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SIMULTANEOUS SHAPE AND MATERIAL OPTIMIZATION OF SANDWICH PANELS WITH HONEYCOMB CORE FOR ADDITIVE MANUFACTURING

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Summary: *this works deals with the problem of the optimum design of a sandwich plate composed of CFRP faces and Al honeycomb core. The proposed design strategy is a multi-scale numerical optimization procedure that does not make use of any simplifying assumption to find a global optimum configuration of the system. The goal of such a procedure consists in simultaneously optimizing the shape of the unit cell of the honeycomb core (meso-scale) and the geometrical as well as the material parameters of the CFRP laminated skins (meso and macro scales). To prove its effectiveness, the multi-scale optimization strategy is applied to the problem of the least-weight design of a sandwich panel subject to constraints of different nature: on the positive-definiteness of the stiffness tensor of the core, on the admissible material properties of the laminated faces, on the local buckling load of the unit cell of the core, on the global buckling load of the panel and geometrical as well as manufacturability constraints linked to the fabrication process of the honeycomb core.*

1. PROBLEM DESCRIPTION

This study can be placed within the conceptual framework of the works originally proposed by Catapano and Montemurro [1-3] and can be seen as a generalization and also as an extension of those works. The objective of the present work is twofold: on one hand, we want to formulate and solve the problem of designing a sandwich panel as an optimization problem on different scales and, on the other hand, we want to realize a simultaneous shape and material optimization of the whole structure (at every scale).

The optimization strategy presented in this work is applied to a sandwich plate composed of two CFRP quasi-homogeneous fully orthotropic laminated (identical) skins and an aluminum honeycomb core whose unit cell has a shape that will be optimized during the design process as illustrated in Fig. 1. The goal of the design strategy is the minimization of the weight of the sandwich plate subject to constraints of different nature, i.e. mechanical, geometrical, feasibility and manufacturability constraints. The optimization procedure is articulated into two distinct (but linked) problems as described in the next section.

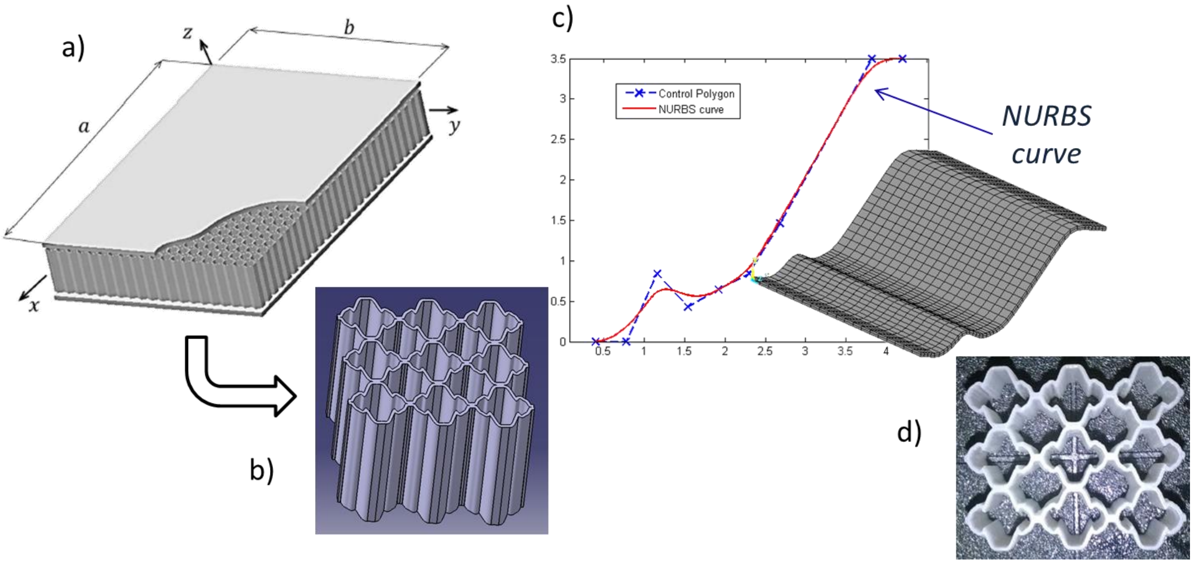

Figure 1: a) geometry of the sandwich plate, b) geometry of the core, c) geometry of the representative volume element (RVE) of the unit cell and the related FE model and d) the fabricated prototype

2. THE TWO-LEVEL OPTIMIZATION STRATEGY

2.1 First-level problem

The aim of this phase is the determination of the optimal shape of the unit cell (described in the mathematical framework of NURBS curves [4]) together with the material and geometric parameters of the laminated skins in order to minimize the weight of the structure and to satisfy, simultaneously, the full set of optimization constraints. At this level each skin is modeled as an equivalent homogeneous anisotropic laminate whose behavior at the macro-scale is described in terms of laminate polar parameters, see [2, 5]. Concerning the model of the honeycomb core, the first-level problem involves two different scales: the meso-scale of the repetitive unit cell characterized by its geometric variables, as well as the macro-scale where the core itself is modeled as a homogeneous orthotropic solid whose equivalent material properties depend upon the geometric parameters of the unit cell. Therefore, the link between these two scales is represented by the homogenization phase of the honeycomb core, see [1, 2].

2.2 Second level problem

At the second level of the strategy, we have to determine the optimal lay-up for both skins (the skin meso-scale) meeting the optimal combination of their material and geometrical parameters provided by the first level of the strategy. The goal of this phase is, hence, to find at least one stacking sequence which has to be quasi-homogeneous, fully orthotropic and that has to satisfy the optimal polar parameters resulting from the first step. At this level of the strategy, the design variables are the layer orientations, see [2].

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