# Blending Constraints in Composite Wing Aeroelastic Optimization

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**Improving large composite structure can be achieved by locally optimizing thicknesses and ply orientations. However, this strategy can lead to structural discontinuity or unfeasible structure from the manufacturing point of view. Therefore, enforcing blending during structural optimization is fundamental in order to achieve ready-to-manufacture solutions. The present paper is expected to prove the effectiveness of blending constraints in the aeroelastic optimization of a variable stiffness wing. The paper should prove that more realistic optimal continuous design can be achieved due to the application of the blending constraints. Moreover, such constraints will be implemented in the commercial software Nastran SOL 200 demonstrating their ease of implementation.**

## I. Introduction

Composite materials are being used more and more often in the aerospace industry thanks to their high stiffness and strength to weight ratios when compared to the more conventional aluminum counterpart. The anisotropic properties of composite, together with the possibility of designing the laminate stacking sequence, allows aircraft designers to tailor the stiffness of composite structures according to the loads they are predicted to experience. Improving stiffness design of a large composite structure can be obtained by dividing the structure in sections and locally optimizing thickness and stacking sequence in each of the section. However, this might lead to stress concentration between adjacent sections in case of thickness and/or stacking sequence discontinuities. In order to avoid this stress concentration, blending has to be taken into account in order to ensure ply continuity for the whole structure.

Ply continuity can be imposed in different ways. Inner and outer blending have been introduced by Adams et al.[1] , in these definitions only the innermost and the outermost plies can be dropped as shown in Figure 1a. Two alternative definitions, the generalized and relaxed generalized blending, have been formulated by Van Campen et al.[2] and are presented in Figure 1b. Generalized blending requires all plies of the thinnest section to be continuous in the whole structure; relaxed generalized blending demands that no discontinuous plies should be in direct physical contact with each other. Throughout this paper, blending is always associated to the generalised blending definition of Van Campen et al.[2] for sake of clarity.

## II. Methodology

Several authors[3456] have used bi-step strategies where a gradient based (continuous) optimization of homogenized stiffness parameters (e.g. lamination parameters) is followed by genetic algorithm (discrete optimization) to retrieve blended stacking sequence. By doing so, mechanical constraints are verified during the continuous step while most of the manufacturing constraints (e.g. blending) are enforced only in the discrete step. This can result in significant discrepancies between the two optimization steps[7] and therefore there is no guarantee to find an equivalent of the optimal continuous design after the discrete

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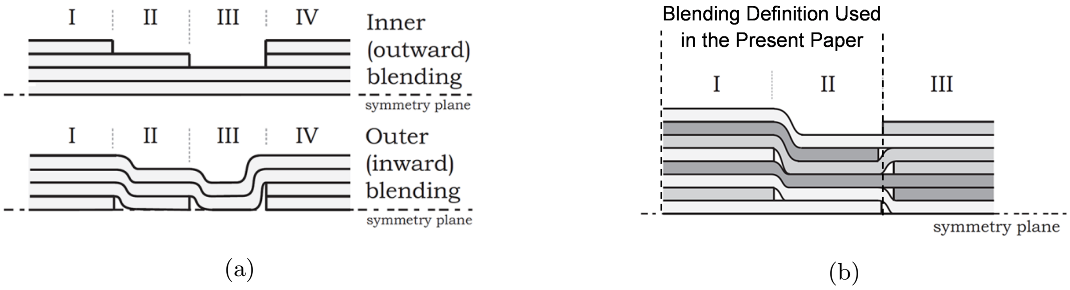


Figure 1: (a) Outward and inward blending, and (b) generalised (I and II) and relaxed generalised (II and III) blending. Original figures from.[2]

step.

In view of the above, Macquart et al.[8] have derived a set of continuous blending constraints in order to achieve more realistic continuous design and reduce discrepancies between the two optimization steps. The blending constraints have been derived for lamination parameters. The key concept for the derivation of the continuous blending constraints is to evaluate the change in lamination parameters ($\Delta V$) due to ply drops. Blending constraints have been derived for both in-plane and out-of-plane lamination parameters.

## III. Results

This paper wants to investigate the effectiveness of continuous blending constraints in the aeroelastic optimization of a variable stiffness composite wing (Figure 2). The paper considers the effect of blending constraints relaxation and grouping. Finally, to prove that the optimization has converged to a reasonable improved design, a multi start strategy is applied to ensure the robustness of the optimization. Following the continuous optimization a stacking sequence table based GA is used to retrieve a blended stacking sequence. Since the blending constraints reduce the design space to more realistic solutions and to avoid the use of expensive fitness function, the GA objective is to match the lamination parameters of the optimal continuous design. The optimization is carried out with *MSC Nastran SOL 200* proving that the constraints can be easily implemented in commercial optimizer.

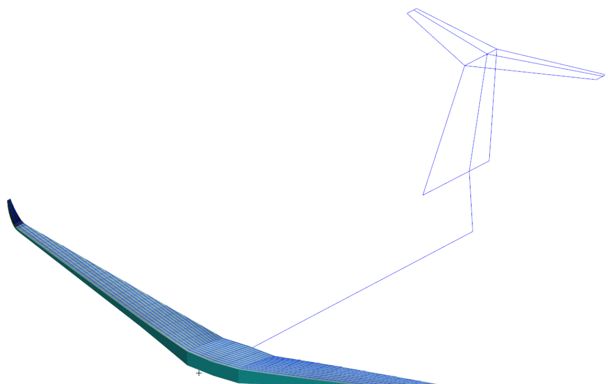

Figure 2: Aircraft wing model used in the optimization.

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