

Mixed continuous-discrete variable optimization of composite panels using surrogate models

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One of the major challenges in successful design of modern aeronautical structure is to reduce the total weight of the system. In the recent decades, applications with unidirectional thermoplastic composite parts are considerably increased. Thermoplastic composites show performance benefits compared to previous used material. Moreover, unlike conventional materials, composites can be tailored with specific lay-out to satisfy certain requirements. However, the high number of variables involved and the complex mechanics associated to composites, makes the optimum design difficult to achieve. Structural optimization, due to its systematic nature and to the possibility of setting defined objectives, becomes the most suitable approach to support the designer, obtaining the expected properties.

Nowadays, most of the optimization codes deal with continuous variables. On the other hand, new production technologies of unidirectional composite panels require handling some discrete parameters (e.g. thickness), giving more freedom for others (e.g. fiber orientation). Tape placement is considered the most promising. It consists in placing continuous strips of unidirectional thermoplastic composite and consolidating them *in-situ*. Therefore, a continuous-discrete variable optimization approach becomes essential to obtain a feasible optimum design from the engineering point of view.

In this work, the authors show a weight optimization procedure developed for the design of composite panels under axial-compression. Minimum weight is the objective. Fiber angles are assumed to be continuous variables; thicknesses of single layers have discrete values. Moreover, the problem is subject to first-buckling constraints. This is a crucial point for the accomplishment of a successful optimization. The constraint behavior is not known *a priori*. A high number of FEM analyses have to be run. The data interpolated and the first-buckling function approximated. Otherwise, to reduce computational and experimental costs, a surrogate model, that provides a fast approximation of the considered function, can be used. It is generated from a limited number of information given from FEM calculations and/or from tests. To create the surrogate, several designs are generated (PRE-OPTIMIZATION, figure 1). Every design space is filled with N sampling points, which represent N combination of variables (DOE, figure 1). Generating the surrogate using the original variables means using a high number of parameters and it results in high non-linear functions. It is wise to use the thickness and orientation information to generate the equivalent ABD matrix that permits to handle a fixed number of parameters and to reduce the non-linearity. The best design is selected in the ABD space according to the Latin hypercube criteria. The surrogate is then generated for the constraints and the optimization is carried

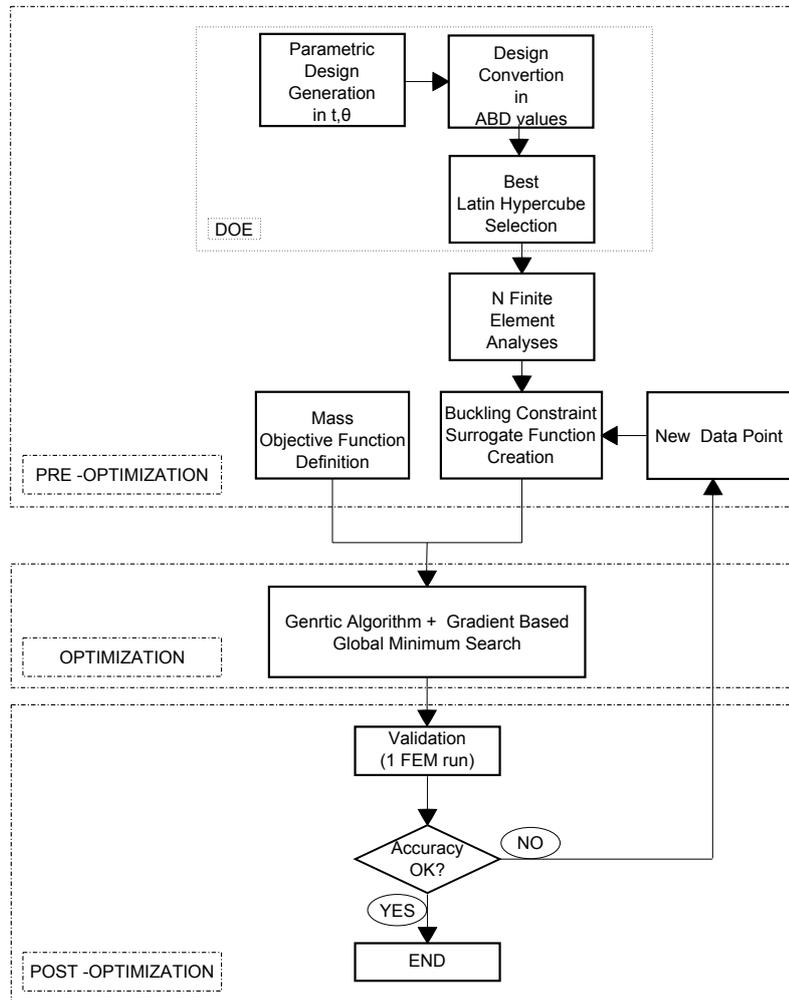


Figure 1: *Optimization flow-chart*

out. In the post-optimization phase, the surrogate, so the optimization result, is validated running a single FEM analysis. The information is used as new point in the pre-optimization phase to generate a more accurate surrogate of the selected design. A new optimization is performed. Once the constraints are satisfied from the surrogate, validated from the FEM analysis and no improvements are shown after p optimum evaluation, the optimization ends.