



Delft University of Technology

## Steady-State Solver for a Ram-Air Kite Aeroelastic Model Based on Dynamic Relaxation

Thedens, Paul; Bungart, Merlin; Schmehl, Roland

### Publication date

2019

### Document Version

Final published version

### Citation (APA)

Thedens, P., Bungart, M., & Schmehl, R. (2019). *Steady-State Solver for a Ram-Air Kite Aeroelastic Model Based on Dynamic Relaxation*. 131-131. Abstract from 8th international Airborne Wind Energy Conference (AWEC 2019), Glasgow, United Kingdom.

### Important note

To cite this publication, please use the final published version (if applicable).

Please check the document version above.

### Copyright

Other than for strictly personal use, it is not permitted to download, forward or distribute the text or part of it, without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license such as Creative Commons.

### Takedown policy

Please contact us and provide details if you believe this document breaches copyrights.

We will remove access to the work immediately and investigate your claim.

*This work is downloaded from Delft University of Technology.*

*For technical reasons the number of authors shown on this cover page is limited to a maximum of 10.*

*Computer rendering of the Skysails Power 200 kW AWE system*



*Skysails Power 200 kW AWE system in operation as rendering (left) and in the workshop (11 September 2019)*





**Paul Thedens**

Skysails Power GmbH  
Research & Development

Luisenweg 40  
20537 Hamburg  
Germany

paul.thedens@skysails.de  
[www.skysails.info](http://www.skysails.info)

**SkySails**  
POWER

**AWESCO**  
Airborne Wind Energy  
System Modelling, Control & Optimization

## Steady-State Solver for a Ram-Air Kite Aeroelastic Model Based on Dynamic Relaxation

Paul Thedens<sup>1,2</sup>, Merlin Bungart<sup>1</sup>, Roland Schmehl<sup>2</sup>

<sup>1</sup>Skysails Power GmbH

<sup>2</sup>Delft University of Technology

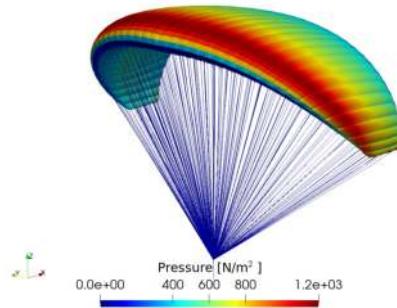
We present a computationally efficient steady-state solution method to model the aeroelastic deformation of a ram-air kite for airborne wind energy applications. The kite's weight in comparison to the aerodynamic forces is small which justifies a quasi-steady analysis, neglecting gravitational and inertial force effects [1]. The approach is suitable to efficiently determine the deformed configuration of a ram-air kite for design and optimization purposes as found in [2]. Because of the expected large deformations and changes in the flow field, fluid-structure interaction has to be taken into account in the analysis.

Ram-air kites have been modeled in the past using explicit time integration, such as in [3], to study transient flight behavior and maneuvers. At SkySails Power we aim to model the steady-state for specific angles of attack using dynamic relaxation (DR) by finding the equilibrium state between flow and structure. The steady-state solver ignores transient effects and therefore dramatically reduces computation time.

The kite's deformations are computed with the finite element method. Membrane elements with a non-compression and orthotropic material model are used for the canopy, and the bridle system is modeled using cable elements. The aerodynamic forces are computed with a 3D inviscid panel method which allows a fast pressure field computation.

The solver is used to determine the deformed shape and forces acting on the kite's structure during flight and can

be used for geometric parameter optimization.



Deformed ram-air kite under pressure load determined by fluid-structure interaction.

### References:

- [1] R. van der Vlugt, et al., Quasi-steady model of a pumping kite power system., *Renewable energy* 131 (2019): 83-99.
- [2] P. Thedens, et al., Ram-air kite airfoil and reinforcements optimization for airborne wind energy applications., *Wind Energy* 22.5 (2019): 653-665
- [3] R. Flores, E. Ortega, E. Oñate, Simple and efficient numerical tools for the analysis of parachutes, *Engineering Computations*, Vol. 31 Issue: 5, pp.957-985, 2014.