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AIRFOIL FOR APPLICATION IN WIND TURBINE BLADE: A Review

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ABSTRACT

Global warming as well as increasing environmental and economic cost of fossil fuels, conservation of non-renewable resources like wing energy motivate to explore the new avenues for electricity generation which could be clean, safe as well as offers a pollution-free and most valuable to serve the society for a long period. After study of many literatures it has been concluded that the airfoil of S834 and S835 is the airfoil design for application of wind turbine has been gives more useful to other airfoil. An overview of the current and future trends in wind turbine blade structural design process is presented.

KEYWORDS: Wind turbine blade, Airfoil, NACA0012, S809, S834 and S835.

I. INTRODUCTION

Wind turbines have more in size over the years since business wind turbines were introduced around 1980. Once several years throughout, which the focus was on increased reliability, we once again (2011) see growth in the size of wind turbines, see Figure 1. Using normal scaling laws, the weight of wind turbine blades should increase with length to the power of three. However, historically, according to Figure 1, blade weights have only increased to the power of 2.3 as blade manufacturers have successfully improved the aerodynamic performance and control of wind turbines, as well as their structural design, and have optimized the use of materials and process technology. Wind turbine blades are now so large that gravity and inertia loads have started to dominate more than aerodynamic loads. It is therefore of increasing importance to reduce weight [1].

Research carried out at the Department of Wind Energy at the Technical University of Denmark (DTU Wind Energy) on wind turbine blades has shown that the classical failure mechanisms such as buckling, material failure, etc., are not enough to determine the design of the blades. Other failure mechanisms need to be taken into account. One mechanism which may lead to failure is cross-sectional shear distortion. This mechanism has been demonstrated in full-scale tests and is not covered by type certification tests.

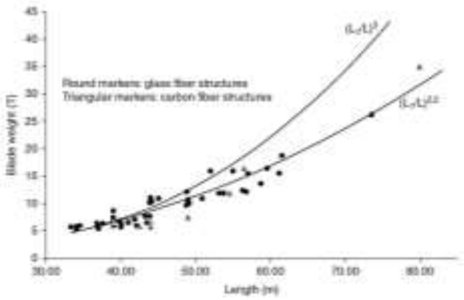

Fig 1. Blade weight vs blade length (L).

II. LITERATURE REVIEW

He et. al., (2000) [16], in their research paper on study of tapered laminated composite structures, have elucidated the advantages of dropping off some plies at discrete positions in the laminate to be the structural tailoring capabilities, damage forbearance and moreover their potential for creating substantial weight saving properties in the field of engineering applications. They have discussed various approaches to model and analyze inter-laminar response of tapered composite structures using finite and non-finite elements. A review of displacement based finite elements and hybrid finite elements are also provided. Stress-strength and fracture mechanics approaches are studied for contribution to delamination of composite laminates. They have analyzed that terminating plies to create tapered laminates often lead to geometric and material discontinuities. These discontinuities act as a vital source of delamination initiation as well as propagation. It was concluded that delamination naturally initiates from the taper root and material non-linearity must always be considered. Moreover, detailed experimentation is needed on resin toughness and inter-laminar fracture strength and multiple delamination should be considered. In this current work, effort has been made towards modeling the same blade geometry in CATIA and carrying out dynamic vibration analysis to validate the natural frequencies to those published in the research paper. Further, the research paper does not give any insight into the life of the component. This issue has been taken up in this current work as fatigue life prediction of the windmill blade considering different materials for different blade parts as compared to those in the research paper.

Joncas et al. (2004) [3], In this work-in-progress paper, topology optimization is used to find optimum preliminary designs for Megawatt size wind turbine blades (60+m in length). These large wind turbine blades are great candidates for topology optimization techniques that are able to converge to designs that would not be intuitively discovered by designers since blades are asymmetric structures subjected to complex loading. At the present stage of the project, extreme load cases were identified and optimum structural lay-outs have been found for different individual and multiple load cases using the finite element based optimization software Optistruct.

Rijswijk (2006) [2], The main goal of this thesis is to develop reactive processing technology for manufacturing of thermoplastic composite wind turbine blades. This chapter presents the outcome of the thesis by grouping various results and issues mentioned in the individual chapters into thematic conclusions. In conclusions with respect to the reactive processing technology itself are discussed, whereas specifically on the use of the presented technology for manufacturing of wind turbine blades.

Rijswijk (2007) [1], Due to the increasing costs of fossil fuels and the improved efficiency of wind turbines in the last decade, wind energy has become increasingly cost-efficient and is well on its way of becoming a mainstream source of energy. To maintain a continuous reduction in costs it is necessary to increase the size of the turbines. For the blades, a structural redesign is inevitable and an aircraft-wing-like design consisting of ribs, spars and skins made of thermoplastic composite parts is proposed. Unfortunately, state-of-the-art melt processing of thermoplastic composites requires heavy presses, which makes it impossible to produce large and thick structures like wind turbine blades.

