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Fast Aeroelastic Model of a Leading-Edge Inflatable Kite

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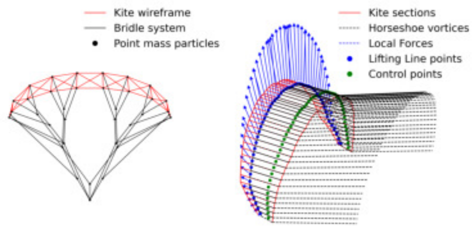
When designing an airborne wind energy system, it is necessary to be able to estimate the traction force that the kite produces as a function of its flight trajectory. Being a flexible structure, the geometry of a soft kite depends on its aerodynamic loading, and vice versa, which forms a complex Fluid-Structure Interaction (FSI) problem. Currently, kite design is usually done on an experimental basis, since no model meets the requirements of being accurate and fast at the same time.

In this project, an FSI methodology is developed to study the steady-state aerodynamic performance of leading-edge inflatable (LEI) kites by coupling two fast and simple models.

On the structural part, the deformations are calculated with a particle system model [1], based on the assumption that the shape of the kite can be modeled using a wireframe wing model represented by the bridle line attachment points, whose coordinate changes are modeled using a bridle line system model and canopy ballooning relations.

On the aerodynamic side, the load distribution is calculated with a 3D nonlinear vortex step method [2,3], coupled with 2D polars obtained with a correlation model derived from CFD data [4], to account for viscous effects and flow separation, as well as the changes in airfoil geometry. Based on 2D thin airfoil theory, the 3/4c point is used to determine the magnitude of the forces and the 1/4c point is used to determine direction of these forces. Moreover, the model developed for LEI kites is capable of taking into account ballooning and variations in kite and airfoil geometry, while proving to be robust and inexpensive. This model has been validated with several geometries, together with a RANS analysis of the LEI kite, showing great accuracy for pre-stall angles of attack.



Particle system model representation (left), vortex step model discretization example (right).

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