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Exploration of Materials Used to Design Airfoil the Vertical Axis Wind Turbine

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***Abstract*: This paper presents the study about role of materials to design airfoil on the analysis of a Vertical Axis Turbine (VAWT) with strength and reliability of airfoil that attached to its supporting arm joint to the main shaft of the VAWT. The materials used in production of airfoil blade wind turbine have been made resistive, cheeped, low weight. The materials Aluminum Composite has light weight, low tensile strength, and good reliability. PVC is very light weight material. This composite material has good thermo-mechanical and chemical properties. The velocity and pressure field which affects the efficiency of different airfoil angles of attack at a series of VAWT rotation angles can be obtained. The position the net force on the airfoil can also derived from the formula based on the pressure field and the airfoil geometry. Hence it is, directly related to the efficiency of the VAWT.**

***Keywords*: Airfoil, Materials, Vertical Axis Wind Turbine (VAWT).**

1. Introduction

Now-a-days, the demand for the electricity is collectively increasing day by day and its production not able to fulfil the requirements. Thus, there is a requirement of alternative source of energy production, which is independent of the fact that the source of the energy should be renewable and non-polluting. The Wind energy produces no environmental harm during the production of electricity. The wind energy source has various properties among another's. In the wind turbine the blades are mounted shaft is placed at surface level so that it is much easier to install and maintain. Hence, it has low operating cost. The wind turbines are categorized into two classes depending upon the axis of rotation of blades. They are classified as Horizontal Axis Wind Turbine (HAWT) and Vertical Axis Wind Turbine (VAWT). The VAWT can accept air from any direction. There are various categories of vertical axis wind turbines. The Darrieus wind turbine is a special category of VAWTs that based on lift forces for its operation. The long and straight blades of VAWT can fail due to high value of aspect ratio which causes a large value of bending moments and deflections [2]. In the, VAWT generator and clutch can be placed at the bottom of turbine which is set up near by the ground. There are numerous of challenges tasks on VAWT that are low starting torque, low peak efficiency, narrow operating range, pulsatory torque, and stability problems. The parameters of the airfoil blades such as the angle of attack v/s lift coefficient for the performance improvement [3]. The Experimental results show all the improved angle of attack. when it is compared to the materials of the airfoils. The vibration parameters for vertical axis wind turbine such as natural frequencies and mode shapes. The modal analysis composite straight bladed vertical axis wind turbine blade has low natural frequency compared to the blade made up of Aluminum material, from the static analysis, the minimum stresses and maximum deformations are developed in composite vertical axis wind turbine blade material when compared with the Aluminum blade material VAWT blade [4]. Hence, the power extraction improves the system as a result of employing airfoil.

2. Vertical Axis Wind Turbine

Table 1
Description of material used in VAWT

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

The general components of vertical axis wind turbine are following: A tower to support the rotor. Hub is known as the center of the rotor to which the rotor blades are connected. The Cast iron or cast steel is commonly used. There are types of hub in VAT are upper and lower hub. This is because the blades are attached at two points. Rotor it is a part which converts wind energy into mechanical power. The design of the particular blades also affects the overall design of the rotor. A Shaft can be turned by the turbine blades. The conversion of mechanical energy into electrical energy is done by the generator. 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. The description of material used in VAWT shown in table1

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and foundation is necessary to prevent the turbine from blowing over in high winds [5].

A. Airfoil Model

The main objective of this study is to determine the 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 airfoil angles ranging from 0º to 16º 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 [6]. The shapes based upon rectangular coordinate system are given by the following equations:

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

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 the maximum camber.

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

where y_{thick} is the y coordinate of the thickness distribution, t_{max} is the maximum thickness value. 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), the thickness is not quite zero.

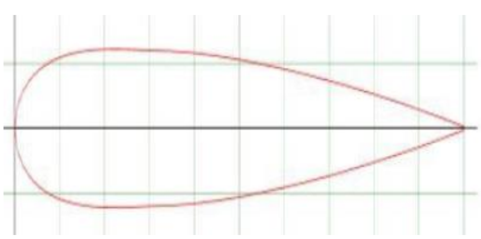

Fig. 2. Geometry of airfoil design

The total force acting on the airfoil surface can be calculated by integrating the force vector.

B. Material Properties

The variety of materials like wood, steel, aluminum, fiber materials, carbon fiber, aromatic polyamides are available for designing airfoil. Among these materials these are selected based on their properties and performance. The studies on material selection for airfoil, this study include comparative analysis on giving performance percentage for different materials. Aluminium alloy is materials used to design airfoil of VAWT, and other like stainless steel and polycarbonate sheet are also. The study on material is suitable on the basis of our requirement. The fabricating of testing model, aluminium material is used. Aluminium is in ductile nature having a low fatigue levels. Because of its sensitivity to moisture and processing costs modern materials such as glass fiber reinforced plastic (GFRP), carbon fiber reinforced plastic (CFRP), steel and aluminum are replacing the traditional wooden units [7].

C. Assumptions

The following assumptions have been made for the analysis provided.

- Power and torque are neglected.
- 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 ≈ angle.
- The airfoil only slightly disturbs free stream $U', v' \ll V_\infty$.

3. Simulation Results of the Airfoil Materials

A. Simulation analysis

In the Finite Element method (FEM), variance procedure is initiated by this method. The analysis of eddy current in structural counting part and minimization of losses in electrical machines 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 vector potentials after inserting a boundary condition and sub domain plot by this technique. The magnetic vector potential between primary and secondary effects the magnetic 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 air gaps after inserting a boundary shape and sub domain plot By the Adaptive meshing technique the refine mesh has been served. The magnetic field density is increasing. The air gap between primary and secondary affects the magnetic field. There are three types that the magnetic field in the air gap. It travels with positive direction (normal field), entry end effect and exit end effect. Hence the optimal performance is varied with the air gap [8-10].

