Review on Wind Turbine Blade Design Optimization and Materials

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Abstract— Wind energy source is the fastest growing energy source in the world. Wind energy is clean and renewable of energy. The important components in wind turbine are blade which produces electricity from wind. Blade which it capturing the energy from wind and also blade must have good strength and minimum mass. In this paper, a comprehensive review on fatigue life optimization, blade performance, blade materials, blade design ,fatigue performance are reviewed in this paper.

Keywords: wind turbine blade, blade design, blade materials, fatigue performance

I. Introduction

One of the renewable energy is the wind energy which is predicted to provide up to 8% of the world's electricity consumption by 2021. The latest feature in wind turbine blade design reviews the blade design and their functionality as for various requirements. Furthermore, the usages of the composite materials in the design and the challenges are reviewed.

The paper provides an analysis about the wind turbine blade design including aerodynamic and aero elastic features, characteristics of wind turbine blade and fatigue loads on wind turbine blades. Performances analysis of blades has been studied for the improvement of the wind turbine blade design. Since wind energy field is a vast area, we had a very good opportunity to perform the design analysis of wind turbine blades. The paper aims to provide an improvement in the performance of the wind turbine.

II. Literature Survey

Satish kumar V Tawade et.al (1) had done research about different types of loads acting on the Wind Turbine blade and consequential stresses developed in blade. ANSYS software is used to study the Finite Element model of Wind Turbine blade. Developed the fatigue stresses on the Wind Turbine blade due to change in wind speed. It is observed that the 4-noded SHELL 63 element proved to be a successful finite element in the analysis of the structures of three-dimensional, as it takes into description six degrees of freedom at each element node.

B. F. Sorensen et.al [2] this paper investigation about the use of composite materials in wind turbine blades, including common breakdown modes, test methods ,strength-controlling material properties and modeling approaches at the material scale, component scale and sub-component. Its develop composite material in wind turbine blade to improved efficiency.

Peter K. Fossum Lars Frøyd et.al [3] this presentation is aeroelastic design and fatigue analysis of large utility-scale wind turbine blades have been performed to investigate the applicability of different types of materials in a fatigue Environments. It is known that higher performance materials more favorable in the spar-cap construction of large blades which are designed for lower wind speeds.

Vipin Kumar Singh et.al [4] had described that the blade should have the maximum strength and minimum mass. He insists that the blade design should be in a manner to extract maximum energy from winds. The methodology for design wind turbine blade by optimizing various characteristics and parts of blade. In order to extract extra power, we have to increases the swept area by increasing length of blade.

Peter J. Schubel et.al [5] had presented the detailed review of the current state-of-art for wind turbine blade design. Further he had included the theoretical maximum efficiency, practical efficiency, HAWT blade design, propulsion, and blade loads. The review gives a complete picture of wind turbine blade design and shows the dominance of modern turbines almost exclusive use of horizontal axis rotors.

V. Parezanovic, B. Rasuo et.al [6] had featured the following things in this paper. The main point of this paper is the design of the airfoils that could increase the overall efficiency of wind turbines. Every aero dynamic surface must undergo an expensive process of testing of its performance in a wind channel. The most part of the results of the simulation of these few airfoils are in good agreement with available wind channel measurements.

A.V.Pradeep et.al [7] had modified the design of gas turbine turbo machinery for designing wind turbine blade. The development of the design for gas turbine turbo machinery has been carried out now days. A different approach is presented which can control many of the design codes and processes developed for axial turbine, open rotor, fan and axial compressor.

Rongrong Gu et.al [8] This paper presents an optimization method for the structural design of horizontal-axis wind turbine (HAWT) blades based on the particle swarm optimization algorithm (PSO) combined with the finite element method (FEM). This paper describes an optimization method for the structural design of HAWT blades. Two modules are used for this purpose: a PSO algorithm and a structural analysis model implementing FEM.

Naishadh G. Vasjaliya et.al [9] this paper is composite wind turbine blade MDO is divided into three steps and the design variables considered are related to the twist distribution, pitch angle shape parameter and the relative thickness based on number of composite layers. The constraints are tip deformations and allowable stresses. This complex MDO process presented here can be applied to the design of wind turbine blades to obtain a structurally optimized blade design with optimal blade thickness distribution and maximum power output without compromising its aerodynamic performance.

Aravind kumar. N et.al [10] this paper deals with the experimental verification the small wind turbine blade without and with winglet. Winglet is minor portion to be new in the end of blade and measured its noise and performances. The winglet design process complete using ProE software after that the analyses work has been carried out using the required software in a standard method.

Arman Safdari et.al [11] this paper presented in the Aerodynamic characteristics of small-scale of Archimedes spiral wind turbine blades. Then analyzed PIV techniques and numerical methods were performed to study the behavior of the flow around the turbine and efficiency power near the wake of the Archimedes spiral wind turbine bladeS. The inner low speed part rotated the same turning direction of the blade. The relative velocity of the flow is close zero to the blade. The investigation of the obtained results determined the straight interaction between the mean flow at the rotor downstream and the induced velocity due to the tip vortices.

T.Mahendra pandian et.al [12] this paper describes the Wind turbine blade must be designed aerodynamically to achieves optimum performance in both design and off design condition. It is observed that the power increase with the angle of attack up to 10° and after that it reduce.Hence, the critical angle of attack is 10°. The power increase with the air velocity from 3 m/s to 10 m/s and after that the power decreases.

