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Improving Lifting-Line/Vortex-Step Methods for Kite Applications Using 2D Unsteady Thin Airfoil Theory Results

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Fast and efficient aerodynamic models are needed in AWES to optimize the aircraft design and optimize the control and operation. Lifting line models are attractive due to the balance between fidelity and computation efficiency. However, care is needed since a flawed implementation, used in optimization, can lead to the algorithms exploiting numerical errors to make solutions that in reality give poor performance. Recent work for wind turbines employs lifting line methods to expand the existing engineering modelling complex with great success to include properly the effects of blade sweep and dihedral [1-3]. During this work it has proven crucial to revisit first-principles theory to "get the implementation details right". Specifically, key information has been extracted from careful analysis of unsteady 2D thin airfoil theory. This is a suitable basis for the "inner" 2D model of lifting line models.

The present work revisits the unsteady 2D thin airfoil theory framework [4] in the context of lifting line/vortex step methods for use in power-kites. The results show that this approach yields a lifting line model very similar to the aerodynamic model of Rannenberg [5]. The evaluation of the local lift is analogous, but the added benefit of the present approach is that the consistent treatment of the drag removes the need for Trefftz-plane analysis. For a straight flying wing the results from the present method are identical to those resulting from a Trefftz-plane analysis. The added benefits of the present method is that the local value of the drag along the span can be obtained as well as a consistent calculation of the drag during general unsteady motion (e.g. roll motion) of the kite. This is not possible using a Trefftz-plane analysis.

The present work show results from different implementations of Lifting Line methods found in literature compared to the present one, as well as a higher fidelity Vortex Lattice Method. Comparisons include different aspect ratios, wing dihedral and sweep.

References:

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