High Fidelity aero-structural optimization of a wing using a step-range approach

Paolo Francesco Scaramuzzino†, Andrea Siciliani† and Giuseppe Quaranta†

†Dipartimento di Sceienze e Tecnologie Aerospaziali, Politecnico di Milano
via La Masa, 34 Milano 20156 Italy
email: giuseppe.quaranta@polimi.it

ABSTRACT

The ever-growing realm of applications and the explosion in computing power is driving optimization research toward new and exciting directions. A considerable amount of research has been conducted on multidisciplinary design optimization (MDO) and its application to aircraft design [1]. In most cases sound coupling and optimization methods were shown to be extremely important because some techniques, such as sequential discipline optimization, were unable to converge to the true optimum of a coupled system. Aerostructural analysis has traditionally been carried out in a cut-and-try basis. Aircraft designers have a preconceived idea of the shape of an optimal load distribution and then tailor the jig shape of the structure so that the deflected wing shape under a 1-g load gives the desired load distribution. Although this approach might suffice for conventional transport aircraft, for which there is considerable accumulated experience, in the case of either new planform concepts or new flight regimes the lack of experience combined with the complexities of aero-structural interactions can lead to designs that are far from optimal. The objective of our work is to develop an MDO framework for high fidelity analysis and optimization of aircraft configurations. The paper presents the current capability of this framework through the aerostructural design of a transonic business-jet wing. This paper focuses on the demonstration of an integrated aero-structural method for the design of aerospace vehicles. Both aerodynamics and structures are represented using high-fidelity models. The aerodynamic outer-mold line and a structure of fixed topology are parameterized using a large number of design variables. The aerodynamic sensitivities with respect to outer-mold line shape variables are computed using an accurate and efficient adjoint procedure. The structural sensitivities with respect to structural design variables are computed using finite differences. The cross-gradients are evaluated analytically.KreisselmeierSteinhauser [2] functions are used to reduce the number of structural constraints in the problem. Results of the aerodynamic shape and structural optimization of a natural laminar-flow transonic business jet are presented. The available literature about MDO applied to aircraft design uses the Breguet range equation as objective function. This means that the variation of attitude during cruise, which is related to the loss of weight caused by fuel consumption, is not taken into account. The innovative approach presented in this work is to divide the cruise into a certain number of steps; over each step the attitude is considered to be constant, so that the Breguet range formula can be applied. The total range is then evaluated as the sum of the ranges of each step, leading to a sort of multi-objective optimization. The bigger is the number of step considered, the more accurate is the solution obtained. This new approach is called step-range and its results are compared with those obtained through sequential discipline optimization and single objective optimization.

REFERENCES

[1] Martins, J. R. and Lambe, A. B. (2013). Multidisciplinary design optimization: a survey of architectures. *AIAA journal*, 51(9), 2049–2075.

[2] Kreisselmeier, G. and Steinhauser, R. (1979). Systematic control design by optimizing a vector performance index. *International Federation of Active Controls Syposium on Computer-Aided Design of Control Systems, Zurich, Switzerland.*