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A Review over the Design of Wind Turbine Blade for Changing Its Materials and Profile Shape

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Abstract- The demand for renewable energy sources has created revolution in the wind turbine industry. Modern turbines are bigger with large rotor diameter that captures more wind to produce electricity. The efficient and effective use of wind turbines is still a new technology and has many challenges, including the amount of power generation. The wind turbine blades affect various forces like compressive, aerodynamic, gravitational etc. Mechanical behaviour is critical for any wind turbine blade because it must withstand a variety of mechanical stresses as well as deflections. It observed from the literature that enormous research work had done on various types of wind turbine blades.

Keywords- Optimization of blades; energy cost; wind turbine design; aerodynamics

I. Introduction

The wind turbine blades are complex structures. They are modelled in finite elements to deal with their structural complexity. The finite element analysis is done for the validation of the structural design as well as the dynamic or modal response of the blades, as vibration at natural frequencies is an important part of blade design. (Schubel and Crossley, 2012) The finite element analysis of wind turbine blades can be done with varying degrees of complexity. The blade can be modelled as a beam with varying degree of complex or simple beam elements. (Beauson and Brøndsted, 2016)

Wind turbines installed in high-wind-speed areas have gradually lost support to those installed in low-wind-speed areas. (Alaoui *et al.*, 2018)As of 2010, low-speed wind turbines have progressed dramatically. The shift toward lower specific power is reflected in the growing market penetration of wind turbines in low wind speed regions. (Schubel and Crossley, 2015)To offset capital expenses and energy production, low wind speed turbines have larger and thinner rotors.(Mathew, 2006)For instance, the Asian wind energy market has been dominated by low wind speed turbines in the last decade mainly due to the lower quality wind resources in most places of China and India.(Kirsch, 2009)

On the other hand, the structural analysis of wind turbine blades provides an overview of the blade's actions, it is still essential to understand the blade's failure limitations. It also explains how it could go wrong. For this purpose, various research papers have been studied which are mentioned in the section given below.

II. Literature Review

(Shah and Tarfaoui, 2016) said that the wind turbine blades are complex structures in terms of their geometry and the materials used. They need to be modelled, on the one hand as accurately and precisely as possible, while on the other hand the models should be light enough to be run in a reasonable amount of time using reasonable computational resources. One of the motivations behind sub-modelling is the capacity to develop highly refined and detailed models, without using increased computational resources, as the refined model domain is small and hence has a smaller number of elements. There are different methods of sub dividing the problem domain into smaller simpler domains, of which the transfer of nodal displacement form one parent model to its child will be used in this study. Furthermore the use of surface to solid sub- models is also discussed.

(Ashuri *et al.*, 2014) presents a method for multidisciplinary design optimization of offshore wind turbines at system level. The implementation and execution that allow the rotor and tower to have integrated aerodynamic and structural design at the same time are mentioned in details. The cost of generating electricity is the target function to be eliminated. The model includes various design constraints: stresses, deflections, modal frequencies and fatigue limits along different stations of the blade and tower. Chord as well as twist distribution, blade length, rated rotational speed, and structural widths along the range are all rotor design parameters. Tower thickness and diameter as well as tower height, are tower design parameters. A representative mass model is being used to include other wind turbine components' complex interactions in the system. To calculate the system costs, representative cost models of a wind turbine located in an offshore wind farm are used. To show the potential of the method and to verify its usefulness, the 5 MW NREL wind turbine is used as a case study.

(Vasjaliya, 2013) present a “multidisciplinary design analysis optimization” (MDAO) process is defined for a composite wind turbine blade to optimize its aerodynamic and structural performance by developing a fluid-structural interaction (FSI) system. Consequently, an optimum blade design is found within the pre-defined design variable parameters and structural constraints by considering maximum power output, minimum weight, and value as prior targets. Sensitivity analysis is used to see how each input parameter affects each output parameter, allowing for better control of the MDAO process. Furthermore, a new design strategy with changed Tip (winglet) and rotor section is examined to enhance the blade's aerodynamic efficiency, and a significant increase in power produced over a high-quality baseline wind turbine blade is proposed.

(Tongguang *et al.*, 2012) evaluated that a revised NSGA-II algorithm based on a fast and genetic non-dominated sorting algorithm is made with the purpose of achieving a novel multi-objective optimization design algorithm for wind turbine blades by integrating regulated elitism and dynamic distance crowding techniques. As an example, a high-performance 1.5 MW wind turbine blade, taking maximum annual energy production and minimum blade mass as the optimization objectives, was designed. A 1/16-scale model of this blade was tested in a 12 m × 16 m wind tunnel and the experimental results validated the high performance. Furthermore, the aerodynamic efficiency was calculated using both the computational fluid dynamics (CFD) method and the free-vortex method (FVM), which was compatible with the experimental results.

