Intégration des contraintes de *blending* dans les méthodes d'optimisation déterministes pour les stratifiés composites

Composite layup blending constraints for determinist optimization methods

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Advanced composite materials are well known for their excellent mechanical properties. Tailoring these properties to achieve lightweight and efficient structures represents a real challenge for both researchers and industries. Indeed, for a composite structure made of unidirectional plies, tailoring results in a variable thickness distribution, thus, a variable distribution of plies number. In literature, the term "blending" is used to identify the manufacturing constraints to be applied when designing tailored composite plates [1]. Indeed, blending constraints are formulated to ensure that the stacking sequences of adjacent regions of the plate are consistent, e.g. paths of plies belonging to adjacent stacking sequences cannot cross each other (see Figure 1).

In literature, two approaches have been typically used to formulate blending constraints. In the first one the laminate is modeled explicitly via its stacking sequence and manufacturing constraints are directly imposed to adjacent stacks [2]. The main drawback of this approach is that a huge number of design variables is generated unless major simplifications are introduced, i.e. limited number of ply orientations.

The second approach is based on the formulation of blending constraints in lamination parameters (LPs) or polar parameters (PPs) space in the framework of multi-scale optimization strategies for composite structures [3]. Generally speaking, a multiscale optimization strategy is characterized by two-step: in the first step the macroscopic parameters (LPs or PPs) of the laminate are considered at design variables and the laminate is modelled as an equivalent homogeneous anisotropic plate. At this level the goal is to find the optimum value of the laminate mechanical parameters satisfying the requirements of the problem at hand by including suitable blending constraints. Conversely, during the second step the goal is the determination of at least one optimum stacking sequence that must satisfy the optimum value of the laminate mechanical parameters resulting from the first step.

However, LPs show a main drawback: they do not have a simple and immediate physical meaning. Moreover, unlike PPs, LPs are not tensor invariants and cannot be properly exploited to impose fundamental requirements on the laminate elastic symmetries. In this work, the multiscale two-level optimization (MS2L) strategy [4] [5] has been enriched by considering the manufacturing constraints linked to the ply drop and add technique, i.e. the blending constraints to tailor the composite structure. The optimization problem as well as the laminate blending constraints are stated in the general theoretical framework of the polar formalism [6]. The main advantage in using PPS resides in the fact that the polar invariants have an immediate physical meaning which is linked to the different (elastic) symmetries of the stiffness tensors of the laminate. In particular, in this study blending constraints have been integrated directly within the first-level problem (the structural optimization) in order to let formulate the second-level problem (the lay-up design) as an unconstrained minimization problem as all the requirements (geometrical, technological, mechanical, etc.) are satisfied since the first step of the MS2L strategy.

In order to limit the computational effort, the polar formulation of blending constraints has been integrated within a gradient-based optimization algorithm.

To assess the proposed optimization framework, a numerical test-case taken from the literature [7], addressing a composite structure of aeronautic interest, is considered. The proposed benchmark focuses on the least-weight design of a composite wing-box by considering requirements on the first buckling load, on the maximum strain and blending constraints as well.

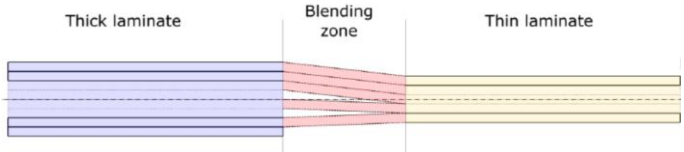

Figure 1 – Generic blending between adjacent regions.

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