Improvement of the cruise performances of a wing by means of aerodynamic optimization. Validation with a far-field method

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ABSTRACT

Under collaboration with AIRBUS-Military it was considered the improvement of the cruise performances of the wing of a prototype military transport aircraft. On one hand, it is needed to validate the CFD tools being developed internally by the Aerodynamics Department of INTA. Additionally, it was a good occasion to afford the improvement of a wing already designed using traditional engineering tools. That leads to an important number of constraints which reduced so much the feasible design region.
This wing design code was started to be developed within the VELA project of blended wing body configurations [1]. It is a gradient based optimization code. Several techniques for unconstrained or constrained numerical optimization are implemented for the search direction methods. An important number of constraints of geometrical or aerodynamic nature are implemented.
The wing is modified by plan form changes and wing section changes. Normally, a wing is defined by a limited number of airfoils to define the wing sections. Then, it is permitted to modify some wing sections, and the rest can be a linear interpolation of the main sections, or equal to them, partly or on the whole wing.
There are different ways to modify the wing sections. One is using perturbation functions for the thickness and/or mean line distributions. Other technique is by fitting the section to a Bèzier curve of certain degree, and then, the Bèzier curve is modified by changing the co-ordinates of the control points that define the control polygon. This is shown in Figure 1. There is also implemented a technique using cubic B-splines curves to define the wing sections.
Due to the optimization is done with partially converged solutions, each solution considered as a good candidate was analyzed with other flow solver, basically with the TAU flow solver. And a drag extraction method developed internally at INTA [2] was also used to compute the drag, and to break down all the components of drag.
The DragON tool is based on a mixed approach to perform the drag breakdown: the volume approach from van der Vooren and Destarac [3] is applied to extract the profile drag (viscous and shock wave drag components) and a wake plane approach [4] is used to extract the induced or vortex drag.

Several configurations were studied in the optimization procedure. There were constraints in the wing loading, the wing span, minimum thickness-to-chord ratio, sweep angle, etc.
The goal was to maximize the aerodynamic efficiency at cruise condition.

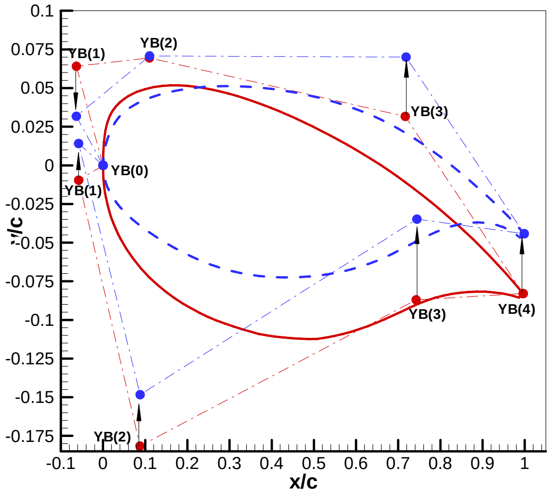

Figure 1: Wing section and control points of two quartic Bèzier curves. The changes in control points lead to a new wing section

After several trials, a wing was analyzed with TAU code and the DragON far-field drag tool was used to compare the drag at the given lift condition.
The result is given in Table 1. The near-field results are obtained by integration of the forces, after the TAU solution. The far-field solution was based on TAU flow variables information and was obtained with DragON tool.

Geometry	**ΔCD (near-field)**	**ΔCD (far-field)**
Original	------	------
Design17	-0.00048	-0.00083

Table 1: Drag comparison for TAU code calculations at cruise condition.

When using the far-field method, the new wing has a more favourable comparison with the original one: there is a reduction of 8.3 d.c.

It is important to mention that the wing loading was limited. And the wing span was not permitted to be increased. Then, the possibilities of improvement by reduction of induced drag were very limited. The original wing had a good Oswald factor. Then, the major improvements were only obtained by a reduction in friction drag (fully turbulent flow) and a reduction in pressure drag.

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