Composite photo of the 20 kN SkySails Power Functional Prototype in crosswind flight

Extended Periods of Automated Tethered Flight at SkySails

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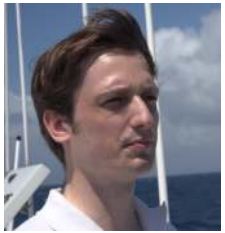

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This contribution is divided into two parts: Most recent data from extended periods of automated tethered flight of a 20kN SkySails Yacht System [1] will be discussed in a first part. Experimental data from the aforementioned system as well as from the SkySails Power small-scale functional prototype [2] will be used for model validation in a second part.

Flight data for the first part has been acquired on the hybrid solar- and kite-propelled yacht "Race For Water" [3] during her circumnavigation. This yacht has been first equipped in 2017 with a SkySails Yacht system, as presented on AWEC 2017 [4]. Updates to the autopilot software in early 2018 included a stepping set point adaptation for the wind window angle for traction force control. Through this increased level of automation the system can be operated for daylong flights with minimal additional burden for the ship crew. The working principles of the set point adaptation will be explained and propulsion performance will be presented.

Acquired experimental data has been used for model validation. Here, a comparison is made between open-loop model validation, where recorded steering inputs are replayed during simulation and closed-loop model validation, where only the set-points are replayed and the steering inputs are a recomputed output of the closed-loop controller. In the case of closed-loop validation, simulated trajectories of a full power-cycle are in good accordance with experimental data. In the case of open-loop validation, resulting trajectories are typically first in good agreement, but then diverge after a few seconds. This divergence is attributed to the fact that recorded steering inputs actually include the closed-loop control response to unmeasured disturbances, such as wind gusts and wind shear. Furthermore, it shows that the flown trajectories require control action to keep the system on a stable trajectory.

In summary, results of this model-validation show that a simple 4-state non-linear state-space model [5] capture the relevant dynamics adequately and can be envisioned for the use in non-linear model predictive control and other model-based control approaches.

References:

[1] http://www.skysails-yacht.com

[2] Erhard, M., & Strauch, H.: Flight Control of Tethered Kites in Autonomous Pumping Cycles for Airborne Wind Energy. Control Engineering Practice, ***40****, 13–26 (2015)*

[3] http://odyssey.raceforwater.org

[4] Quack, M., & Erhard, M.: Recent Advances in Automation of Tethered Flight at SkySails. In Book of Abstracts, Airborne Wind Energy Conference, October 5-6, Freiburg (2017)

[5] Erhard, M., Strauch, H., & Diehl, M.: Automatic Control of Optimal Pumping Cycles in Airborne Wind Energy. In Book of Abstracts, Airborne Wind Energy Conference, June 15–16, Delft (2015)

Skysails "Race for Water" Catamaran (25 January 2018)