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Physical-data driven hybrid modelling for structural optimization of buckling resistance of wind turbine blades bio-inspired by beetle elytron

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ABSTRACT

Wind turbine blades, designed as sandwich structures, are susceptible to compressive buckling [1,2], due to Brazier effect caused by the curvature that arises from flap-wise bending deformations [3,4]. This study, therefore, introduces a beetle elytron-bioinspired trabecular core, featuring thin-walled cylindrical trabeculae with lateral supports and end's chamfers, providing superior compressive performance over conventional web cores [5]. However, there has been a lack of study on optimizing the parameters in terms of compressive strength (σ_u) of trabecular cores. Three trabecular-related dimensionless parameters are introduced: the ratio of trabecular radius to cellular length (η), chamfer radius to trabecular radius (ξ_t) and core height to core thickness (β), which have been incorporated into 32 sets of coupon test, revealing that local buckling is the preferred mode. Due to the complex relationships between these parameters, a physical-data driven hybrid modelling is used to establish optimization functions. The physical condition, preference for local buckling in trabecular cores, guides the derivation of the buckling mode critical function $\phi(x)$, which is adapted from that of comparable cylindrical shells; and the boundary constraint coefficient (x) of trabecular cores is then determined using a data-driven predictive model trained on test results. The optimization results are validated through experimental data and numerical models, which are employed to identify the optimal combination of trabecular-related parameters with various radius-to-thickness ratio (D) for the sectional design of trabecular cores in wind turbine blades.

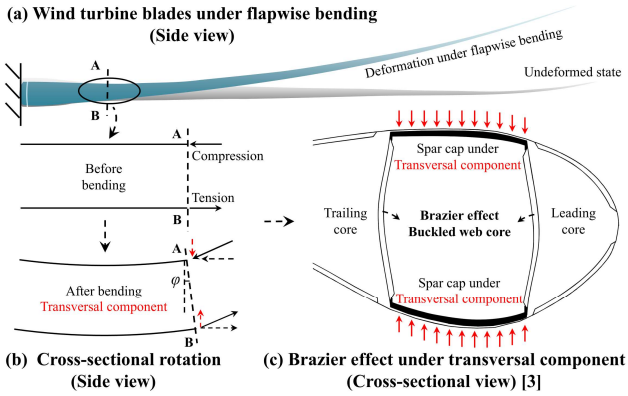

Figure 1: Wind turbine blade and its mechanical analysis model under Brazier effect.

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