Jelle Poland

MSc Student
Delft University of Technology
Faculty of Aerospace engineering
Wind Energy Group

Kluyverweg 1
2629 HS Delft
Netherlands

jellepoland@gmail.com
kitepower.tudelft.nl

Modelling Aeroelastic Deformation of Inflatable Membrane Kites

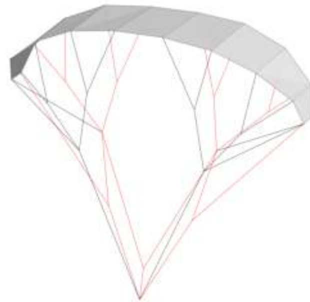
Jelle Poland, Roland Schmehl
Delft University of Technology

A fast design tool that allows shape optimization can increase aerodynamic performance and hence the energy production of airborne wind energy systems. Most membrane kite design tools are too computationally expensive or not accurate enough. Deformations occur at large and are relevant because they substantially change the aerodynamic characteristics [1]. Asymmetric actuation twists the kite, which contributes to its ability to turn. Symmetric actuation bends the wing in spanwise direction, thereby changing the generated aerodynamic force.

The tubular frame of the V3 kite of TU Delft is fully bridled on both the leading and trailing edges [1]. Therefore, the deformation is regarded as caused by the changing geometric layout of the bridle line system. The line attachment points form a wireframe representation of the wing, consisting of nine plates. Each plate has three edges of constant length, each being a rigid representation of a tube segment. The plate models have varying trailing edge lengths when including the effect of canopy billowing. A photogrammetry analysis provided kite width change for different symmetrical actuation settings and empirical relations, used to model canopy billowing.

We developed a particle system model (PSM), in which each bridle line connection is represented by a point mass. The particles at the plate corner points are subject to a discrete aerodynamic force, which is scaled based on the respective plate width and local angle of attack. The aerodynamic force is balanced by the spring and damper forces of the bridle line system, plate edges and plate diagonals. For asymmetric actuation, the orientation-based aerodynamic force scaling leads to the required dynamic stabilization.

The PSM can predict the change in width due to symmetrical actuation within, on average, 1% of the experimentally obtained width. Due to its accuracy, relatively low-computational cost and ability to predict both main deformation modes, the PSM is considered an excellent building block towards the development of next-generation design models.



The PSM for a fully powered kite. Red lines are bridles attached to the trailing edge and black to the leading edge.

References:

[1] Oehler, J. and Schmehl, Aerodynamic characterization of a soft kite by in situ flow measurement. Wind Energy Science (4), 1-21 (2019)