Optimal control for flow energy harvesting as applied to long-endurance fixed-wing UAVs

End-of-study project proposed by: Prof. Jean-Marc MOSCHETTA, Prof. Valérie FERRAND and Post-doc Nikola GAVRILOVIC

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A basic example of energy extraction within sinusoidal vertical gust is illustrated in Figure 1 and will be explained further. A small UAV suddenly experiences a vertical gust with a certain magnitude, at speed *Uo*. Since lift acts perpendicular to the local wind, the new lift vector will be tilted forward with a small additional component acting as an effective thrust. This additional lift component is performing a positive work on the aircraft and negative work on the gust. The figure also shows the case of a downdraft, where the aircraft is experiencing negative g's. This case also brings positive energy gain to the aircraft.

This project will involve theoretical analysis of the energy-harvesting mechanism of a simultaneously flapping and pitching two-dimensional wing and potentially three-dimensional wing. The conditions of flight will be taken to match a typical mini UAV flight, while the objective of the analysis will be to determine the optimal control in the angle of attack during energy-harvesting cycles. The base flow around an airfoil will be computed using a URANS algorithm (CFD software package). The comparison and analysis will be performed between experimental results (from test setup shown in Figure 2) of a pitching and heaving 2D wing, theoretical approach for the calculation of forces by integration on a control surface and numerical CFD computations.

Driven by the nature of turbulence, control activation is at high frequency. Therefore, the wing will perform rapid maneuvers followed by violent variations of the angle of attack. Depending on the frequency and magnitude of pitching and heaving motions, trailing vortices are generated introducing unsteady behavior of the aerodynamic forces. In that purpose, the study should result in a determination of the energy-harvesting efficiency in the function of phase lag. The study will be based on the theoretical approach developed by Zhou [1] and Kinsey [2] compared with Navier-Stokes computations and experimental results.

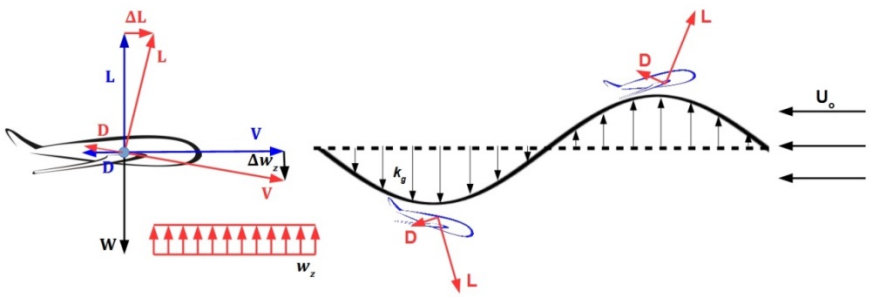

Figure 1Gust energy extraction mechanism

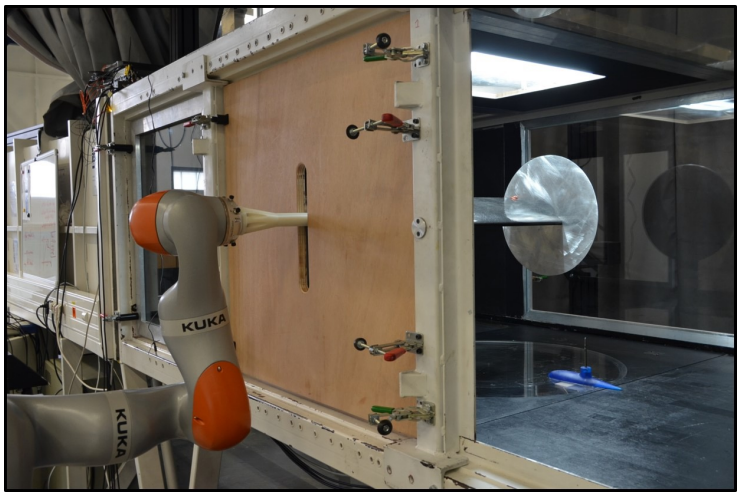

Figure 2 Experimental setup

Students looking for a **final master thesis internship** are welcome to apply. Skills in numerical simulations and fluid mechanics dynamics/aerodynamics will be greatly appreciated. Knowledge in the following software/languages will be a plus: StarCCM+/Fluent, MATLAB, PYTHON

References:

[1] Qiang Zhu, "Optimal frequency for flow energy harvesting of a flapping foil," Journal of Fluid Mechanics, Vol. 675, 2011.
[2] T. Kinsey and G. Dumas, "Parametric Study of an Oscillating Airfoil in a Power-Extraction Regime," AIAA Journal, Vol. 46, No. 6, 2008.

Time period: 5-6 months between February and September 2020
Candidate profile: Master student in Aeronautics, with major in Aerodynamics

Please note:
Only candidates that search for an end-of-study-project will be considered.