Abstract No.
Flight stability of rigid wing Airborne Wind Energy Systems

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Airborne Wind Energy Systems (AWESs) are tethered flying devices, which harvest power from the wind. To become a viable alternative to conventional wind turbines, AWESs flying crosswind need to prove reliable operations for long periods. Thus, all the design sub-problems should to be solved aiming at a robust system with respect to external disturbances and failures. Keeping this in mind, this presentation focuses on a methodology to approach the flight mechanics of rigid wing AWESs.
The flight mechanics problem of AWESs is fundamentally different from the one of conventional aircrafts for mainly three reasons: the presence of the wind, needed for the power generation, the presence of the tether, which transfers the thrust force to the ground, and the AWES continuous flight maneuvers.
It is therefore clear that conventional design techniques assuming straight and level flight can hardly be used for AWESs. Makani power, before the shutdown, started investigating the possibility of designing the flight path and the AWES aerodynamic derivatives to achieve passive stability [1,2]. Stable AWESs would maintain the flight path with the least amount of control inputs.
To achieve stability, the flight path should be properly chosen: a circular path makes the problem axial-symmetric and it exists one turning radius, for a given system with considerable mass, which ensures maximum thrust force on the tether [3]. This flight path is selected for this investigation (Figure 1). The AWES aerodynamic design should then help, as much as possible, the control system to stay in the chosen path.
In this presentation, an analytical modelling approach to study flight stability is shown. The 6 d.o.f equations of motion are linearized about the steady state motion of the AWES in the circular path. The steady state motion is computed by considering all the fluctuating terms as disturbances. In this analysis, the inertial velocity is varying linearly along the main wing, as shown in Figure 2, making aerodynamic loads to vary consequently. The derivatives of external forces and moments are finally taken, to study the dynamic response of the linear system.
This linear model allows for a simplified investigation of the influence of a) tether attachment position b) main wing geometry (position, shape, sweep, dihedral) c) main wing aerodynamics d) control surfaces geometry (position, shape) e) control surfaces aerodynamics f) steady flaps g) tether elasticity and h) gravitational force on the flight stability. First, no power generation will be considered, to study the free flight of rigid wing AWESs. Later, the feature of the two generation types (tether reel-out velocity and on-board wind turbines) will be included in the analysis, to study their influence on the flight stability. This model, still under development, could give guidelines for the aerodynamic design of rigid wing AWESs, be coupled with design and optimization tools and used for simplified control laws derivation.

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Description: Relative wind velocity and aerodynamic forces

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Description: Reference systems and flight path

References:

[1] Geo Homsy. (2020). Oktoberkite and the MX2. in Echeverri P., Fricke T., Homsy G., Tucker N. (eds.) The Energy Kite Part I. pp. 7-89
[2] Jerome Sicard, Geo Homsy, Michael Abraham (2020) Kite Stability in Crosswind Flight. in Echeverri P., Fricke T., Homsy G., Tucker N. (eds.) The Energy Kite Part II. pp. 223-232
[3] Filippo Trevisi, Mac Gaunaa and Michael Mcwilliam (2020) The Influence of Tether Sag on Airborne Wind Energy Generation. Journal of Physics: Conference Series, Volume 1618, 032006. Available at: doi:10.1088/1742-6596/1618/3/032006