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Ram-Air Kite Reinforcement Optimisation for Airborne Wind Energy Applications

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Ram-air kites are made of thin coated woven fabric and are attractive for the airborne wind energy industry due to their low weight and easy storage ability. The aerodynamic load is transferred from the top canopy through the ribs into the bridle system causing high stresses on the ribs. In order to spread the load as equally as possible, reinforcements are added on the ribs which also sustain the airfoil shape. The most common reinforcement strategy is to simply sew additional fabric onto highly stressed locations of the ribs. For the kite designer one of the challenges is to find a balance between the right amount and orientation of reinforcements, and the extra weight added to the structure.

In this study the layout of a rib reinforcement used in ram-air kites is expressed as an optimization problem. The objective is to find an optimum reinforcement layout such that the deformation of the rib is minimized. Also, the force from the kite acting on the tether is included into the expression and should be maximized, leading to a multidisciplinary optimization (MDO).

For simplicity, the optimization is initially done in a two-dimensional analysis of the flow and structure. To obtain the aerodynamic pressure acting on the rib the panel method software XFOIL [1] is utilized. The resultant deformations are computed with the finite element method which takes the position of the reinforcements into account, augmenting the element's stiffness based on [2]. Finally the optimum layout is found with a gradient based optimization method.

The optimization is easily extendable to 3D which will eventually yield a more realistic load case acting on the rib structure due three-dimensional flow effects. Also the inflated kite structure in three dimensions behaves considerably different due to the curvature of the canopy.

References:

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