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**Iván Castro-Fernández**

PhD Researcher  
Universidad Carlos III de Madrid  
Department of Bioengineering and  
Aerospace Engineering

Avda. de la Universidad. 30  
28911 Leganés, Madrid  
Spain

ivcastro@ing.uc3m.es  
aero.uc3m.es/airborne-wind-energy



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

Iván Castro-Fernández<sup>1</sup>, Rauno Cavallaro<sup>1</sup>, Roland Schmehl<sup>2</sup>, Gonzalo Sánchez-Arriaga<sup>1</sup>

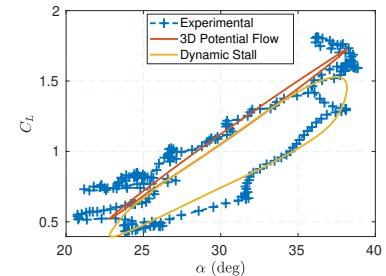
<sup>1</sup>Universidad Carlos III de Madrid

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

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 em-

pirical part of the model.



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

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