ENERGY SAVINGS FOR UAV FLIGHT IN UNSTEADY GUSTING CONDITIONS THROUGH TRAJECTORY OPTIMIZATION

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The purpose of this thesis is to show how micro unmanned aerial vehicles can extract energy from periodic wind gusts and how this energy extraction is affected by the effects of unsteady aerodynamics and the spatial structure of the gust component.

The trajectory of aircraft flying through wind gusts is simulated with a two degree of freedom model. A non-dimensional model is set to include vertical and horizontal gusts of varying amplitudes and durations. From this model an optimization routine is performed in order to obtain the minimum gust amplitude needed to obtain a neutral energy trajectory. It is shown that neutral energy flight is possible through gusts speeds of only 10 to 30% of the flying speed of the aircraft. Analysis of the results shows that the lift coefficient has to be changed very rapidly in order to perform these maneuvers in short duration gusts. Moreover high lift values are often required.

To achieve this kind of rapid change in the lift and drag forces, fast variations of the angle of attack are needed. The high lift values also require high angles of attack that are likely to cause separation of the flow over the airfoil. These fast variations at high angle of attack are shown to cause unsteady non linear aerodynamic responses.

Traditional CFD simulations are far too computationally expensive to be implemented into the optimization routine. To solve this issue a low order model based on a paper by Goman and Khrabrov is developed and validated against experimental results. This model produces accurate predictions of the lift and drag coefficients for a wide range of angles of attack and for different type of pitch inputs.

With this GK model the influences of the unsteady aerodynamics on the energy extraction problem are highlighted. The main difference with quasi-steady aerodynamics model was found to be for gusts at a reduced frequency higher than 0.07. Around these values the potential performance is improved by introducing the unsteady model. The trajectories obtained include more violent changes in angle of attack in order to take full advantage of the unsteady effects.