Project: Variable Kinematics Continuum Finite Element for Modelling Wind Turbine Blades

Key focus: An efficient method to capture local displacement and stress in wind turbine blades

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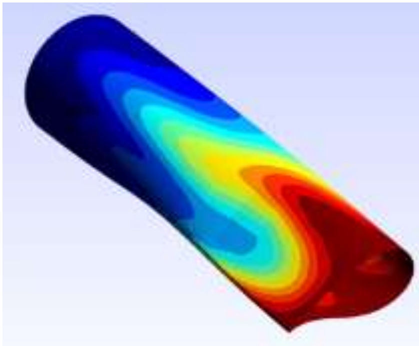
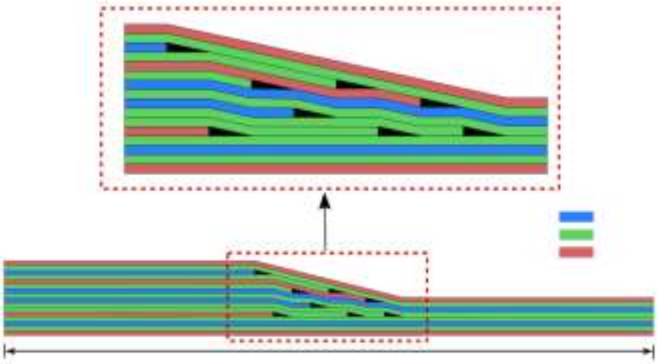
Background



Wind turbine blades use composite materials and tailored geometries to meet stringent weight and efficiency requirements. Such structures are slender, thin-walled and include variable-thickness semi-monocoque shells. These features compound to make stress/strength analyses both cumbersome and expensive. Accurate estimation of stress distributions in such structures is essential for predicting failure initiation and propagation. At early design iterations, one-dimensional and two-dimensional finite element models are employed for efficiency. However, their capabilities are limited to describing global, stiffness-driven, behaviour. Recovering local features, such as through-thickness transverse stresses or displacement field gradients close to singularities are addressed at later stages of the des ign process by treating the structure as a three-dimensional (3D) continuum. An approach that is challenging, as cases could require modelling hundreds of composite layers. There is a need to develop an efficient mathematical method that can capture salient displacement and stress features in structures for incorporation into early-stage design iterations.

Project description

We have developed a variable kinematics modelling approach that builds upon the hierarchical Serendipity Lagrange finite elements. This approach can predict accurate 3D stress fields with reduced computational effort, including local features such as geometric, kinematic or constitutive boundaries. The model can analyse multi-layered composite structures either by adapting global approximation theories based on Equivalent Single-Layer (ESL) approaches or by employing discrete-layer approximation theories based on Layer-Wise (LW) approaches, and can switch between these approaches depending on the desired level of accuracy. The global response (i.e. nonlinear deflection) of the structure is captured by an ESL model, while the root, where transverse stresses are significant and can cause delamination failure, is modelled using the LW approach.



The goal of this project is to extend this methodology, towards an adaptive multi-scale model for turbine blades, eliminating the need to perform a separate global/local analysis. This approach, in the first iteration, the global response of the entire structure is predicted by employing the ESL model. In subsequent iterations, based on the modelling error, hot-spots are identified and the kinematic fields in these regions are varied following an adaptive strategy, either by increasing the expansion order or by mesh discretisation until all plies in that region are explicitly modelled. Thus, different level of responses can be obtained. This framework can serve as a model for an optimization framework.

Research outcomes/impact

To fine-tune the performance of next-generation wind turbines, the integration of efficient computer simulations early in the design process is essential to improve the product design.

Project Sponsorship:

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