Analysis of Vertical Axis Turbine With The Flow Around Airfoil By Finite Element Method

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Abstract- *The airfoils are one of the most important parameter and having significant impact on performance of Vertical Axis Wind Turbine (VAWT). The angle of attack α and effects of pressure coefficient are investigated has been studied flow around an inclined NACA 0012 airfoil. The analysis, performance, method is described that based on FEM. In this theme, we introduced the variable effect of airfoil as well as a potential flow solution in VAWT. The effect of SST turbulence model and compares capabilities of the k-ω model with the superior free-stream behavior of the k-ω model to enable accurate simulations of a wide variety of internal and external flow problems in VAWT. The density in the airfoil is also examined. This application has successfully proved in nowadays.*

Keywords- Vertical Axis Wind Turbine (VAWT), Airfoil, Finite Element Method (FEM).

I. INTRODUCTION

The wind energy source has reliable properties among another's. In the wind turbine the rotor shaft is placed vertically with vertical axis wind turbine (VAWT) much easier to install and maintain. Hence it has low operating cost. Since the generator and clutch can be placed at the bottom of VAWT which is set up near by the ground. The another benefit of this arrangement is that there is no need to point it into the wind energy trends [1]. All of these there are lift-based Darrieus category of VAWT [2] rotors firstly preferred started and later on discussed about cycloturbines [3] to drag based the performance of Savonius rotor[4], There are various types of challenges tasks on VAWT to performing the results that are low starting torque, low peak efficiency, narrow operating range, and dynamic stability problems. The low starting torque is one of the most changeling problems in VAWT can be overcome by the derived rotor Giromills design, because it has various advantages over other types of turbines[5] and the Helical blades [6] but at the sacrifice of another advantage i.e. high peak efficiency. The parameters of the airfoil blades such as the Angle of attack v/s lift coefficient for the performance improvement [7]. The Experimental results show all the improved angle of attack, operating range and higher efficiency when it is compared to the mentioned flow around the airfoils. In Recent a dynamic control system including both pitch and camber control of airfoil are presented in figure 1 shows the schematic (top view) system consisting of two blades with flaps at the trailing edge. Each blade is supported by a blade supporting its arm which is attached to the vertical axis with the hub as shown in figure 2. By using individual actuators, pitch control at each of the blade can be achieved by rotating the blades around their own blade pivot point, while the camber control can be achieved by rotating the trailing edge flap around its pivoting point which is placed between the blade airfoil. Power extraction improves the system as a result of employing airfoil.

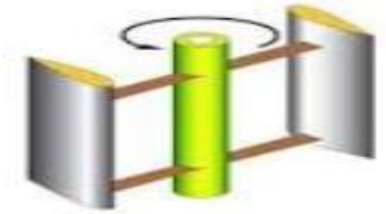


Figure 1. VAWT consisting three airfoils with Supporting Arm [8]

III. VAWT DISCRIPTION

The Vertical axis wind turbine have the following general components: There are types of hub in VAT are upper and lower hub. This is because the blades are attached at two points. The design of the particular blades also affects the overall design of the rotor. Rotor blades push the energy out of the wind. They mainly capture the wind and convert this kinetic energy into the circulation of the hub. A Shaft can be turned by the turbine blades. The Cast iron or cast steel is commonly used. The conversion of mechanical energy into electrical energy is done by the generator. The foundation is necessary to prevent the turbine from blowing over in high winds. Rotor it is a part which converts wind energy into mechanical power. A tower to support the rotor. Hub is known as the center of the rotor to which the rotor blades are connected [9].

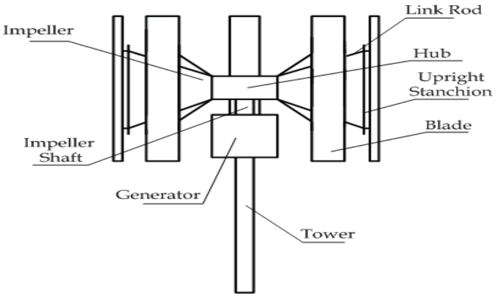
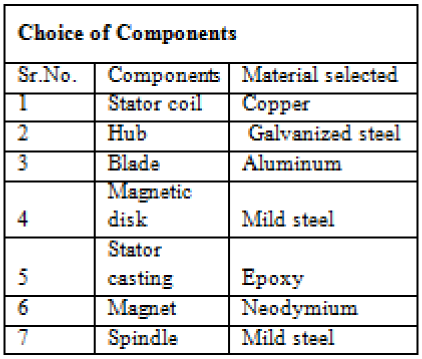


Figure 2: Components of VAWT.