Aditya Rachman et.al [13] this paper explores the annual energy production of a wind machine on the variation of the blade number and the rotational operation with consideration of the wind frequency characteristics conditions. the observed that same tendency of the high annual energy production for the high bladed turbine with low rotational operation and the high annual energy production for the low bladed turbine with high rotational operation.

Navin Prasad et.al [14] This paper describes small-scale wind turbines have quite different aerodynamic behaviour than their major counterpart. The little wind turbines in use at low wind speeds regularly face the problem of poor performance due to laminar separation and laminar separation bubbles on the blade. The review provide modified a case 1profile (chord thickness increased by 30%) had given the best results when compare to other profiles and this modified NACA 4415 blade is designed for low wind speed.

Ryosuke Ito Hikaru Matsumiya et.al [15] The paper reports a series of technical approach including design/analysis, tracktests, and field tests conducted in support to the design process . Operation data at high wind siteswere well collected andused for mechanical analyses. A new term “captureability” as an indicators of WT performancewas proposed.

Herbert J. Sutherland et.al [16] This paper analyzes typical loads data from operating wind farms andthe failure of coupons subjected to spectral loading. The predicted service lifetimes that are based on the CLD constructed from 13 R-values are compared to the predictions for CLDs constructed with fewer R-values.

Victor Lopez G. et.al [17] this paper proposes a methodology for design and manufacturing of wind turbine blades of low capacity with CAD (Computer Aided Design)/ CAM (Computer Aided Manufacturing) techniques and composite materials. The design of the blades was performs with help of specific software, one of them developed in the author’s institute. The manufacturing of the blades model was executed in machining center of three axis CNC, DYNA MYTE DM-4800. They final manufactures of composite materials was performed. The wind turbine manufacturing techniques using CAD / CAM ensures perfect aerodynamics and this directly affects the mechanical efficiency of the machine.

Ashwani Kumara et.al [18] The main objective of this research work is to introduce a new material for wind turbine blades. Al 2024 is select for the suitability analysis. Finite element Method or Finite Element Analysis is a approximation techniques used for the analysis of complex objects and geometriese. Wind energy or wind power is measured as a clean source of energywhich produces noenvironmental harm during operation. This research work provides a detail study of Al 2024 wind Turbine blade using structural and modal analysis.Current analyzing trends are summarize, and several analysis result of blade are presented. Preliminary blade design were developed for 25m heights, and work bench analysis were perform to investigate the potential benefitsand options for inclusion of Al 2024 material and blade structure are discussed within the context of FEM analysis.

Vaibhav R.Pannase et.al [19] This paper explores the design space that exists between multi blade, high-solidity water-pumping turbines with trapezoidal blade design and modern rectangular horizontal axis wind turbines (HAWTs). In particular, it compares the features and performance of a small 18-blade, high-solidity Horizontal axis wind turbine with trapezoidal blades to that of a rectangular bladed 18-bladed HAWT. This is achieved through a Modal analysis on the exist trapezoidal blade and optimize rectangular blade along with dynamic response analysis of blade in the software of ANSYS. The model of blades was developed in CATIA. Dynamic analysis was performed for the blade by using the finite element method.

Nitin Tenguria et.al [20] This paper describes the blade and spar are of same composite materials. The FEA of designed blade is done in ANSYS. This work is focused on the two segment of blades, root segments and conversion segments. Result obtained from ANSYS is compare with the previously done experimental work. In this work a horizontal axis wind turbine blade is designed with the help of Glauert'soptimal rotor theory, a computer programs is developed for receiving the chord, thickness andtwist distribution while maintaining the lift coefficient constant throughout the blade.

Sanjay R. Arwade1 et.al [21] This paper describes an approach that can deliver assessments of the probability distribution of wind turbine and wind farm performance metrics such as availability, the length of operating and losing periods. The model, as explain, accept many different kinds of input parameter, yet the set of input parameter has been limited to those which can be calibrated to available field observations. Without any theoretical adjustments, however, the model could be adapted to include site specific condition, turbine specifics, wake induced structurals loading, and component redundancy and dependency.

John F. Mandell et.al [22] This paper provides an overview of the results of recent studies of composite laminates ofinterest for wind turbine blade construction. In addition to the primary requirements of stiffness,strength, and ease of processing, wind blade materials must withstand severe fatigue loadingunder service environments. Major issues have been identified which can produce severe fatigue damage or failure in goodquality coupons at low maximum absolute strains, in the range of 0.2 to 0.4%. Additional issues are carbon fiber laminate compressive strength, which is sensitive to fabric or other fiber waviness, and delamination and adhesive breakdown in complex details under both static and fatigue loading.

Danny Sale et.al [23] In this work we develop a numerical methodology for the structural analysis and optimization of composite blades for wind and hydrokinetic turbines. While the methodology presented here is equally applicable to the design of wind turbines, this paper focuses on its application to hydrokinetic turbines. Studying the relationships between material properties and structural performance provides further insights into creating high-performance, high reliable, and turbine blades cheaper.

III. Conclusions

This paper provides an overview of the using current state and futures challenge in the wind turbine blade in fatigue life optimization, blade performance, blade materials, fatigue performance, blade design. The design of the wind turbine blades must be structurally optimized with optimal blade thickness distribution and maximum power output. The wind turbine blades are manufactured using composites materials with carbon fiber reinforcements. These materials are having less cost, high strength and stiffness.

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