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Aero-Servo Simulations of an Airborne Wind Energy System Using Geometry-Resolved CFD

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Properly understanding the unsteady interaction between the wind and the aircraft is critical to developing reliable airborne wind energy (AWE) systems. High-fidelity simulation tools are needed to accurately predict unsteady aerodynamics, providing insights into the design and operation of advanced and efficient AWE systems.

This work considers the reference multi-megawatt AWE system megAWES [1]. A two-way aero-servo coupling between AWEbox [2] and a geometry-resolved CFD model, which consists of the wing, ailerons, rudders, and the elevator, is established. We opt for the Chimera/overset technique, which has shown its ability to reproduce the motion of AWE systems in the flow domain [3]. Each component can move according to the combination of the aircraft's motion and its relative orientation. Each component is meshed separately and the Chimera/overset technique detects the overlapping cells between each component and applies interpolation to exchange flow data between the components. The aerodynamic forces and moments of the CFD model are fed to the dynamics simulator of AWEbox to compute the flight path. The model predictive controller (MPC) returns the rates of control surface deflections to the CFD model to track the reference flight path.

This novel approach effectively captures how the large aircraft motion, the deflection of control surfaces, and their interactions with the flow field influence the unsteady aerodynamics of the aircraft during operation. It allows to perform CFD simulations of complete power cycles in the atmospheric boundary layer.

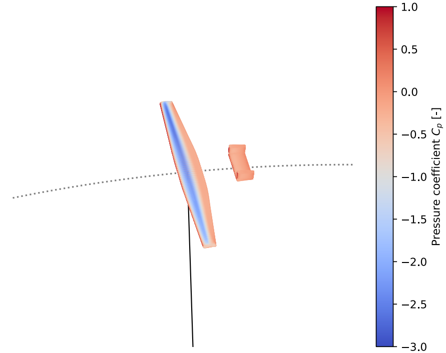

Figure 1: Pressure (C_p) distribution over the aircraft for a 1- loop power cycle prescribed to the CFD model.

In future work, the aero-servo model presented here will be coupled to a structural model of the MegAWES aircraft to obtain a high-fidelity aero-servo-elastic model.

References:

[1] D. Eijkelhof, R. Schmehl, Six-degrees-of-freedom simulation model for future multi-megawatt AWES, Renewable Energy, 2022.

[2] AWEbox: Modelling and optimal control of single- and multiple-kite systems for airborne wind energy. https://github.com/awebox/awebox

[3] N. Pynaert, J. Wauters, G. Crevecoeur and J. Degroote. Unsteady aerodynamic simulations of a multi-megawatt airborne wind energy reference system using computational fluid dynamics. Journal of Physics: Conference Series, 2022.