Table 1: Description of material used in VAWT



Choice of Components		
Sr.No.	Components	Material selected
1	Stator coil	Copper
2	Hub	Galvanized steel
3	Blade	Aluminum
4	Magnetic disk	Mild steel
5	Stator casting	Epoxy
6	Magnet	Neodymium
7	Spindle	Mild steel

A. Airfoil Model

The main objective of this design is to determine the wind pressure field on the airfoil surface. It is based on the pressure field properties to develop an optimal airfoil pitch control pattern as VAWT rotating for maximum output. The first approach is a series representing various wind angle of attacks (thus airfoil angles) ranging from 0°to 180°Force on airfoil and corresponding torque by using the models which have been described in the above sections. The air velocity and pressure fields around the airfoil for various VAT rotation angles and airfoil pivot angles can be obtained. The total thrust forceactingontheairfoilsurfacecanbecalculatedbyintegratingthe forcevectorover it.

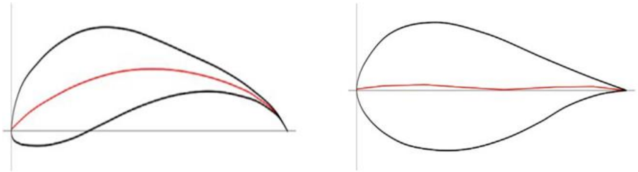


Figure 3: The shapes of airfoil design.

B. NACA 0012 Properties

The thickness and camber are two parameters having major influence on rotor aerodynamic performance, which should be selected as design variables. The airfoil geometry generation is that one allows the translation of the design variables into the actual airfoil. The present work is on the basis of NACA 0012 airfoil which has been utilized by the majority of VAWTs. The shapes based upon rectangular coordinate system are given by the following equations:

$$\left\{\begin{matrix} \dfrac{c_{max}}{(1-x_{cmax})^2}\left[(1-2x_{cmax})+2x_{cmax}x-x^2\right] \\ \dfrac{C_{max}}{x_{cmax}^2}(2x_{cmax}x-x^2) \end{matrix}\right\}$$

where $y_{camber}$is the y coordinate of the mean camber line, $c_{max}$is the maximum camber value, $x_{cmax}$is the x coordinate of themaximum camber.

$$\pm y_{thick} = 5t_{max}\left(0.2969\sqrt{x} - 0.126x - 0.3516x^2 + 0.2843x^3 - 0.1015x^4\right)$$

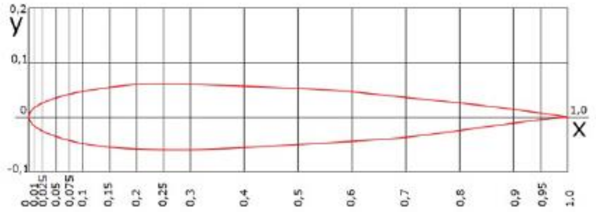


Figure 4: Gemotry of airfoil design.

The *x* is the position along the chord from 0 to 1.00 (0 to 100%), is the half thickness at a given value of *x* (centerline to surface), *t* is the maximum thickness as a fraction of the chord The equation, at $x/c = 1$ (the trailing edge of the airfoil)where $y_{thick}$is the *y* coordinate of the thickness distribution, $t_{max}$is the maximum thickness value, the thickness is not quite zero.

C. Assumptions

The following assumptions have been made for the analysis provided.

- The airfoils are rigid; no distortion due to radial and tangential force is felt by these factors.
- The airfoil is thin $n \ll C$
- The angle/slopes are small.i.e $sin\alpha \approx \alpha, cos\alpha \approx 1$, slope $\approx$ angle.
- The airfoil only slightly disturbs free stream $U', v' \ll V_\infty$.
- Power and torque are neglected.

III. SIMULATION RESULTS

The Finite Element method (FEM), variance procedure is initiated by this optimization method. The analysis of airfoil in structural counting part and minimization of effects in VAWT is possible in FEM. The aim of FEM to finding the resonant frequencies and mode shapes very acutely. It helps us to achieve the high dynamic rigidity with low mass. All types of boundaries are taken into it and handle all types of loading. An adaptive meshing is performed with various magnetic potential solution after inserting a boundary condition and sub domain plot by this technique. The potential flow solution between angle of attack effects on the geometry domain. That change in mesh point, quadrilateral, boundary elements, element quality, and the level of freedom vary with this technique. A meshing is performed with various modes of angles. The inserting a boundary shape and sub domain plot by the Adaptive meshing technique the refine mesh has been served. The value of α is increase randomly. The angle of attack between wind pressure and lift coefficient effects geometry field. There are various modes of flow around the airfiol. It travels with positive direction (normal field), curve effect and pitch effect. Hence the optimal performance is varied with the angle size [10].