(Jeong *et al.*, 2012) observed that design optimization of the wind turbine of a NREL 1.5-MW HAWT blade was studied to minimize the fluctuation of the bending moment of the blade in turbulent wind. Quick code has been used as a simulation code to measure the unsteady aerodynamic load of a wind turbine. TurbSim has been used as a turbulent wind simulator to recognize turbulent wind as the wind input model in FAST. The chord length as well as twist angle were represented using the shape modelling function for successful geometrical representation of the aerodynamic shape of a wind turbine blade. By keeping the wind turbine's necessary power constant, the out-of-plane bending moment at the blade root fluctuated as little as possible. Through the redistribution of the section force in the radial direction between both the primary and tip regions, the magnitude of the fluctuation of the out-of-plane bending moment was reduced by about 20%, and the rated power of 1.5- MW was maintained. As compared to the baseline blade, the optimised blade's local angles of attack were near the point of maximum lift-to-drag ratio in the main and tip regions. And within operating range of the wind speed, the optimised blade's fluctuating unsteady aerodynamic load was decreased.

(Eke and Onyewudiala, 2010) presents a design tool for optimizing wind turbine blades. The research focuses on tuning the blades of wind turbines in order to maximise their energy yield. The shape variables of the chord, twist, and relative thickness of the blade are the design variables. Two wind turbines of various sizes were analysed using a genetic algorithm to demonstrate the optimization technique. The reported results are in good agreement with other published findings.

(Lee and Chae, 2008) evaluated the effects of squealer rim height on the three-dimensional flow and aerodynamic loss downstream of a high-turning turbine rotor blade for a typical tip gap-to-chord ratio, h/c, of 2.0%. The squealer rim height-to-chord ratio is changed to be hst/c = 0.00 (plane tip), 1.37%, 2.75%, 5.51%, and 8.26%. Major findings are summarized as follows:

- As hst/c increases, the tip leakage vortex tends to be weakened, and the interaction between the tip leakage vortex and the passage vortex becomes less severe.
- With the increment of hst/c, the mass-averaged total-pressure loss coefficient decreases noticeably meanwhile the mass-averaged profile loss coefficient remains almost unchanged.
- The aerodynamic loss reduction by increasing hst/c is limited only to the near-tip region within a quarter of the span from the casing wall.

(Jureczko and Pawlak, 2005) examined that the aerodynamic profiles of wind turbine blades have crucial influence on aerodynamic efficiency of wind turbine. However, when blades are longer than 45m the dynamic behavior of the blade must be also taken into account. Then, the position and shape of spars have to be considered and analyzed. The location of the main spar together with the location of the stiffening ribs will have the biggest influence on the bending modes of the blade. The model of blade is made of shell elements were used in multi-criteria optimization procedure. The blade is to be twisted around the elastic axis. The position of elastic center can be changed by modifying the position of spars and its shape. The solid model of the blade is created in order to obtain required properties of the blade and position of spars.

(Fuglsang and Madsen, 1999) analyzed that majority of wind turbine blades is made of fiberglass reinforced with polyester or epoxy resin. Construction using wood–epoxy or other materials also can be found. Small turbine blades are made of steel or aluminum, but they are heavier. Lighter and more effective blades decrease material requirements for other wind turbines component making overall costs to be lower. Longer blades require another materials to be applied, usually carbon-based composites. Carbon fiber composites allow to lower blade's mass (from 20 to 18 T at 61.5m long blade). Carbon-based composites allow also reconstructing older blades made of fiberglass reducing mass and increasing its stiffness. However, use of carbon materials requires increased accuracy and makes manufacturing costs to be higher.

