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A general strategy for the optimal design of composite laminates by the polar-genetic method

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ABSTRACT

The object of the present work is the development and application of a totally general approach to optimal design of composite laminates where all the required properties for the laminate are explicitly expressed as criteria of the optimisation process. Our formulation is in the form of a highly non-linear and non-convex single- or multi-objective optimisation problem subject to equality and inequality constraints. We show here applications to the design of maximum stiffness, maximum buckling load, maximum eigenfrequencies, maximum strength as well as combinations of the afore mentioned criteria; all types of elastic symmetries can also be taken into account. In order to keep the same greatest generality in solving our optimisation problem, we developed an evolved version of the genetic algorithm BIANCA for the design of composite laminates. We show here a number of numerical solutions found using BIANCA.

1. Introduction

The use of composite laminates finds many applications in mechanical structures, and that has been for few decades so far. It is worth note that the aims in the application of composite laminates are also renewed. In fact, in a first place the application of composites was inspired by the need of replacing metals in order to obtain lightweight structures. However, composite materials show very special features in comparison to metals because of their heterogeneity, and the architecture of their reinforcement structure can be tailored in order to obtain different types of anisotropy and couplings among different behaviours, which can find such applications as in smart and adaptive structures.

Therefore, the concept of design and optimisation of the constitutive material is established as a fundamental step in the process of design of composite structures [1]. In such a way, designers need to consider more general elastic properties in the design of laminates. Actually, it is not easy to formulate and solve a design problem in taking into account all the general properties and researchers generally restrict the search of solutions to a limited class of laminates, usually to symmetric stacking sequences or balanced laminates. This procedure simplifies the problem, but it is restricted to a class of laminates, or considers just a part of the whole problem. Therefore a technique to provide a general formulation able to take into account several design criteria simultaneously seems to be essential.

2. Discussion

Number of research works in this area showed how design of composite laminates raises very hard difficulties, and that is based on several different reasons. First of all, the manifold of variables in the design process, which are all the constitutive parameters of a laminate (number of layers; material, thickness and orientation of each layer) and which might take continuous real values as well as discrete values. On the other hand, the cumbersome dependence of the laminate properties on its constitutive parameters, that induces anisotropy and couplings. Finally, the high non-linearity of laminate behaviours depending on its constitutive parameters, namely layer orientations.

The afore mentioned difficulties, affecting at the same time the theoretical formulation of the design problems as well as the numerical methods for resolution, imposed some limits in the treatment of design and optimisation of composite laminates.

On one hand, the use was to restrict the number and nature of variables in the design process, especially in terms of orientation angles which are classically chosen within the discrete set 0, ±45, 90. On the other hand, authors used to introduce some simplifying hypothesis in order to ensure the respect of few fundamental properties of composites such as some kinds of elastic symmetries. For instance, it is a common use to choose symmetric stacking

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