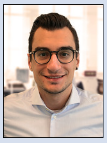

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Subject Area	Energy and Environment
Project Partner	Skypull SA, Lugano, TI

Computational Fluid Dynamics Analysis and Optimisation of a Multi-Element Airfoil

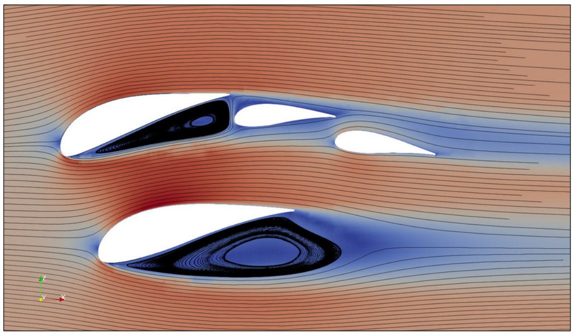

Fig. 1 - CFD Results for Velocity and Flow Separation (AoA = 0°)
Own presentment

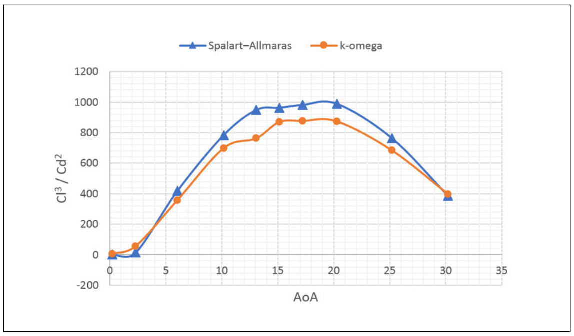

Fig. 2 - Variation of Performance with Angle of Attack
Own presentment

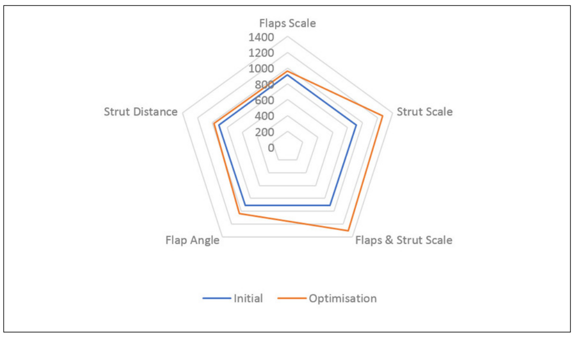

Fig. 3 - Variation of Performance with Geometric Optimisation Approaches
Own presentment

Introduction: To address climate change properly and accelerate energy transition from fossil fuels, renewable energy generation technologies are required. A new and upcoming energy design concept are airborne wind turbines. This technology harvests wind energy by exploiting the aerodynamic forces generated by autonomous tethered wings, flying fast in crosswind conditions. The advantage of this technology is that higher altitudes are reachable, compared to conventional wind turbines, where the wind is generally stronger and more consistent. Another advantage is that load on the holding structure is under tension instead of pressure and bending, so that the material fatigue can be lower with the same output power. All in all, the more consistent wind at higher altitudes means higher utilisation of the wind turbines by up to 50% more than the conventional wind turbines at simultaneously lower costs. A today's ambitious developer of such airbone concepts is the Swiss start-up Skypull SA, located in Lugano.

Definition of Task: The aerodynamic performance of an airborne wind turbine has an enormous effect on the expected power output. Depending on the shape and structure of an airfoil, it is often not trivial to predict which property improves the performance most. CFD tools provide an economical and effective way to analyse and optimise the airfoil's performance of such airborne wind turbines. In this work, a multi-element airfoil is analysed and optimised to help Skypull create a high-lift device by applying the CFD code OpenFOAM to the airfoil, set up for steady-state 2D calculations to simulate and to find the maximum of the term C_L^3 / C_D^2, which is proportional to the power production. This is done by firstly analysing the various angles of attack for predicting the variation of performance, as shown in Fig. 1. Having found the ideal angle of attack, presented in Fig. 2, a geometric optimisation is attemped. The scaling of the flaps and strut are increased and decreased as well as the angle of the separate flaps and the vertical distance of the strut are modified. Furthermore, the interaction of these separate approaches is investigated, together with a regression analysis. These different modifications allow to find the trends of improvement and can be shown in various diagrams, such as polar diagrams or two-dimensional contour plots.

Conclusion: The results in Fig. 3 show that this applied method of manual optimisation is successful and that is generally possible to optimise the Skypull's airfoil performance by up to 43.4% compared to the initial design. This is demonstrated especially by the strut scale as well as by the angle of the front flap. It is also shown how non-linear aerodynamic phenomena and behaviours interact for both the whole multi-element airfoil system and the separate airfoils in this system. Several improvements to the CFD validation method need to be done in order to validate the simulation results more accurately. Therefore, some experimental wind tunnel data are required, which is being planned in a further project.