Table 1. Design of turbine blade in previous study

Authors Name & Year	**Study Area**	**Design**

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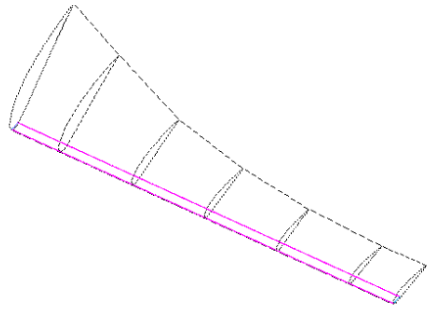
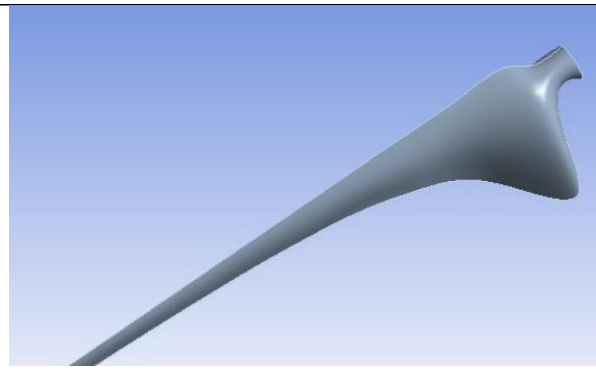
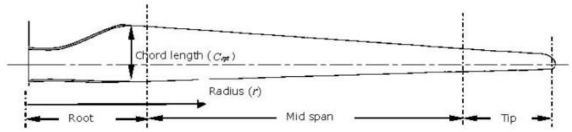
(Wang *et al.*, 2016)	To analyse vibration model characteristics Based on the three-dimension modelling of the wind turbine blade with MRF sandwiched	
(Kumar, Nageswara Rao and Farooq, 2016)	To find out better material for blade manufacturing	
(P.Premalatha and S.Rajakumar, 2016)	The main objective of this research is to analyse the effect of winglets in horizontal axis wind turbine	
(Schubel and Crossley, 2014)	Aim is to find out best design for wind turbine blades	
(Schubel and Crossley, 2012)	A detailed review of the current state-of-art for	

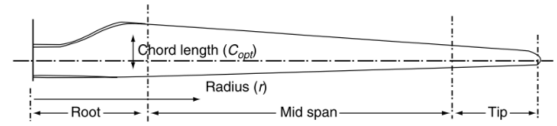
	wind turbine blade design	

Table 2. Parameters of analysis wind turbine in previous study

Authors Name & Year	**Study Area**	**Outcome**
(Wang *et al.*, 2016)	smart wind turbine blade with magnetorheological fluid (MRF) sandwiched	MRF should not be arranged in the middle of wind turbine blade. The best position of MRF is at the root of the wind turbine blade, which can avoid torsion vibration occurring in advance.
(Kumar, Nageswara Rao and Farooq, 2016)	Improve the wind turbine performance the blade material is being changed from epoxy glass to epoxy carbon.	From strength and stiffness point of view Epoxy carbon materials performing better than the other material
(P.Premalatha and S.Rajakumar, 2016)	NACA 63215 airfoil profile used in the root section modified NACA 63(2)215 airfoil used in the mid section and NACA 63415 airfoil used in the tip section of the rotor blade	According to the results obtained from the analysis program, the best winglet angle is 80 degree because the pressure around this winglet is less whereas velocity is high.
(Sarathi *et al.*, 2015)	analyses the performance of a wind turbine under accelerating and decelerating air inlet velocity. A Horizontal-Axis Wind Turbine (HAWT) blade with 10,000 Watt power output has been designed	

III. CONCLUSION

This paper proposes a method for optimizing wind turbine blades that combines both aerodynamic and structural factors. In low-wind environments, the blade's aerodynamic efficiency and structural performance are also enhanced. This method focuses on the airfoils, the essential factors of the wind turbine blades. Therefore, this study will help in structural optimization of wind turbine blade which has the potential to improve the overall performance of the blade and decrease the aerodynamic loads.The structural optimization method used can be improved using more structural theory models similar to classical lamination theory, linear (eigenvalue) buckling theory and also some in depth finite- element model analysis. After studying the above mentioned literature reviews, it can be concluded that:

- Many software are used for designing of blade such as solid works, CATIA, CREO. CATIA is most appropriate among these for this design because of its simple and useful interface and proper commands.

- FEM analysis is done on ANSYS software to find out load distribution and quality of blade design with appropriate boundary conditions.
- Material selection is also an important part in designing of blade, some materials used in previous studies are Structural steel, Stainless steel, Titanium Alloy, Aluminium Alloy, T-Graphite Epoxy.
- According to (Sarathi *et al.*, 2015), Horizontal axis wind turbine(HAWT) is more efficient as compare to vertical axis wind turbine(VAWT).
- (P.Premalatha and S.Rajakumar, 2016) suggested that it is important to select proper National Advisory Committee for Aeronautics (NACA) profile for design of blades, some of the NACA profiles used for designing are :- NACA 4420, NACA 4420, SG6042, SG4043.
- Blade element momentum theory is used in some cases for determining local forces on wind turbine blades, with this theory we can calculate the effect of forces on blades and we can resign our blade profile according to results shown by BEMT.

