Single-level Aeroelastic Tailoring Optimisation of Composite Wings via Ply-Book Parameterisation

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Composite structures are becoming more common in aerospace structures (e.g. 787 and A350); however, most of the use has been based upon the superior strength-weight characteristics rather than exploiting the anisotropic behaviour that is possible. Despite the X-29 demonstrating the potential of aeroelastic tailoring for aircraft structures in the early 1980s, and despite many studies being undertaken since then, there are still no large scale applications of aeroelastic tailoring on aircraft structures. One possibility for this lack of application is the need for an efficient way to optimise such composite structures.

We present a methodology for global and passive aeroelastic tailoring based on a single-level optimisation framework. The framework is used to obtain the internal architecture and the detailed ply-books for a metallic wing with composite skins. The structure is tailored to match a specific aerodynamic shape, whilst minimising weight. The static aeroelastic shape of the airframe, hence its aerodynamic performance, is compared to a target shape by defining a curve matching problem. An attempt to minimize the loss of performance at off-design cruise conditions is made by maximizing the similarity of the desired aerodynamic shape with the deformed wing shape including bending and twisting deformations. The design variables used in the optimisation process include: (a) the thicknesses of the metallic components; (b) the number, spacing and orientation of ribs and stringers; (c) the number of layers and stacking sequences for each of the spanwise partitions in which the composites skins are divided. Aeroelastic constraints include static stresses, maximum deflections, and flutter speed. In order to obtain the ply-book in a single step optimisation, a laminate parameterisation is elaborated to reduce the number of design variables, while imposing manufacturability and feasibility constraints. A multi-objective Genetic Algorithm is used to deal with integer variables and ensure a full exploration of the design space. A Pareto Front is used to assess the trade-off between the design metrics in the fitness function. Different design studies have been performed to compare conventional and nonconventional ply orientations for wing weight minimisation while targeting the ideal aerodynamic shape for multiple cruise flight conditions.

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