Automated Multi-Parameter Optimisation of Multi-Element Airfoils

Aerodynamic optimisation of Skypull's multi-element airfoil for its airborne wind energy system.

Graduate

Gianluca De Fezza

Introduction: The today's energy transition requires the change from fossil fuels to new and renewable energy technologies, which have to be reliable, efficient and provide sufficient low cost energy. Airborne wind energy (AWE) systems have the potential to play an important role in this transition. The Swiss start-up Skypull is an ambitious developer of such AWE systems. The double wing design of the drone maximises lift with reduced wingspan. Each wing is made of a multi-element airfoil. Such high-lift devices are very complex in terms of their aerodynamic characteristics. The potential power production of an AWE system is heavily influenced by its aerodynamic performance. This can be improved by optimising the layout of the separate elements. For this, several parameters must be changed simultaneously and automatically in order to complete the optimisation in an efficient process. Otherwise, it might be difficult to anticipate which parameter increases performance the most depending on the shape and arrangement of the airfoil's elements.

Definition of Task: In this work, an automated optimisation strategy allowing simultaneous adaption of several geometric parameters is created to improve the aerodynamic behaviour, measured by the maximum of the equivalent Loyd's Power Ratio (LPReq). This is done by firstly setting the optimisation parameter and coding a Python script, based on the panel method tool Viiflow. The objective function is visualised with an interpolated scatter plot, shown in Figure 1. Having found the optimal layout of the elements, a Computational Fluid Dynamic (CFD) analysis is carried out in order to understand the aerodynamic behaviour, especially for configurations that did not converge using Viiflow. The CFD code OpenFOAM is applied to the initial and optimised geometry, set up for steady-state 2D simulations. The aim is to compare the flow over the baseline and optimised geometries.

Conclusion: The results demonstrate that this automated optimisation approach is successful. The airfoil of Skypull can be improved by 104% in terms of LPReq compared to the baseline design by increasing the front flap scale by 75% with a 1° steeper front flap angle and a 5° steeper rear flap angle, as shown in Figure 2. This is demonstrated particularly by the angle and scale of the two flaps, which result in a more rounded. Furthermore, it is shown that the new design leads to higher velocities and therefore to lower pressures at the top side of all elements. The increase in pressure difference causes more lift. In addition, the new design ensures a better formed wake, as the individual wakes of the elements are mixed together faster and thus reduce the drag. This can be seen in Figure 3. These results can be used by Skypull to improve their drone design. Due to some discrepancies between the Viiflow and CFD results, it is recommended to carry out further validation measurements in the future. Moreover, it may be worthwhile to include a CFD in the optimisation tool in parallel with the panel method. This would take a more time to optimise, but would have the advantage of providing more accurate results.

Figure 1: Automated Parameter Analysis of Optimisation Process.
Own presentment

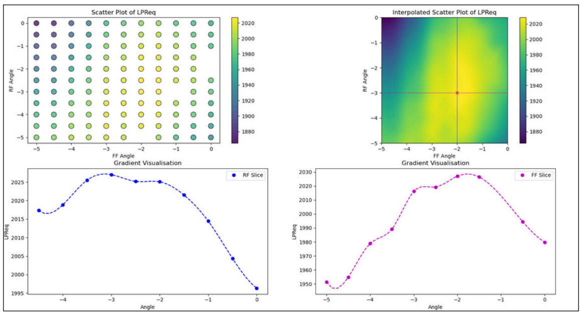


Figure 2: Comparison of Baseline (black) and Optimised (blue) Design.
Own presentment

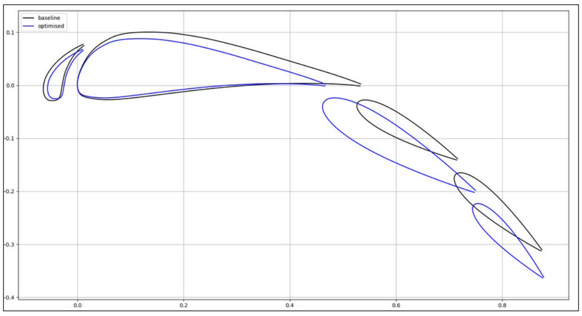
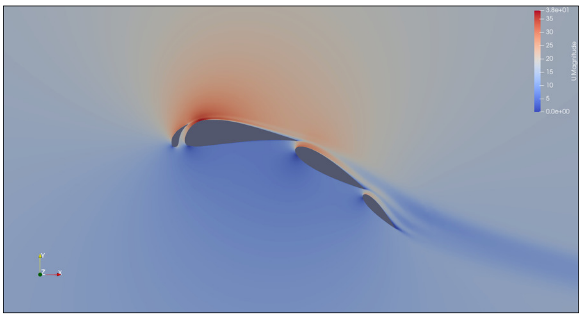


Figure 3: CFD Results for Velocity (AOA = -5°).
Own presentment



Examiner
Prof. Dr. Henrik Nordborg

Co-Advisor
Dr. Sarah Barber

Subject Area
Energy and Environment

Project Partner
Skypull SA, Lugano, TI