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A Semi-Empirical Aerodynamic Model Based on Dynamic Stall for Rigid-Framed Delta Kites during Figure-of-Eight Maneuvers

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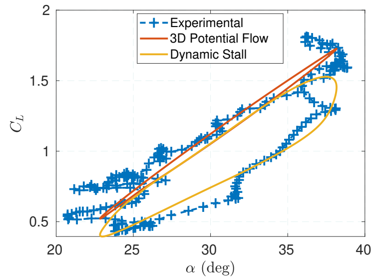
Effectively developing airborne wind energy systems requires reliable aerodynamic models. The figure shows recent experiments with a two-line rigid-framed delta (RFD) kite, revealing hysteresis in the lift and drag coefficients versus angle of attack during figure-of-eight maneuvers [1]. This might be caused by dynamic stall (DS), which is normally experienced by wings undergoing periodic pitching motions, which are naturally induced during the figure-of-eight maneuvers. This interesting phenomenon mostly affects the longitudinal aerodynamic coefficients (lift, drag and pitching moment). Pure potential flow theory captures the average value for the lift coefficient, but cannot reproduce the hysteresis [2]. This work presents a semi-empirical aerodynamic model for the RFD kite by combining unsteady potential flow theory with a dynamic stall phenomenological model. The goal is to find a model with a low computational cost to be coupled with dynamic simulators.

The study is based on a modification of the semi-empirical DS model by Leishman and Beddoes [3], involving four building blocks: i) attached flow model, ii) leading edge separation model, iii) trailing edge separation model, and iv) leading edge vortex model. For block (i) we use an in-house 3D potential flow model [4], while blocks (ii-iv) are governed by a set of dynamic equations which take as inputs longitudinal kinematics variables (angle of attack and pitching rate) and the 3D unsteady potential flow outputs from block (i). Static and dynamic viscous parameters, obtained from the literature [3] and the flight test campaign [1], respectively, are used to feed the empirical part of the model.



Experimental and numerical (potential flow and semi-empirical DS) lift coefficient during a figure-of-eight maneuver.

References:

[1] Borobia-Moreno, R., et al.: Identification of kite aerodynamic characteristics using the estimation before modeling technique. Wind Energy 24 (6), 596-608 (2021)

[2] Castro-Fernández, et al.: Three-Dimensional Unsteady Aerodynamic Analysis of a Rigid-Framed Delta Kite Applied to Airborne Wind Energy. Energies 14 (23), (2021)

[3] Boutet, J., et al.: A modified Leishman-Beddoes model for airfoil sections undergoing dynamic stall at low Reynolds numbers. JFS 93, 102852 (2019)

[4] Cavallaro, R., et al.: Amphibious Prandtl Plane: Preliminary Design Aspects Including Propellers Integration and Ground Effect. 56th AIAA/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference (2015)