Wake Model for Kites in Airborne Wind Energy

Supervisors: Roland Schmehl, Oriol Cayon
Email: r.schmehl@tudelft.nl
MSc Track: SET – Aerodynamics & Wind Energy, EWEM
Keywords: *airborne wind energy, vortex methods, kite dynamics, wake modeling, lifting-line theory*

Background

Airborne Wind Energy (AWE) systems generate power by flying tethered kites in cyclic crosswind trajectories. These motions shed vorticity into the flow, forming a wake similar in nature to that of conventional wind turbines. However, due to the high variability and maneuverability of kite trajectories, classical turbine wake models are not directly applicable.

Problem Description

Existing quasi-steady models for kite flight can capture aerodynamic forces but do not resolve the wake field in space and time. For applications such as airborne wind energy or ship propulsion, a mid-fidelity wake model is required that can represent the history-dependent flow field generated by an unsteady flight path. This model should be adaptable to any flight pattern the kite flies, including figure-eight trajectories and circles.

Main Objective

The goal of this thesis is to develop a mid-fidelity wake model for tethered kites based on vortex methods. The work builds on an existing lifting-line-inspired vortex-step model already validated for single kites [1]. The student will extend this model to include a discretized free wake that evolves in time and space, allowing the simulation of wakes produced by arbitrary periodic trajectories. The resulting framework should be compatible with quasi-steady flight simulations and enable visualization and analysis of the wake structure. An engineering model of the induction of kite power systems was presented in [2].

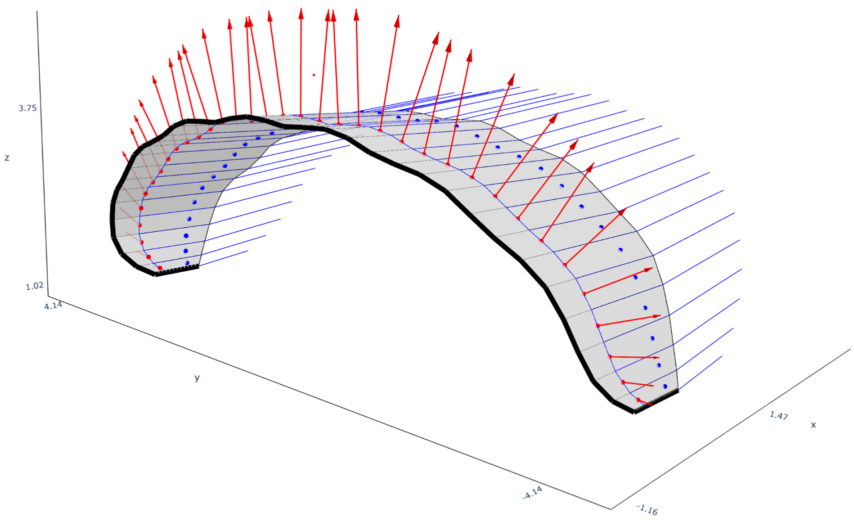

Figure 1: Caption

Tasks

- Review existing vortex models and wake shedding strategies
- Extend the current lifting-line model to track wake elements along a 3D trajectory
- Implement a discretized wake structure (e.g. free vortex filaments or panels)
- Simulate representative flight trajectories and visualize the resulting wake fields

- Analyze wake features such as coherence, length, and interaction potential

Preferred Background

Strong programming skills (preferably Julia or Python), and a solid understanding of aerodynamics. Prior exposure to lifting-line theory or vortex methods is highly beneficial.

References

[1] Oriol Cayon, Mac Gaunaa, and Roland Schmehl. "Fast Aero-Structural Model of a Leading-Edge Inflatable Kite". In: *Energies* 16 (Mar. 2023), p. 3061. DOI: 10.3390/en16073061.

[2] U. Mac Gaunaa et al. "An engineering model for the induction of crosswind kite power systems". In: *Journal of Physics: Conference Series* 1618 (2020), pp. 1–12. DOI: 10.1088/1742-6596/1618/3/032010.