Design of a High-Lift System for a Laminar Wing

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ABSTRACT

The design and optimization of High-Lift (HL) systems represents a challenging task within the aerospace community, due to its multidisciplinary, multi-objective and multi-point nature. As an example, the design of HL devices typically involves the improvement of performances related to different flight phases, *e.g.* take-off (TO) and landing (LDG). Normally, in each flight phase several performances indexes need to be improved or at least controlled, and airworthiness requirements additionally pose important boundaries to the design space and complicate the optimization problem formulation. Moreover, manufacturing constraints must be respected, as the designed shape must ensure enough structural stiffness to maintain the high aerodynamic loads occurring whereas, the external shape of the retracted wing must be compliant with the designated cruise clean wing shape. Finally, during the design phase the kinematical reliability must be accounted for, in order to avoid unrealistic designs. All these features make the HL system design and optimization phase particularly difficult and often representing stiff sceneries.

The DeSiReH project (Design, Simulation and Flight Reynolds Number testing for advanced High Lift Solutions), founded by the European Commission in the 7th Framework Program, aim at improving the aerodynamics of HL systems by considering, in a coordinated approach, the development of both efficient numerical design strategies and efficient measurement techniques for cryogenic wind tunnel conditions. A target application of the DeSiReH project is the design of a HL system for a High Aspect Ratio Low Sweep (HARLS) wing, featuring Natural Laminar Flow (NLF) at transonic cruise conditions. Within this paper, an overview of the CFD-based optimization activities carried out in two phases of the DeSiReH project will be illustrated. In the first “analysis”

phase (Task 1.2), a realistic multi-objective/multi-point optimization problem (Figure 1) was defined [1] and solved by a group of partners adopting different approaches in terms of employed flow model (*i.e.*, RANS 2D/2.5D/3D), meshing, geometry parametrization and optimization strategies. The results obtained are compared and efficiencies/deficiencies of the adopted approaches will be highlighted.

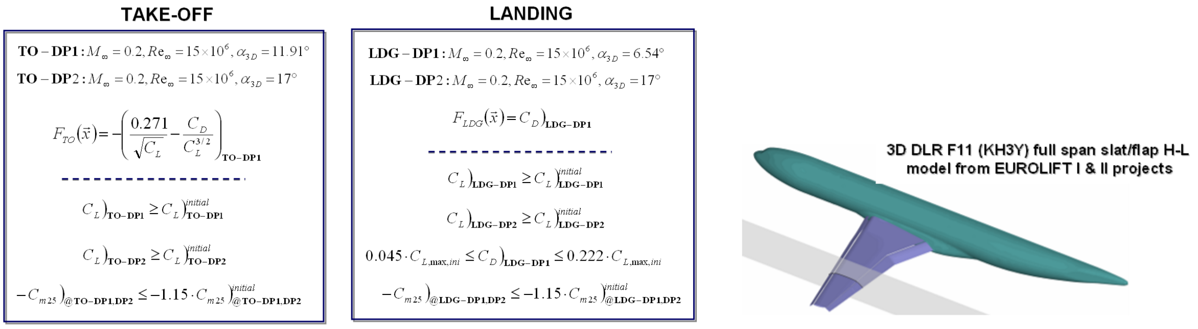

Figure 1: 3D HL design problem definition including aerodynamic and airworthiness constraints (left).

The experience gained in the first phase of the project has been exploited in a second "application" phase (Task 2.1), wherein an aerodynamically designed optimal feasible HL system has been developed for the HARLS-NLF wing. As shown in

Figure 2, the design work was initially concentrated on the 2D assessment of several candidate concepts, by considering CFD-based 2D optimization targeting lift maximization. Mechanical integration of the HL concepts was investigated in parallel, leading afterwards to a constrained refined optimization of the concepts.

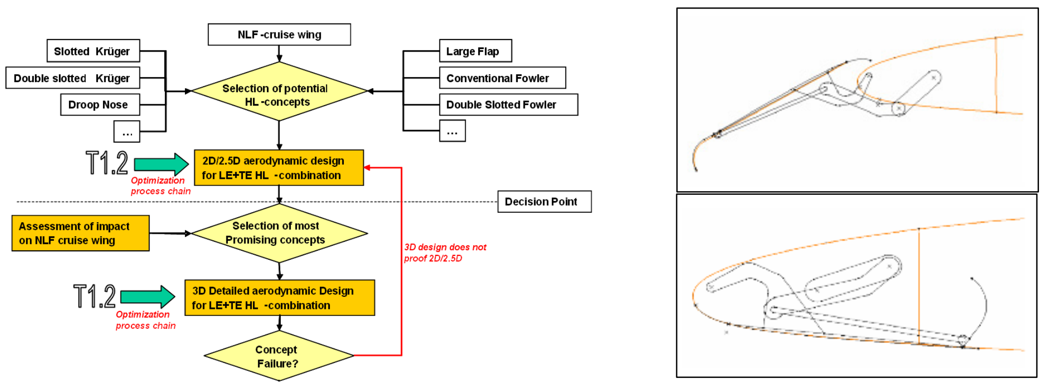

Figure 2: DeSiReH T2.1 activity flow chart (left) and kinematical layout and the mechanical integration studies of concepts optimized in 2D/2.5D framework (right).

According to the above procedure, a group of (2D) optimized feasible concepts was available. The most promising concepts for 3D wing integration were selected based on the achieved 2D aerodynamic performance and integration feasibility aspects. According to the 2D selection input, a detailed 3D numerical optimization was carried out by participating partners for concurrent leading edge and trailing edge concepts, by including the mechanical and structural constraint directives matured during the 2D optimization loop activities. The solution of the 3D HL optimization problem, and the final results obtained will be described within the paper. Finally, comparisons of the achieved performance vs. a concurrent HL benchmark design based on industrial best practice procedures will be presented in the paper.

References

[1] P. Iannelli, D. Quagliarella: Multi-objective/Multi-point shape and setting high-lift system optimization by means of genetic algorithm and 2D Navier-Stokes equations. *EUROGEN 2011 Conference proceedings*.