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Integration of airfoil design within a system-level optimization framework

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Over the last years, wind turbine design and optimization moved towards a system-design approach, combining mid-to-high fidelity models with suitable optimization schemes in order to automatically achieve the best compromises between all design aspects. Nevertheless, the airfoil shapes along the blade have been included as part of such integrated methods only in few works [1], as they are usually designed in a standalone or simplified environment.

In this background, it seems natural to investigate potential benefits of a complete *free-form* methodology within the consolidated Cp-Max [2] optimization suite. This algorithm consists of a multi-level architecture where an external *macro* loop handles some global parameters of the wind turbine and uses them to guide a set of inner optimization procedures towards cost-minimizing solutions. The latter ultimately perform the complete aero-structural design of the machine and its relative control laws.

In this work, we study the possibility to extend the design capabilities of the code by integrating the design of airfoils in its workflow. At first, to limit the computational time, we focus on a purely aerodynamic optimization of the airfoils, whose shapes are described through the CST parametrization to ensure adequate completeness, robustness and parsimoniousness. The aerodynamic design is then performed by the dedicated submodule of the program which seeks a genuine AEP-maximization.

Further and more complete analyses are currently being carried out on a 3.35MW reference [3], and the presentation will discuss the following challenges:

- How to control the design of airfoils from the *macro* design loop. Clearly, not all the design variables of airfoils can be designed at macro level, so suitable global parameters must be identified. For example, an airfoil shape could be optimized for a certain target thickness (see Fig. 1) with the latter directly controlled by the macro loop.
- The ability of the tool to obtain consistent results when the complexity is increased, for example by moving from a purely aerodynamic optimization towards a complete aero-structural redesign.

The main goal of this work is to find innovative design trends which can improve the efficiency of wind turbines through *ad-hoc* airfoil shapes. Furthermore, we expect that the optimization algorithm will be able to generally improve the KPI of the turbine when compared against a traditional methodology.

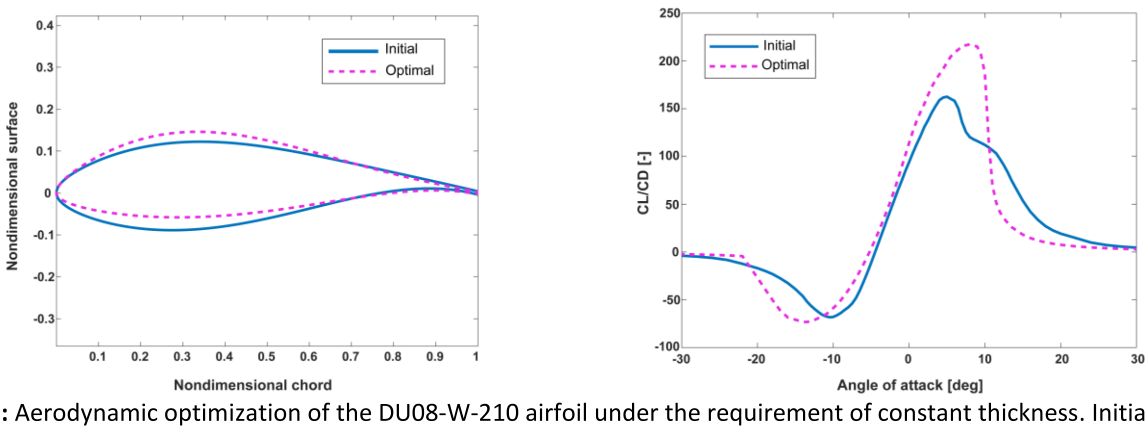

Figure 1: Aerodynamic optimization of the DU08-W-210 airfoil under the requirement of constant thickness. Initial and optimal shapes (left) and aerodynamic efficiency C_L/C_D *versus* angle of attack (right).

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