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Structural Analysis and Optimization of an Airborne Wind Energy System

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For pumping cycle airborne wind energy systems, the airborne mass of the system plays a crucial factor in the performance of the system[1]. This is especially pronounced during low-wind conditions, where the additional force component to overcome gravity is more pronounced in comparison to the aerodynamic forces. Additionally, the airborne mass also affects the take-off speed, thus further influencing the site-specific Levelized Cost of Electricity (LCOE) of the system.

For rigid as well as semi-rigid kites, it is essential to analyse and model the structure of the kite right from the initial design stage, especially given the load couplings commonly witnessed in composite structures. Complete 3D finite element analysis of such composite structures is computationally expensive, and thus uncommon in the initial design stage. However, oversimplified structural models, such as simple uniform and isotropic beams do not capture the intricacies of composite structures and either lead to too optimistic or too pessimistic results, depending on the material assumptions.

An approach to capture the anisotropic coupling effects, which are important for an accurate estimate of composite structure deflections is described here. The main load-bearing member of the structure - the wing box, is modelled as a slender composite beam. The 3D composite shell problem is solved by determining the complete anisotropic 2D cross sectional stiffness, which is then utilised in a 1D beam analysis.

This approach serves to reduce the 3D problem to a 2+1D finite elements problem which is computationally fast, while being sufficiently accurate for initial design. This structural model is then utilised to minimise the weight of the composite wing box, by optimising the internal geometrical shape and orientations of the composite ply fibre.

References:

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