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Design and analysis of Wind Turbine Blade A Review

Prof. Ritesh Banpurkar[1], Rahul Vaidhye[2]
[1]*Professor, Dept. Of Mechanical Engineering, Abha Gaikwad Patil College Of Engineering Nagpur*
[2]*P.G. Student, Dept. Of Mechanical Engineering, Abha Gaikwad Patil College Of Engineering Nagpur*

Abstract
Turbine blade design is the process of designing the all aspects and form a wind turbine to get energy from the wind without any losses and defects. In this paper a review is done on the horizontal axis wind turbine blade. This paper describes the design process of the blade in which it contain rotor blade design aspects. It provides blade design ,blade loads and materials .The objective of the paper is to put forth the history and design process of wind turbine blade. Review described the picture of design of wind turbine blade and some aspects of wind turbine rotor. Aerodynamics plays an important role for designing the wind turbines blades. Aerodynamics criteria is main factor which responsible for smaller major losses to produce energy and work efficiency.
Keywords :- *Aerodynamic, Airfoil, Wind turbine, Rotor blade, Blade loads.*

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I. Introduction

The wind is a free energy resource until government put a tax on it, but the wind is also a very unpredictable and unreliable source of energy as it is constantly changing in both strength and direction. So to ensure we get the most out of the available energy, it is important that the wind turbine blade design is of an optional performance .

Wind turbine blades are designed and shaped to acquire the maximum power from wind at low cost . primarily the design is driven by the aerodynamic requirements ,but the economically blade shape and its material cost is should at reasonable price .In particular the blade tends to be thicker than the aerodynamic optimum close the root, where the stress due to bending are greater. Wind turbine blade design process starts with a best guess compromise between aerodynamic and structural efficiency. The choice of material and its process of manufacturing also perform influence on hoe thin the blade can be built for manufacturing the blade prepreg carbon fiber is most preferred than infused glass fiber due to its stiffness and good mechanical properties . The chosen aerodynamic shape given rise to loads, which are fed into the structural design .The lift force increases as the blade is turned to present itself at a greater angle to the wind, This is called angle of attack the blade “stalls” and the lift decreases again .So there is an optimum angle of attack to generate maximum lift.

II. History

The rise of wind energy during the 1970s began with a trial-and-error process that included a wide variety of rotor configurations. The taxonomy of this decade included a variety of horizontal-axis wind turbine (HAWT) and vertical-axis wind turbine (VAWT) configurations. The HAWT's included upwind and downwind configurations with various performance enhancers, such as diffusers and concentrators. The VAWTs included the lift-type Darrieus configuration and also the drag-type Savonius turbine. The evolution of wind turbines during the 1980's was driven largely by the cost of energy, which resulted in the demise of many of the early concepts. Although VAWTs have the advantage of a drivetrain close to the ground for easy accessibility, their cost-effectiveness does not equal that of HAWT's for reasons not fully documented. Aerodynamically, VAWT's utilize less efficient symmetric airfoils than the higher lift-to-drag ratio, cambered airfoils used on HAWT's. The constant chord, VAWT blades adversely affected blade efficiency and self-start capability.

Rotor wake-induced losses of the VAWT's are greater than those of HAWT's since VAWT's only operate at optimum lift-to-drag ratio over a small azimuth of the rotation. This leads to excessive wind energy going into rotor thrust loads rather than useful power output. The highly cyclic power and thrust generated by VAWT rotors also results in higher fatigue loads. In addition, the VAWT's lack of a characteristic tower eliminates most of the additional energy available higher up due to wind shear.

For HAWT's, almost all the performance enhancers resulted in greater cost than does a modest increase in blade radius to achieve the same energy improvement. Most performance enhancers, such as circular concentrators and diffusers, made it difficult to cost effectively address the hurricane design load condition. Cost considerations also resulted in the popularity of the two- and three-bladed rotor configurations.[1] The two- bladed rotor configuration provides lower cost but more complicated dynamics, which adversely affects reliability.

For large commercial machines, the upwind, three-bladed rotor is the industry-accepted configuration. Virtually all large machines installed during the last several years are of this configuration. The three-bladed rotor offers the following advantages over the two-bladed configuration. Although the upwind choice is based largely on noise considerations, it also results in lower blade fatigue. Tower-shadow noise and impulsive blade loading for an upwind rotor, are less than for a downwind rotor that passes through the tower wake. For an upwind rotor, the blade-number choice is then a balance among blade stiffness for tower clearance, aerodynamic efficiency, and tower-shadow impulsive noise. The three-bladed rotor configuration appears to provide the best balance.

Additional criteria not always acknowledged within the industry, such as reliability, noise, and aesthetic considerations, narrowed the HAWT configurations further in the 1990s. Based on these criteria, the configuration of choice by the wind industry the last several years has been the upwind, three-bladed rotor. The moderate-size, lightweight, two-bladed teetering rotors, which lend themselves to tilt-down towers, may still, however, find a niche market in areas where installation cranes are unavailable.