B. Airfoil Material characteristics

Airfoil material characteristics analysis is done using FEM for the present design of straight (VAWT) vertical axis wind turbine blade. In the analysis we had compared various responses such as stress, and deformation from the simulation solutions are to be validated against corresponding previous observations. Further dynamic analysis for the current design is carried out in this work. Modal analysis is performed to determine the natural frequencies and mode shapes of a structure or a machine component while it is being designed. Later, application of composite material properties is done. Models made of two composite materials viz. Carbon Fiber and E- Glass reinforced composites have been analyzed. Fatigue analysis is also carried out for the current design. The fatigue analysis is performed to determine fatigue stresses and fatigue life of the component.

Table 2
Description of materials

Choice of Materials		
S. No.	Materials	Young's Modulus E(G Pa)
1	Carbon Fiber	21
2	E- Glass Composite	9.5
3	Neat matrix Polymer	20
4	Aluminium	70
5	Aromatic Polyamides	35
6	Wood	18
7	Steel	27
8	Plastic	43

C. *Experimental work*

The simplest option when setting the initial condition is to use angle of attack of various materials, which does satisfy the wall boundary conditions. The analysis is carried out with airfoil made of carbon fiber composite for the angle of attack optimized airfoil and analysis results. The model frequencies for carbon fiber got less values when compared with aluminium. The carbon fiber has more strain energy than aluminium. Different cross sectional airfoil there exhibits same frequency values corresponding to the angle of attack. The extracted modes for various cross sections have different varying frequencies are represented.

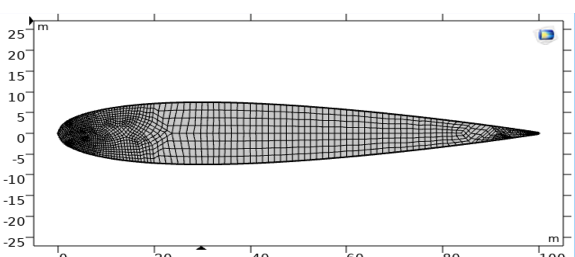

Fig. 3. Adaptive meshing of the airfoil model

The change in frequencies is due to the effect of flap wise bending and torsional bending. Irrespective to the type of bending the 1mm thickness airfoil models shows higher frequency values among all the other cross sectional airfoils. The frequencies for various cross section airfoils made with neat matrix for airfoil. The Compare with aluminum and carbon fiber the neat has lower frequencies with respect to wall thickness for different airfoils. The different wall thicknesses airfoil models show varying frequencies corresponding the modes are illustrated. The angle of attack for airfoil made of neat matrix starts with lower frequencies and ends with high values. The E -glass composites the model frequencies are relatively low in compared with aluminium, 1%caron fiber and neat matrix. It can be observed that the frequencies increase from angle of attack.

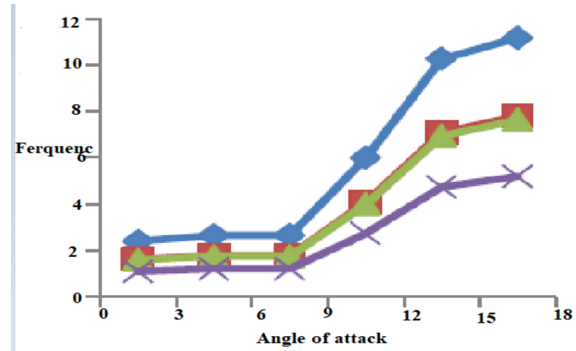

Fig. 4. Relation b/w angle of attack and frequency of different materials

The frequency values for remaining modes are inappropriate so it is not mentioned in the plot. Solid airfoil model frequencies are lower compared with reaming airfoil model frequencies it can be observed that frequencies plots of first three airfoil models solid airfoil model thickness airfoil model are in lower level compared with remaining three airfoil models.

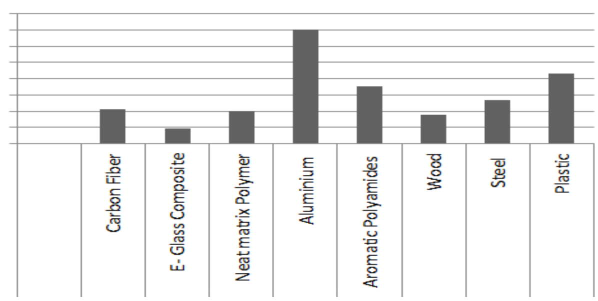

Fig. 5. Variation on Young's Modulus E(G Pa) of different materials

The Composite materials put forward some low frequency values in disparity with aluminium for optimized wall thickness airfoil model. The frequencies graph for Neat matrix follows close path with the frequencies graph of carbon fiber, because the material properties are very close. E – Glass material has lower value over the other three materials (i.e. carbon fiber, neat matrix and aluminium).

4. 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. frequency. The optimized straight hallow cross section airfoil (VAWT) during static analysis for, aluminium is high as compared to neat matrix and E-glass material respectively. These stresses are below yield stress of their respective materials composites are less compared with aluminium. The Young's Modulus of aluminium is also be grater among the other materials The total deformations induced during static analysis for aluminium, carbon fiber, neat matrix and E-glass material respectively. And Deformations induced in the composites are more compared to aluminium. Frequencies of composite materials less compared with aluminium. So, replacing of aluminium with carbon fiber and neat matrix reduces the frequencies to 33% of its natural frequency, or replacing aluminium with E- glass composite decrease its frequency to 54% of its natural frequency.

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