Ganesan and Zabihollah (2007) [15], in their formulation and parametric study of vibration analysis of tapered composite beams used a higher order finite element to solve a Finite Element Model to obtain natural frequencies and mode shapes of the beam under consideration. Their motto was to study the free un-damped vibrations of beam structures. They did analysis of externally tapered composite beams as well as mid-plane tapered and internally tapered composite beams. They formulated element matrices for the 3 different cases namely element stiffness matrices and element mass matrices. The coefficients of these matrices were derived by symbolic calculations in MATLAB. Numerical example of a uniform thickness composite beam was considered for solving to give a clear cut analytical idea of the mathematical solution process. The differential equation of motion of the beams and their corresponding variation finite element formulation considering the tapered composite structure of beams was developed. A higher-order finite element model was developed based on classical laminated theory for investigating the vibration response of classic laminated tapered composite beams. Various types of tapered composite beams were investigated for their vibration response. The developed variation formulation was validated by considering some numerical examples and relating the results with exact solutions and/or Ritz method, where applicable.

Ming et al. (2010) [9], Structure first design of the blade and Wilson design use the same objective function as the optimization object. While, the former added the constraints of blade shape to ensure the blade meet the requirements of manufacturing, which inevitably makes the tip speed ratio of the former smaller than the latter. That is to say the structure first design of the blade will lead part loss of the aerodynamic performance, especially in the vicinity of the tip speed ratio, but actually the wind wheel cannot always run in the vicinity of the tip speed ratio, so this method has little effect on the overall aerodynamic performance. Structure-first design of the blade, therefore, is closer to the actual design of blade.

Kumar et al (2010) [11], conducted an experiment using NACA 4420 airfoil from 0o to 12o of attack using CFD. They concluded that 50 of attack resulted high lift/drag ratio.

Medjroubi et al. (2011) [5], are simulated incompressible, viscous flow over a two-dimensional NACA0012 airfoil oscillating in heave at mean incidences 12o< a < 20o and Reynolds numbers 800 ⩽ Re ⩽ 104. The two-dimensional Navier–Stokes equations are solved using a Spectral/hp Element Method for the spatial discretization and a high-order splitting scheme for the evolution in time. A moving-frame of reference technique accounts for the airfoil motion. We consider the effects on the aerodynamical flow and the force coefficients caused by the variation of the mean incidence, the Reynolds number and the sinusoidal heave motion of the airfoil. The numerical simulations are in good agreement with previously published experimental and computational work, in particular the increase in the force coefficients due to the increase in the Reynolds number and/or the mean incidence are confirmed by the present study. Furthermore, we present here new details of the spatiotemporal non-linear flow pattern evolution where for the first time the Spectral/hp Element Method associated with the moving frame of reference is used for this kind of flow.

Baldacchino and Bussel (2012) [4], in the present study, a simple inviscid vortex ring (VR) modelling approach is used to represent the developing rotor wake. This allows a straightforward investigation and comparison of the impact of uniform, yawed and sheared flow conditions on the development of the rotor wake, with the additional possibility of including ground effect. The effect of instabilities on the development of the wake is manually introduced in the form of perturbations of strength, ring position and size. The phenomenon of vortex filament interaction or leapfrogging, could play a role in the observation of unsteady phenomena and is therefore also addressed. Such a study is hence performed in light of recent conflicting views on the causes of wake meandering: is the observed dynamic wake behaviour a result of large scale turbulent forcing or do more subtle and intrinsic wake instabilities play a role? This study concludes that the presence of the ground and external perturbations, most notably changes in the wake pitch and the rotor thrust coefficient, can significantly affect the steady development of the wake. However, in the absence of unsteady inflow, it is shown that the wake of a Horizontal Axis Wind Turbine (HAWT) is certainly prone to displaying unstable, dynamic behaviour caused by these additional factors.

Manyonge et al. (2012) [6] made a mathematical model of wind turbine to understand the behaviour of the wind turbine over its region of operation. Griffiths, the maximum conversion efficiency of the horizontal axis wind turbine (HAWT) is 16/27. Air is treated stationery, non-viscous and incompressible in the flow analysis. Unique main significance of wind turbine design is its number of blades. Number of blades is significantly prompting, the horizontal axis wind turbines (HAWT). Most common number used are 2 and 3 blades. Nearly some HAWTs might have more than 3 blades, and usually because they are used for low speed wind turbines and most of the current viable turbines used for power generation have three blades. It is well-known that additional blades offer a larger available surface area for the wind to push, so it would yield additional rotating power but in the similar period a larger number of blades upsurge the weight to be rotated by the turbine.

