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A New Wind Turbine Blade Optimisation Framework

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Incrementally increasing the size of wind turbine rotors in order to harness more energy has been the primary approach employed to reduce the cost of wind energy[1]. The rates at which design driving fatigue and extreme loads increase with rotor size are, however, greater than the rate of increased energy capture. Up-scaling older technology is, as a result, not an economically viable solution and designers must continually balance this power to load trade-off as wind turbines become larger[2]. The evolution of wind turbines has mostly been incremental and laminates have generally been limited to quasi-isotropic layups in the absence of rapid means of exploring the full design space provided by composite materials. By contrast, a composite parameterisation based on lamination parameters is employed in this work in order to enable the rapid and robust exploration of the structural blade design space and possibly lead to more cost effective blade designs.

We propose a framework for investigating new blade design concepts, employing optimisation as a means to explore the uncharted design space resulting from decades of incremental evolution. The aim of the developed framework is to provide a single design and optimisation tool which compactly describes the variations of structural properties along the blade span while also computing cross-sectional and beam properties, and performing aero-servo-elastic analyses. In addition to a standard BEM aerodynamic solver, the proposed framework relies on a compact and continuous parameterisation of the blade structures in order to enable gradient-based optimisations. This parameterisation based on lamination parameters and B-spline surfaces, as illustrated in Figure 1, replaces the heavy and cumbersome standard approach relying on laminate stacking sequences while also offering great tailoring capabilities. The spline surfaces are then used to generate beam and shell finite element (FE) models of the blades. A specific beam model was also developed in order to capture the main structural couplings (e.g. bend-twist) and cross-sectional property variations along the element length[3].

At the present time, the blade structural parameterisation and FE models have been verified against the DTU 10MW blade[4], giving us confidence that conventional blade designs can be successfully reproduced[5]. We have also begun investigating the potential benefits of geometric (i.e. induced by sweep) and material bend-twist coupled blades for large rotors, employing a 7MW wind turbine model provided by DNV-GL as a case study. A full aero-servo-elastic optimisation of this concept is due to be performed later this year.

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[1] Ho, Andrew, and Ariola Mbistrova. The European offshore wind industry-key trends and statistics 1st half 2015." A EWEA report.
[2] Sieros, G. et al., 2012. Upscaling wind turbines: theoretical and practical aspects and their impact on the cost of energy. Wind energy.
[3] Macquart, T. et al., 2017. A Finite Beam Element Framework for Variable Stiffness Structures. In 25th AIAA Adaptive Structures
[4] Bak, C. et al., 2013. The DTU 10-MW reference wind turbine. Danish wind power research.
[5] Macquart, T. et al. 2017. A New Optimisation Framework for Investigating Wind Turbine Blade Designs. In 12th World Congress on Structural and Multidisciplinary Optimization

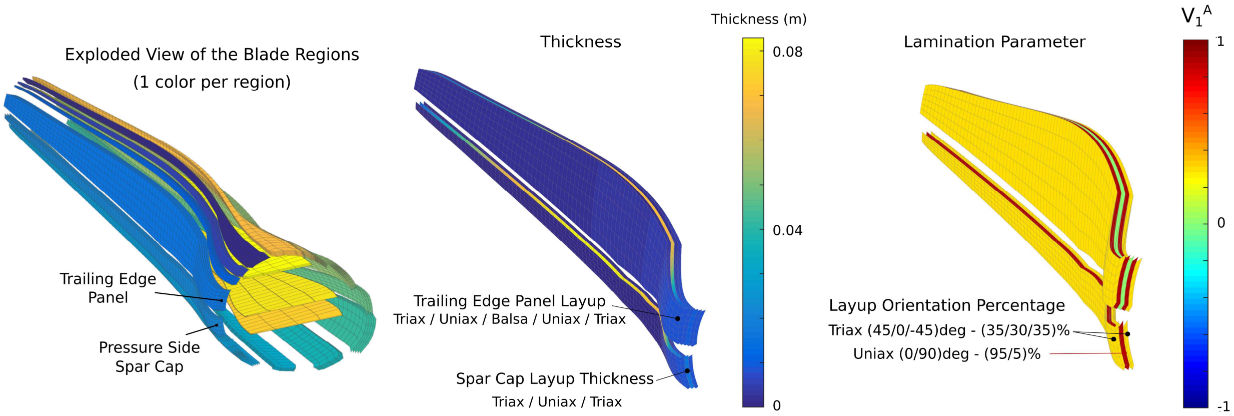

Figure 1: Exploded view of the DTU 10 MW blade and continuous structural parameterisation based on spline surfaces