A. Airfoil characteristics

The chord-lengths awaybe upstream, top, and bottom edges of the computational domain are located 80chord-lengthsand downstream edge is located 100 chord-lengths away. This is to reduce the effect of the applied boundary conditions. The NACA 0012 airfoil flow around an inclined by using the SST turbulence model and compares the results with the experimental lift data coefficient. The SST model combines the capabilities of the k-ω model with the free-stream action of the k-ω model to enable accurate simulation of a wide variety of internal and external flow problems for the SST turbulence model in the CFD Module. The relative flow to a reference frame fixed on a NACA 0012 airfoil with chord length. The airfoil is inclined at an angle α to the oncoming stream. The temperature of the ambient air is 20ºC and the relative free-stream velocity is U_∞=50 m/s resulting. The Reynolds number based on the chord length is approximately equal and Hence, we can assume that the boundary layers are turbulent over practically the entire airfoil.

B. Experimental work

The simplest option when setting the initial velocity field is to use a constant velocity, which does not satisfy the wall boundary conditions. A more accurate and robust initial Laplace equation can be obtained solving the potential flow equation.

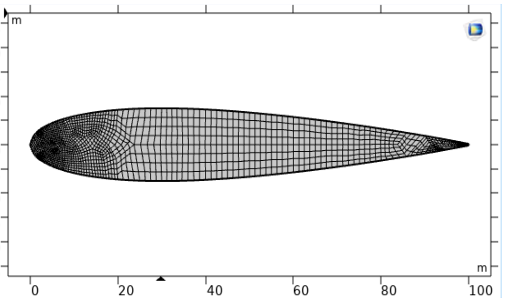


Figure 5. Adaptive Meshing of the airfoil model.

The study performsAdaptive Meshing of the airfoil model. The degree of freedom DOF is used to refine parameter of airfoil design. Due to which boundary condition is carried out, while resolving by the Laplace equation. A Parametric Sweep with the angle of attack α taking the values. The maximum torque is lies between 0º to 16ºdue to which it swept the wind pressure.

$$\alpha = 0^o, 2^o, 4, 6^o, 8^o, 10^o, 12^o, 14^o, 16^o$$

The velocity magnitude and the streamlines for the steady flow around the NACA 0012 profile atA small separation bubble appears at the trailing edge for higher values of α and the flow is unlikely to remain steady and two-dimensional, data for the lift coefficient versus the angle of attack.

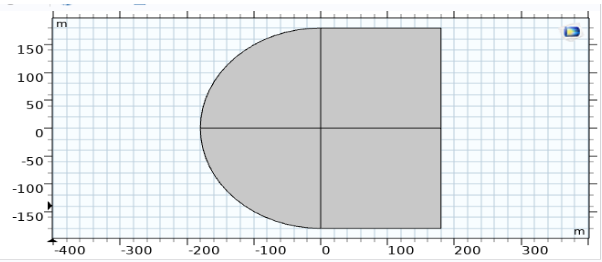


Figure 6: The domain around a NACA 0012 airfoil.

In the figure 7 .The radius is 0.5 on the first conditions, due to which maximum distance is 1.

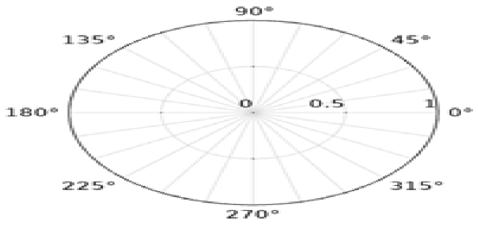


Figure 7: The polar graph of the airfoil at different angles.

The curve chart on the polar grid is obtained. Hence, thepolar equation can be evaluated for various types of symmetry with respect to the polar axis yields by the equivalent equation.

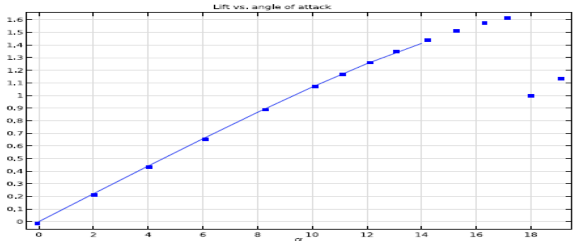


Figure 9: Results for the lift coefficient vs. angle of attack.

The computations results within the range of α values used in the simulation process. The initial condition is 0 and the final condition is 16, after that there is occurrence in the saturation. The experimental results continue through the parameter region occurs where the angle of attack in airfoil is performed. The comparison between the computed lift coefficient at $\alpha = 10^{o}$.

IV. CONCLUSION

In this paper, the analysis is carried out on development of Vertical Axis Turbine with objective of optimizing the attacking of angle w.r.t. wind pressure. This development of airfoil includes selecting appropriate number of size and orientations of shapes with reference to each other. The effects of these design parameters on the performance parameters viz. lift and angle of attack coefficients are studied using finite element method numerical technique analysis of airfoil on VAT model.

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