Bottasso (2012) [7], described a method for the structural optimization of wind turbine rotor blades for given prescribed aerodynamic shape. The study was gives overview of different methods, to evaluate the aerodynamic performance of wind turbine. Hosman made a performance analysis and improvement of small wind turbine. Abottanalyzed the properties of airfoil using 32 theory of airfoil section. According to Griffith, the output power of the turbine depends on lift/drag ratio.

Douvi and Margaris (2012) [17], was presented a comparison between a National Advisory Committee of Aeronautics (NACA) airfoil, NACA 0012 and a wind turbine airfoil from the National Renewable Energy Laboratory, NREL S809, using a computational fluid dynamics code. Both airfoils were simulated at various angles of attack and operating at Reynolds numbers Re = 1×106 and Re = 3×106, in order to compare and find out the airfoil with the better aerodynamic performance at these conditions that are common in wind turbine applications. For validation purposes, a comparison between reliable experimental data and the numerical results of the present simulation was made. The impact of various turbulence models, especially Spalart–Allmaras, Realizable k-ε and k-ω shear stress transport (SST) model, on the predicted aerodynamic forces is also analyzed. The realizable k-ω SST model was noticeably more accurate than the other models. The comparisons of the S809 airfoil and the NACA 0012 airfoil showed that the S809 airfoil exhibits higher lift coefficients for the whole range of the angles of attack and a lower lift coefficient only in the region of the stall conditions, which are not applicable in practice. This means that S809 is more advantageous vs. NACA 0012 airfoil for wind turbine applications.

Hsiao et. al., (2013) [10], Three different horizontal axis wind turbine (HAWT) blade geometries with the same diameter of 0.72 m using the same NACA4418 airfoil profile have been investigated both experimentally and numerically. The first is an optimum (OPT) blade shape, obtained using improved blade element momentum (BEM) theory. A detailed description of the blade geometry is also given. The second is an untapered and optimum twist (UOT) blade with the same twist distributions as the OPT blade. The third blade is untapered and untwisted (UUT).

Sherry et. Al (2013) [14], studied the vortex interface and steadiness of the helical whirlpool strands within a (HAWT) horizontal axis wind turbine wake.

Saxena and Agrawal (2013) [13], analyzed a basic aerodynamic theory of wings and the provided and methodology for wind tunnel testing. They found angle of attack at which the lift is maximized in order to get the best performance of this wing when in flight.

Oskarsdóttir (2014) [12], gives a general account and evaluation of (HAWT) horizontal axis wind turbines and (VAWT) vertical axis wind turbines. It was determined the existence of the earth and exterior distresses, most particularly, alterations in wake pitch and the rotor thrust coefficient.

Douak and Aouachria (2015) [8] designed a vertical axis wind turbine using NACA 0012 aero foil structure. MATLAB software is used to obtain lift and drag coefficients, angles of attack and relative wind speeds.

Kapdi et. al., (2016) [16] With new emerging technologies and innovations in energy sector future seems to be bright. But there’s still few years for implementation of those technologies in commercial market. In time, there is need to optimize existing technologies and increase their efficiency. Present research is one step towards that goal. This paper analyses and determine the optimum angle of attack at specific wind velocity for horizontal axis wind turbine. Analysis is done by setting wind speed to 10m/s (as this is average wind speed in most open area where wind turbines are placed) and by changing the angle of attack (6, 7, 8, 9 degrees) variation in different properties such as the power output, pressure distribution is determined.

Hosseini and Imani (2016) [18], the designs of horizontal axis wind turbine (HAWT) blades involves several geometric complexities. As a result, the modeling of these blades by commercial computer-aided design (CAD) software is not easily accomplished. In the present paper, the HAWT blade is divided into structural and aerodynamic surfaces with a continuity imposed on their connecting region. The widely used method of skinning is employed throughout the current work for surface approximation. In addition, to ensure the compatibility of section curves, a novel approach is developed based on the redistribution of input airfoil points. In order to evaluate deviation errors, the Haus Orff metric is used. The fairness of surfaces is quantitatively assessed using the standard strain energy method. The abovementioned algorithms are successfully integrated into a MATLAB program so as to enhance further optimization applications. The final surfaces created by the procedure developed during the present study can be exported using the IGES standard file format and directly interpreted by commercial CAD and FE software.

III. CONCLUSION

After study of many literatures it has been concluded that the airfoil of S834 and S835 is the airfoil design for application of wind turbine has been gives more useful to other airfoil. An overview of the current and future trends in wind turbine blade structural design process is presented.

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