REFERENCES

Alaoui, R. El *et al.* (2018) 'Investigation and Analysis of Static and Dynamic Behaviour of a New Natural Composite Material of a Wind Turbine Blade Using the Finite Element Method', 8(4).

Ashuri, T. *et al.* (2014) 'Multidisciplinary Design Optimization of Offshore Wind Turbines for Minimum Levelized Cost of Energy', pp. 1–24.

Beauson, J. and Brøndsted, P. (2016) 'Wind Turbine Blades : An End of Life Perspective Wind Turbine Blades : An End of Life'. doi: 10.1007/978-3-319-39095-6.

Eke, G. B. and Onyewudiala, J. I. (2010) 'Optimization of Wind Turbine Blades Using Genetic Algorithm', 10(7), pp. 22–26.

Fuglsang, P. and Madsen, H. A. (1999) 'Optimization method for wind turbine rotors', *Journal of Wind Engineering and Industrial Aerodynamics*, 80, pp. 191–206.

Jeong, J. *et al.* (2012) 'Design optimization of a wind turbine blade to reduce the fluctuating unsteady aerodynamic load in turbulent wind †', 26(3). doi: 10.1007/s12206-011-1106-4.

Jureczko, M. and Pawlak, M. (2005) 'Optimisation of Wind Turbine Blades Optimisation of wind turbine blades', *Journal of Materials Processing Technology*, (August). doi: 10.1016/j.jmatprotec.2005.06.055.

Kirsch, M. J. (2009) 'DESIGN OF A SMALL WIND TURBINE FOR ELECTRIC POWER GENERATION (1-5kW)', (November).

Kumar, V. M., Nageswara Rao, B. and Farooq, S. (2016) 'Modeling and analysis of wind turbine blade with advanced materials by simulation', *International Journal of Applied Engineering Research*, 11(6), pp. 4491–4499.

Lee, S. W. and Chae, B. J. (2008) 'Effects of squealer rim height on aerodynamic losses downstream of a high-turning turbine rotor blade', *Experimental Thermal and Fluid Science*, 32, pp. 1440–1447. doi: 10.1016/j.expthermflusci.2008.03.004.

Mathew, S. (2006) *Sathyajith Mathew Wind Energy Fundamentals, Resource Analysis and Economics*.

P.Premalatha and S.Rajakumar (2016) 'CFD ANALYSIS OF THE SMALL HORIZONTAL AXIS WIND TURBINE BLADE WITH AND WITHOUT', *International Journal of Advances in Engineering Research*, 11(6), pp. 38–46.

Sarathi, Y. *et al.* (2015) 'Study on Wind Turbine and Its', *Int. J. Mech. Eng.*, 4(1), pp. 249–256.

Schubel, P. and Crossley, R. (2014) 'Wind Turbine Blade Design', *Wind Turbine Technology*, (August), pp. 1–34. doi: 10.1201/b16587-3.

Schubel, P. J. and Crossley, R. J. (2012) 'Wind turbine blade design', *Wind Turbine Technology: Principles and Design*, 36(4), pp. 1–34. doi: 10.1201/b16587.

Schubel, P. J. and Crossley, R. J. (2015) 'Wind Turbine Blade Design', (August 2012). doi: 10.3390/en5093425.

Shah, O. R. and Tarfaoui, M. (2016) 'The identi fi cation of structurally sensitive zones subject to failure in a wind turbine blade using nodal displacement based fi nite element', *Renewable Energy*. Elsevier Ltd, 87, pp. 168–181. doi: 10.1016/j.renene.2015.09.065.

Tongguang, W. *et al.* (2012) 'Large-scale wind turbine blade design and aerodynamic analysis', 57(5), pp. 466–472. doi: 10.1007/s11434-011-4856-6.

Vasjaliya, N. G. (2013) 'Fluid-structure Interaction and Multidisciplinary Design Analysis Optimization of Composite Wind Turbine Blade FLUID-STRUCTURE INTERACTION AND MULTIDISCIPLINARY DESIGN ANALYSIS OPTIMIZATION OF COMPOSITE WIND TURBINE BLADE by Embry-Riddle Aeronautical Univ'.

Wang, H. *et al.* (2016) '2165. Finite element analysis of smart wind turbine blades sandwiched with magnetorheological fluid', *Journal of Vibroengineering*, 18(6), pp. 3858–3868. doi: 10.21595/jve.2016.16802.