III. Design Parameters

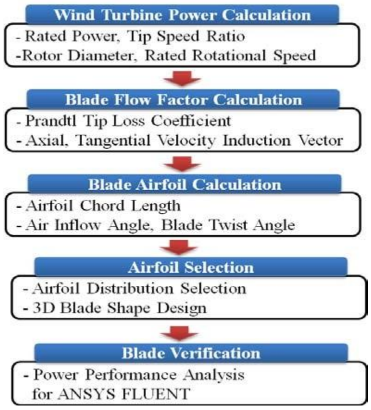

Fig. Design Flow Chart of Wind Turbine Blade

Material

During the past 20 years, large wind turbine blades have been fabricated from steel, aluminum, and composite materials such as wood, fiberglass, and carbon fibers. For a given blade strength and stiffness, the blade should be as light as possible to minimize inertial and gyroscopic loads, which contribute to blade fatigue. Blades made from steel and aluminum suffer from excessive weight and low fatigue life relative to modern composites.[14] Because of these limitations, during the past 10 years almost all blades have been fabricated from composite materials, usually fiberglass. Although carbon fiber provides the highest strength-to-weight ratio and stiffness, it has not been widely used because of its high cost, strain incompatibility when used with fiberglass, and handling difficulties. Common resin systems used in composite materials have included polyester, vinyl- ester, and epoxy. Polyester and vinyl-ester have been most widely used because of their lower cost. More manufacturers are switching to epoxy, however, to achieve better material properties. Epoxy alleviates shrinkage, does not become brittle with age, and provides better fatigue characteristics.

IV. Airfoil selection

Airfoil design has come a long way since the early days of their inception and therefore many different airfoil types have been designed to suit a multitude of unique wind turbine blade, propeller, and aircraft wing designs. The general approach to selecting airfoils for a wind turbine rotor is to utilize at least two different airfoil types to provide for two key goals, structural and aerodynamic performance. The first goal is to have a structurally sound blade, which necessitates the use of a thicker airfoil to withstand the large bending moment caused by the aerodynamic and intrinsic gravity loads exerted on the blade during the wind turbine’s operation at the root of the blade. The second goal is to be as aerodynamically efficient as possible at the outer blade sections in order to generate the required lift force with as little wind speed, and therefore available power, as possible so as to allow for power generation to occur at low wind speeds.

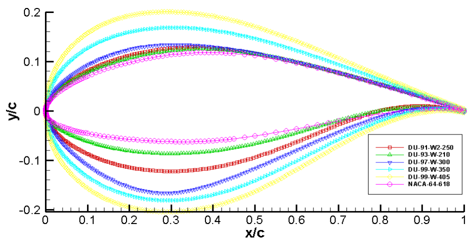

Fig. Airfoil Shape of Wind Turbine Blade

Depending on the specifics of the wind turbine application there may be multiple airfoil types which may suit that particular application with each having its own set of pros and cons. The CPWPRC is a unique wind turbine project in that it is meant for wind power generation research and has the task of testing new rotor blade designs. Therefore, the results of wind power research at the CPWPRC are meant to provide insight into the capabilities of wind power generation which may then be adopted by industry leaders.

V. Loads acts on wind blade

Aerodynamic Load

Aerodynamic load is generated by lift and drag of the blades aerofoil section (Figure 9), which is dependent on wind velocity (V_W), blade velocity (U), surface finish, angle of attack (α) and yaw. The angle of attack is dependent on blade twist and pitch. The aerodynamic lift and drag produced (Figure 9) are resolved into useful thrust (T) in the direction of rotation absorbed by the generator and reaction forces (R). It can be seen that the reaction forces are substantial acting in the flatwise bending plane, and must be tolerated by the blade with limited deformation.

Gravitational Loads

Gravitational centrifugal forces are mass dependant which is generally thought to increase cubically with increasing turbine diameter [38]. Therefore, turbines under ten meters diameter have negligible inertial loads, which are marginal for 20 meters upward, and critical for 70 meter rotors and above [4]. The gravitational force is defined simply as mass multiplied by the gravitational constant, although its direction remains constant acting towards the centre of the earth which causes an alternating cyclic load case.

Centrifugal Loads

The centrifugal force is a product of rotational velocity squared and mass and always acts radial outward, hence the increased load demands of higher tip speeds. Centrifugal and gravitational loads are superimposed to give a positively displaced alternating condition with a wavelength equal to one blade revolution.

Fatigue Loads

The major loading conditions applied to the blade are not static. Fatigue loading can occur when a material is subjected to a repeated non continuous load which causes the fatigue limit of the material to be exceeded. It is possible to produce a wind turbine blade capable of operating within the fatigue limit of its materials. However, such a design would require excessive amounts of structural material resulting in a heavy, large, expensive and inefficient blade. Fatigue loading conditions are therefore unavoidable in efficient rotor blade design.

VI. Conclusions

This review paper explains various aspects of designing of Horizontal Axis Wind Turbine Blade. A clearer understanding is given about the technical and other aspects of the blade of the horizontal axis wind turbine. The literature review explains a variety of aspects and different research works over the relevant topics of horizontal wind turbine blade design. In different directions, this e s exploration has been done through different literary works of recent times. Through this review work, designing of the blade of the horizontal axis wind turbine has been made to take it to further steps.

This project will successful in regards to establishing a reliable method of designing and analyzing HAWT. By going through the processes utilized in this project, a HAWT rotor blade designer may design and analyze a new rotor blade for any number of applications.

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