The 8th European Congress on Computational Methods in Applied Sciences and Engineering
ECCOMAS Congress 2022
5-9 June 2022, Oslo, Norway

Comparison of Gradient-Based and Genetic Algorithms for Infinite-Swept Wing Airfoil Shape Optimization

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Keywords: *Numerical Methods, Optimization, Adjoint, Genetic, Drag Reduction*

Shape optimization tools are widely used to design new airfoils with improved lift and drag performance. Two optimization approaches are gradient-based and gradient-free methods. Gradient-based methods usually converge faster as they rest on derivatives of the objective (e.g. profile drag). Gradients for problems with many optimization parameters may efficiently be obtained via the adjoint method. In contrast, gradient-free methods use heuristic approaches, e.g. the genetic algorithm, offering higher geometrical flexibility.

The gradient-based toolchain employed here consists of the direct and adjoint flow solver TAU, a mesh deformation step based on Radial-Basis Functions, a grid sensitivities solver employing finite differences, and an optimizer. We use an external boundary-layer code and a linear stability solver to optimize flows with transition.
The gradient-free toolchain consists of a set of reference airfoil shapes, parameterized using the Class Shape Transform method to obtain their control points, which are tuned in the genetic optimizer. The objectives and constraints are calculated by coupling a 2D Euler solver (MSES) with Linear Stability Theory for boundary-layer transition prediction.

As shown in previous work by the authors, the gradient-free approach resulted in airfoil shapes with lower drag than the gradient-based results, due to its higher geometrical freedom. Still, it came with higher computational costs and less precision [1]. It was then shown that a combined two-step approach resulted in a larger drag reduction. However, no sweep angle was taken into account, transition therefore happened solely due to Tollmien-Schlichting instabilities.
In this paper, we propose to extend the comparison to infinite swept wings with different sweep angles (10, 15 & 20 degrees) and thus crossflows of various strengths. Cases will include both transition mechanisms, different Mach numbers (0.78 & 0.81), for different shock strengths, as well as at least two different target lifts, influencing the optimal trade-off between wave and friction drag minimization. We further aim to exposit the suggested two-step approach with a deeper look into its results, advantages and shortcomings.

REFERENCES

[1] D. Simanowitsch, A. Sudhi, A. Theiss, C. Badrya and S. Hein, *Comparison of Gradient-Based and Genetic Algorithms for Laminar Airfoil Shape Optimization*, AIAA 2022-0008. AIAA SCITECH 2022 Forum. January 2022