB program, and user inputs such as wind speed, tip speed ratio, overall blade and turbine dimensions, and power required. The model outputs forces and torques produced over a wide range of TSR. The model also uses various angles of attack to determine performance results when pitching is used. Analysis results indicated that passive pitching is an affecting way to boost the turbines ability to self start. It was concluded that a profile with large lift at low speeds used along with passive pitching could achieve self starting status. As a result, three blade profiles will be tested and compared. Results from prototype testing in the wind tunnel will reveal the blade profile that offers the best performance for self-starting.

REFERENCES

- [1] Dr. Abdullateef A. Jadallaha, Dr .Dhari Y. Mahmooda and Zaid A. Abdulqaderb, "Optimal Performance of Horizontal Axis Wind Turbine for Low Wind Speed Regime" , International Journal of Multidisciplinary and Current Research 2014.
- [2] Travis J. Carrigan, Brian H. Dennis, Zhen X. Han, and Bo P.Wang, "Aerodynamic Shape Optimization of a Vertical-Axis Wind Turbine Using Differential Evolution" , International Scholarly Research Network, ISRN Renewable Energy 2011
- [3] Abdulkadir Ali, Steve Golde, Firoz Alama, and Hazim Moria, "Experimental and Computational Study of a Micro Vertical Axis Wind Turbine", Procedia Engineering 49 (2012) 254 – 262
- [4] w. T. Chong , s. C. Poh, a. Fazlizan, and k. C. Pan, "Vertical axis wind turbine with omni-directional-guide-vane for urban high rise application", Journal of Central South University of Technology
- [5] Huimin Wanga, Jianliang Wanga, Ji Yao, Weibin Yuanb, Liang Cao, "Analysis on the aerodynamic performance of vertical axis wind turbine subjected to the change of wind velocity" , Procedia Engineering 31 (2012) 213 – 219

- [6] Huimin Wanga, Jianliang Wanga, Ji Yao, Weibin Yuanb, Liang Cao, “Analysis on the influence of Turbulence model changes to aerodynamic performance of vertical axis wind turbine” , Procedia Engineering 31 (2012) 274 – 281
- [7] In Seong Hwang, Seung Yong Min, In Oh Jeong, Yun Han Lee and Seung Jo Kim, “Efficiency Improvement of a New Vertical Axis Wind Turbine by Individual Active Control of Blade Motion”
- [8] Farooq Ahmad Najar, G A Harmain, “Blade Design and Performance Analysis of Wind Turbine”, International Conference on Global Scenario in Environment and Energy 2013
- [9] Kaminsky Chris, Filush Austin et al, “A CFD Study of Wind Turbine Aerodynamics”, Proceedings of the ASEE North Central Section Conference (2012)
- [10] Jon DeCoste, Denise McKay, Brian Robinson, Shaun Whitehead, Stephen Wright, “Vertical Axis Wind Turbine”, a project report at Department of Mechanical Engineering Dalhousie University December 5, 2005