GA Optimization Design of Multi-Element Airfoil

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Abstract: The CFD analysis and optimization of multi-element airfoils are presented. Window-Embedment technique is used to automatically generate the grids along with the geometry evolving. The CFD code named NSAWET is employed for performance and flow analysis. The Genetic Algorithms are used in along with gradient methods to get a good compromise of global optimization capability and efficiency. Man-in-loop idea is realized in the process. The results of single-point and dual-point optimization are compared.

Keywords: Multi-element Airfoil, Optimization, Navier-Stokes, Genetic Algorithms.

1. Introduction

With the great improvements in CFD, optimization algorithms and computer power, the automatic Aerodynamic Geometry Optimization (AGO) is becoming more and more feasible in modern aircraft design. On the CFD side, the efficiency and accuracy of the CFD analysis, the automation of geometry definition and grid generation are the problems that must be well solved first. In order to get a practical result, the designer’s expertise and experience must be able to be incorporated in to the automated process. This paper will introduce the authors’ recent efforts on incorporating the Navier-Stokes analysis with Genetic Algorithm for the AGO of multi-element airfoils.

2. CFD Analysis and Optimization method

2.1 Geometry definition

The Profile “Cutting” (PC) of the slat from the leading edge of the baseline airfoil are conducted by using the 3rd order spline. The PC of flap are similarly defined。The location and orientation of the flap and slat are defined by Deflection angle, Overlap and Gap (DOG). The coordinates of the PC control points, as well as the DOG parameters, are the candidate design parameters of the optimization.

2.2 Grid Generation and CFD code

The Window-Embedment strategy is employed in the grid generation. A C-grid is first generated about the baseline airfoil. Then two windows are opened for the slat and flap respectively. Two H-grids are generated for them, as well as the changed geometry of the main element, in the windows. With this grid strategy, during the optimization process, the modifications of the geometry are localized in the windows. The grid regeneration is greatly accelerated. The effects of the grid change to the CFD results are also minimized.

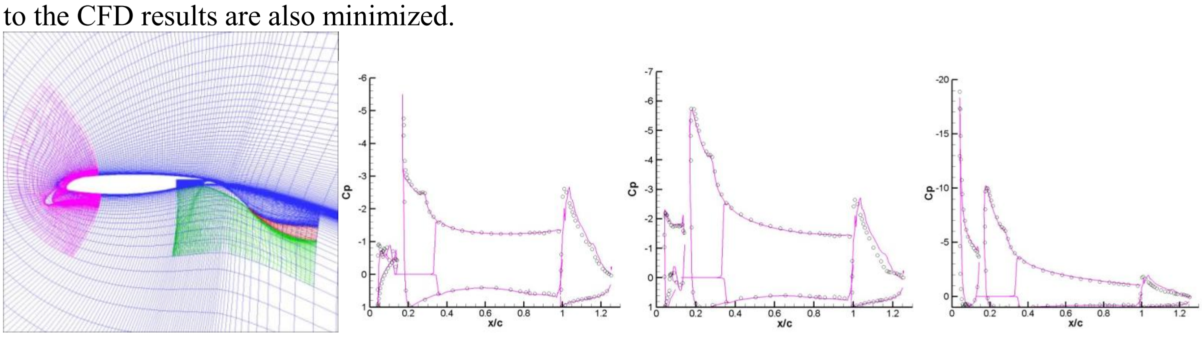


Fig. 1 Validation of the NSAWET code and Window-Embedment grid by MD 3-element airfoil

The in-house developed CFD code NSAWET (Navier-Stokes Analysis based on Window Embedment Technology) is used as the performance analyzer. The grid and code are both verified by standard test cases (fig.1). Both pressure distribution and boundary layer details can be well predicted.

2.3 Optimization Procedure

A typical optimization process is illustrated in fig.2. Genetic method is used at the beginning of the optimization to make it possible to get close to a global optimized solution. During the genetic “phase”, monitoring and artificial controlling of the population are conducted by the designer to gain the control of the direction of the evolvement. When genetic optimization is about to converge, the gradient methods will take over to shorten the whole process.

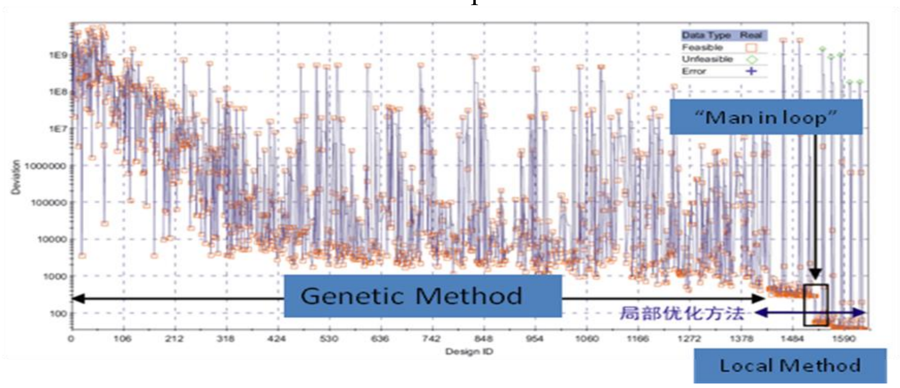
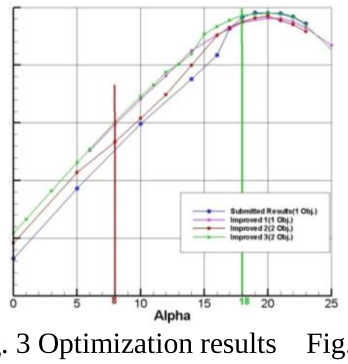


Fig. 2 Flow chart of optimization procedure

3. Optimization Results

For the landing configuration, the single point design is conducted first. The maximum peak Cl should be pursued. However, the design point is set to be M=0.15, Aoa=18deg. The maximum Cl at this point is set to be the design objective.

The optimized result is shown as the blue line in fig.3. A non-linear jump can be found near Aoa=16 deg. A separation bubble on the flap is found to disappear when the Aoa increase from 15 deg to 16 deg. In order to improve the linearity, dual-point optimization is conducted. Maximum CL at M=0.15, Aoa=8 deg is also pursued. With this effort, The Lift at 8 deg increased obviously, while the loss at 18 deg is neglectable. Especially, when the DOG and PC are coupled in optimization, the Pareto front (fig.4) can be greatly improved. The final result can be found as the green line in fig.3.



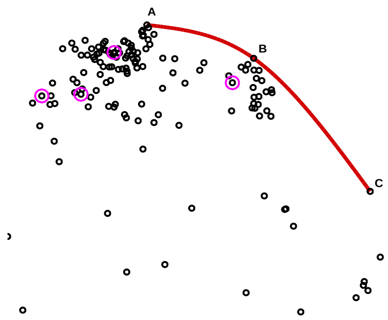


Fig. 3 Optimization results Fig. 4 Parleto front of the dual-point optimization

4. Conclusion and Future Work

The NS analysis is integrated into the automatic Aerodynamic Geometry Optimization of multi-element airfoil. Window-Embedment technology greatly simplified the grid generation and the numerical simulation in the process. Dual-point optimization shows obvious advantages to the results. Based on the methodology, 3-D AGO of realistic civil aircraft high-lift configurations is being carried out.

References

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