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GLOBAL OPTIMIZATION OF LAMINATES

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ABSTRACT

Composite laminates are more and more used in industrial applications, mainly because of their strength and/or stiffness to weight good ratio. Actually, they are the almost indispensable in aerospace structures, but they are very used also in sport and automotive applications.

Though used since about four decades, the design of composite laminates is still a subject of research. In fact, design of laminates is a difficult task, for several reasons: when formulated as an optimization problem, the design of a laminate presents some typical features: non-convexity, different nature of the design variables (continuous, discrete, grouped), several objectives and constraints to be considered and, often, a large number of design variables.

In addition to these features, that can be common to other structural problems, the optimal design of laminates has a very special feature, which constitutes the real main problem of laminate design: the need to account for the elastic symmetries of the final laminate in the same optimal design formulation. This is due to the mechanical behaviour of a laminate, described, in thermo-elasticity, by six different tensors. Such tensors determine not only the magnitude of the thermo-elastic response in each direction, but also the symmetries of this response. Normally, designers want to obtain laminates having a certain symmetry of the response; usually, at least laminates with orthotropy in extension and bending-extension uncoupling are sought for (uncoupling ca be considered, for laminates with equal plies, as a kind of elastic symmetry, corresponding to the isotropy of the coupling tensor).

In a true optimal design, the requirements concerning elastic symmetries should hence be taken into account directly in the design phase; unfortunately, this is not done, generally speaking. Actually, the most part of times, designers look for the solution in a special class of laminates, for instance in that of balanced and symmetric sequences. This is done to circumvent the difficulties of a general true optimal approach, but,

unfortunately, the choice to look for solutions in a special class of laminates does not guarantee the true optimality with respect to a given objective.

Recently, Vannucci [1] and Vannucci and Vincenti, [2] proposed an approach to the design of a laminate with respect to its elastic and thermo-elastic symmetries: the problem is formalized as a minimum problem, the cost function being constructed in a totally general way, i.e. without restrictions, using the so-called polar method of Verchery, [3], [4], a tensor representation based upon tensor invariants linked to material symmetries.

In this paper, the authors have integrated the above approach to the optimal design of a laminate with respect to a given objective; in this case, the objective function is a classical cost function, concerning for instance stiffness or strength or a buckling load and so on, while the design of the prescribed material symmetries of the laminate is stated as an equality constraint of the optimal problem. Other constraints, of different nature, can be taken into account too, as well as several objective functions. In this way, the design of a laminate is reduced to a global, unified approach, without the use of simplifying but restrictive assumptions on the type of the sacking sequence: the true optimal laminate can hence be found.

This approach need the use of a suitable numerical technique for the search of the optimal solution; to this purpose, the authors have improved a previous genetic algorithm, BIANCA, which is now a cluster of genetic algorithms, able to deal with constrained multi-objective problems with variables of any type, and coded in several different ways, at the same time, and making use of several genetic operators (niching, multi-population, elitism, different types of cross-over and selection and so on).

In this paper, the bases of the formulation of laminate global optimal design are outlined, along with the main features of the algorithm BIANCA. Some numerical examples are then presented to show the effectiveness of the approach; they concern stiffness design, strength design, buckling load maximization, frequency design and some multi-objective problems.

REFERENCES

[1] P. Vannucci, "Designing the elastic properties of laminates as an optimisation problem: a unified approach based on polar tensor invariants", *Int. J. Struct. Multidisc. Optimis.*, Vol. **31**, pp. 378-387, (2006).

[2] P. Vannucci, A. Vincenti, " The design of laminates with given thermal/hygral expansion coefficients: a general approach based upon the polar-genetic method", *Composite Struct.*, Vol. **79**, pp. 454-466, (2007).

[3] Verchery G., "Les invariants des tenseurs d'ordre 4 du type de l'élasticité", *Proc. of Euromech 115*, Villard-de-Lans, pp. 93-104 (1979).

[4] P. Vannucci, "Plane anisotropy by the polar method", *Meccanica*, Vol. **40**, pp. 437-454, (2005).