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Least-weight design of composite structures: an unconventional and general approach

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This work deals with the problem of the least-weight design of a multilayer composite plate introducing neither simplifying hypotheses nor standard rules for determining the optimum stack. In this context, the design task is stated as a constrained non-linear programming problem (CNLPP) wherein requirements of different nature are integrated as optimisation constraints. Such constraints include mechanical requirements (admissible material properties, first buckling load, membrane stiffness), together with geometrical and technological restrictions.
A multi-scale two-level optimisation methodology (MS2L) is proposed, [1]-[2], that aims at optimising simultaneously both geometrical and material parameters at two characteristic scales: the macro and meso scales.
The macroscopic behaviour of the laminate is managed by the MS2L optimisation strategy through the polar parameters (in the framework of the equivalent single layer theories) while a special hybrid algorithm (genetic + gradient-based algorithm) perform the lay-up solution search.
In this context, the design problem is split into two different (but related) optimisation problems. At the first level (macroscopic scale) the goal is to find the optimum value of the laminate thickness and its polar parameters that minimise mass and meets the full set of constraints for the problem at hand. The second-level problem focuses on the laminate mesoscopic scale (i.e. the ply-level). Here the goal is to determine at least one stacking-sequence meeting the optimum value of both mechanical and geometrical design variables provided by the first-level problem. The search of the optimum stack is realised in the space of the so-called *quasi-trivial* solutions [1].
The MS2L approach allows to design plates that are lighter (about 10%) than those obtainable with classical approaches typically used for aerospace structures and with equivalent or superior mechanical properties. The effectiveness of the proposed configurations is proven through an experimental campaign conducted at I2M laboratory.

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