# Accepted Manuscript


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PII: S1359-8368(18)32575-7

DOI: 10.1016/j.compositesb.2018.09.028

Reference: JCOMB 5998

To appear in: *Composites Part B*

Received Date: 12 August 2018

Revised Date: 7 September 2018

Accepted Date: 13 September 2018

Please cite this article as: Deng XW, Wu N, Yang K, Chan WL, Integrated design framework of next-generation 85-m wind turbine blade: Modelling, aeroelasticity and optimization, *Composites Part B* (2018), doi: https://doi.org/10.1016/j.compositesb.2018.09.028.

# Integrated design framework of next-generation 85-m wind turbine blade: modelling, aeroelasticity and optimization

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ABSTRACT

The National Energy Administration of China has promoted the use of wind energy to replace the conventional fossil energy, which provides an inexhaustible and eco-friendly alternative to the increasing energy demand. 10-MW wind turbine is the next-generation turbine with 85-m blade length, which poses great challenges in the engineering design, manufacturing, transportation, installation and maintenance. The paper aims to establish a numerical framework that integrates 3D full-scale modeling, analysis and parametric optimization. Isogeometric Analysis (IGA) enables seamless integration between structural modeling and computational analysis by using NURBS as basis functions. Aerodynamic forces and rotor power of blade subject to wind will be obtained by FAST. The Kirchhoff-Love shell element will be employed for 3D blade modeling to reduce rotational degrees of freedom and alleviate shear locking. The integrated framework residing within Rhino-based Grasshopper will be performed to model and analyze the wind turbine. Parametric optimization using pattern search algorithm targets at a family of turbines that satisfies the Tsai-Wu failure criterion and deformation constraint. The framework is deployed on a 10-MW turbine blade based on the initial design upscaled from the NREL 5-MW baseline model. The optimal blade design with shear webs has gained 20.9% improvement in performance.

## 1 INTRODUCTION

Over the past decades, people have heavily relied on the conventional fossil resources including oil, coal and natural gas, which supply over 80% of energy needs. As the largest source of global greenhouse gas (GHG) emission, it not only brings global warming but also leads to catastrophic consequences such as hurricane, glacier melting and sea level rise. Therefore, the energy system is steered onto a pathway converted to the renewable energy resources.

Currently, wind power plays the leading role in the transition away from fossil fuels and continuously blows away the competition on price, performance and reliability. According to statistics shown in Zheng, et al.(2016), the cumulative capacity of global offshore wind energy in 2014 is 8759MW, and most of the offshore wind installations (91%) are in European waters, especially in the North Sea (5094MW, occupy 63.3%). In China, the offshore wind power installed capacity keeps growing. In accordance with the wind energy development goals made by Chinese National Energy Administration, as reviewed in Da, Z. (2011), offshore wind power installed capacity will reach 20GW, 40GW and 100GW in 2020, 2030, 2050 respectively. The ambitious wind energy goals put pressure on wind turbine design and manufacturing as well as bring the demand of enhancing wind power capacity while reducing the costs. More importantly, when the blade length is increased by a scale factor, the rotor power will grow quadratically; however, the mass and the tip moment due to the aerodynamic load will grow even faster, at the