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A Computational Framework for Structural and Fatigue Analysis of a 5MW Wind Turbine Blade Under Wind Loads

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With the pressing requirement of wind energy capacity, the wind turbine blade size has been getting larger and larger in recent decades. For such a large-size blade, it is of prime importance to accurately evaluate the mechanical response under various wind loading conditions. In this work, we present a computational framework to achieve this end. Firstly, a finite element model for a 5MW blade is established according to the well-known NREL report. A composite laminated element is adopted to describe the blade structure. The effectiveness of this model is validated by means of eigenfrequency analysis. Secondly, a one-way partitioned FSI coupling algorithm is developed to consider the wind loading condition applied on the blade surface. The coupling algorithm facilitates the use of two parallel open source codes, e.g., FrontFlow/blue and ADVENTURE. Finally, an empirical approach is adopted to estimate the fatigue life of the blade under wind loads. This approach uses the so-called rainflow counting algorithm to reduce a spectrum of varying stress to equivalent stress cycles with constant amplitude. The remaining service life of the blade is then estimated by means of the Goodman diagram and the Miner's damage accumulation law. Several numerical cases are carried out, which validates the capacity of the proposed computational framework for structural and fatigue analysis of wind turbine blades under various wind loads.

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