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MULTIDISCIPLINARY OPTIMISATION OF FLEXIBLE AIRCRAFT STRUCTURES IN CONSIDERATION OF FLIGHT CONTROL SYSTEM DEMANDS IN THE TIME DOMAIN

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Abstract: This paper presents how the major aircraft design disciplines "flight control systems" and "aerostructural design" are coupled through the application of multidisciplinary design optimisation for time domain problems at Airbus Defence and Space. It shows that respecting flight control system demands in a multidisciplinary way is a must for the success of industrial aircraft projects. Today's major customer requirements target extended flight ranges and loitering times on the one side, and higher manoeuvrability of the product on the other side. Both demands increase the importance of aeroelasticity and flight control system during design. To tackle the novel customer requirements, the Airbus in-house optimisation tool Lagrange was enhanced by the possibility of coupling flight control laws with aeroelastic analyses. The governing equations of the aeroservoelastic system are developed. The control laws are given in terms of a discrete controller, as common in industrial development. The monolithic, aeroelastic model, providing external loads, incorporates inertia relief using a mean axes formulation. Structural dynamics are encountered in the time domain and solved with the generalized alpha method. Basic damping models are considered in order to properly face the servostructural dynamics of the system. Based on the governing equations of the analysis model, the optimisation problem is formulated. Structural mass is considered as the primary objective function. Additionally, the dynamic of the controller is encountered as an objective. Constraints are formulated by means of both structural integrity and flight mechanical aspects. Design variables are structural thickness values, ply angles of laminated materials, as well as control variables like gain factors in the control law. In the early stage of aircraft sizing, industrial aircraft models usually consist of hundreds of thousands of structural, and tens of thousands of aerodynamic degrees of freedom. As an application, a flexible, unmanned aerial vehicle with a high aspect ratio is optimised. Results obtained by following the conventional aircraft optimisation approach are compared to results from the enhanced process for this industrial example. A validation of the approach against different aeroelastic solutions is presented. Calculations from higher fidelity aerodynamic solvers are consulted for this purpose. As an engineering outcome, it is shown how the consideration of controlled loads in the optimisation step significantly changes the range of allowable designs. The paper thus presents the methodical shift at Airbus Defence and Space from designing with conservative, passive reserve factors to designing with active ones.