Overall Aircraft Design optimization of a new aircraft configuration

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This paper aims at describing a Multidisciplinary approach for new aircraft configuration optimization. An overall aircraft optimization aiming at Direct Operative Costs (DOC) reduction will be performed on top of the Aero-structural optimization. Top level variables are chosen in such a way that the trade-off between aerodynamics and structure is found without considering strong coupling variables. For that reason, wing planform and thicknesses are optimized during an Overall Aircraft Preliminary Design phase.

Nomenclature

MDO	=	Multidisciplinary Design Optimization
DOC	=	Direct Operative Cost
OAD	=	Overall Aircraft Design

I. Introduction

The idea is to have the overall aircraft design analysis and optimization in top of the aero-elastic and structural optimization procedure so that the wing planform is optimized for cost reduction, and not for aero-structural needs only. The Overall Aircraft Design (OAD) optimization targets main wing variables that will be used as input for the further optimizations which will give back the sensitivity analysis of the aero-elastic and structural objective functions with respect to the OAD variables. At that point, cost reduction will be addressed again, and the loop repeated till cost convergence is reached.

II. Methodology

The *OAD – Aero-elastic – Structural* optimization is organized in such a way that each discipline is independent but each of them gets some results from the previous optimization level. Actually, the optimization workflow is as follow:

i. Multipoint aero-elastic and structural optimization of the FSW architecture and sensitivity analysis of the objective functions with respect to the OAD parameters;
ii. OAD optimization for decreasing the DOC to provide the new planform variables to be used for the further aero-elastic and structural optimization and sensitivity analysis;
iii. The optimized top level variables are fixed in the next aero-structural process that will provide new values and sensitivity analysis for the OAD optimization.

First of all, the structural optimization is performed in order to minimize the wing weight taking the stress level of each structural component under constraint. The wing load is recomputed over time in order to be consistent with the stiffness change. As shown in Figure 1, once the wing weight is optimized, the new aero-elastic equilibrium based on the new wing stiffness is reached, and the new wing load is used for the next structural optimization. The convergence is obtained when the difference between the optimized weight of the last optimization and the one before is less than 1%.

After that, a multipoint aero-elastic optimization has been set in order to increase the L/D ratio for 3 different cruise conditions. *Twist* and *camber* at different control sections are used as shape parameters. Viti et al [1] investigated on the most appropriate shape variables to be used for different flow conditions.

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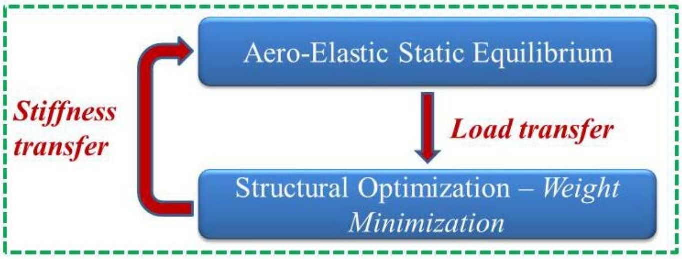

Figure 1: Structural Optimization at the Aero-elastic equilibrium

Concerning the cost reduction, the following 6 top level variables are chosen.

Wing surface	S
Aspect ratio	λ
Tape ratio	c_{root}/c_{tip}
Sweep angle	$\varphi_{25\%}$
Relative thickness at 40% of the span	$t/c_{\ 40\%\ span}$
Relative thickness at the tip	$t/c_{\ tip}$

Table 1: Top level variables for the OAD optimization

The aforementioned variables have direct impact on both aerodynamics and structure. Following the presented approach, the OAD optimization will chose the 6 top-level variables to address cost reduction and the following aero-structural process will increase the efficiency of the aircraft, enriching at the same time the physics of the top-level optimization. This iterative procedure will end once that the DOC of a previous iteration differs from the last by a certain error.

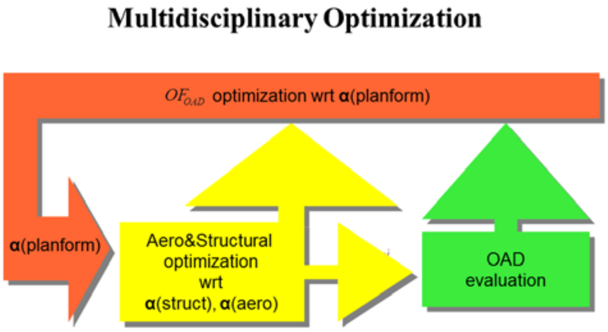

Figure 2: OAD top level optimization on top of the aero-elastic and structural ones; α(struct) and α(aero) are the structural and aerodynamic variables respectively

III. Results and Conclusions

In this paper a new MDO approach for preliminary aircraft design is presented. In particular, the top-level OAD process optimizes 6 wing variables for DOC reduction. Such variables are fixed during the following aero-structural optimization procedure. Preliminary results show the effectiveness of this approach to address simultaneous requirements of different disciplines without adding untreatable complexity and maintaining preliminary design characteristics such as fast and reliable analysis and optimization.

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References

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