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# HIGH-FIDELITY 1D AND 2D MODELS FOR STATIC AND DYNAMIC ANALYSES OF WIND TURBINE ROTOR BLADES

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## ABSTRACT

Wind energy is an essential renewable source to tackle the most critical environmental problems, such as global warming. Recently, the wind blade size has been increasing to maximize turbine efficiency. However, increased dimensions lead to further design challenges due to severe loadings - inertial and aerodynamic - and unavoidable manufacturing complexities. Therefore, extensive simulation campaigns covering as many operational conditions as possible become crucial for sustainable design and manufacturing. Various numerical tools for this purpose have been proposed to predict the response and damage levels of sizeable composite wind turbine blades. Within this context, this paper presents results based on the Carrera Unified Formulation (CUF) on various blade configurations. The CUF is a hierarchical formulation providing classical and higher-order beam, plate, and shell models using arbitrary kinematic expansions. The one-dimensional (1D) and two-dimensional (2D) CUF-based models can ensure a similar accuracy of three-dimensional (3D) solutions with considerable savings in computational efforts. The principle of virtual work and a finite element approximation is used to formulate both geometrically linear and nonlinear governing equations. The numerical results focus on static, dynamic, and failure analyses performed on composite wind turbine blades. The failure index evaluation uses a global/local approach that combines the CUF models with conventional FE solutions. In addition, future challenges related to health monitoring, damage detection, and developing a digital twin for structural verification will be discussed.

**Keywords:** Wind turbine rotor blade; Structural analysis; Finite element method; Carrera Unified Formulation; Refined models; Composite; Geometrical nonlinearity.