Hierarchical optimization of laminated fiber reinforced composites

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Abstract

The aim of this work is to perform hierarchical optimization [1] in laminated composite structures, considering simultaneously macroscopic and microscopic levels in the design of the structure and its material. In the macroscopic level, the optimization algorithm cares with orientations and fiber volume fractions of unidirectional composite material layers. In the microscopic level, the goal is to define the microstructure of the layers by determining the cross-sectional size and shape of the reinforcement fibers. Both macro/micro scales are coupled by a resource constraint and interchange derivative information. The objective is to minimize compliance under a total fiber volume fraction constraint.

A previous work on this line [2] treated the layered composites by finite element models where each layer was represented by a group of 3D finite elements. In each of those layers, a representative cell of the microstructure was defined by topology optimization in accordance with the hierarchical optimization approach. However, in the present case, the layered composites are treated by finite elements based on laminated plate/shell theory. The fibers cross section is constrained to be elliptical, but with variable size and aspect ratio. The present approach is more restrictive but is interesting in face of the cross-sectional shape of fibers more commonly available for composites fabrication.

The variation of the size and shape of the fibers is considered by response surfaces for the constitutive parameters of a composite lamina in terms of the fiber dimensions. Such surfaces are built upon function and derivative information [3] of constitutive parameters, evaluated from material microstructural models using asymptotic homogenization techniques. The layers' orientations are chosen using the discrete material optimization (DMO) approach [4], where lists of candidate materials are interpolated by weighting functions, whose values are to be determined by optimization.

Results in laminated plates show the influence of the reinforcement fibers' shape and volume fraction in the global behavior of the test structures. The optimal microstructures obtained are strongly influenced by the global loading conditions considered. It is shown that the present optimization procedure permits to improve the global behavior of structures when material microstructural characteristics are taken into account.

Keywords: hierarchical optimization, laminated composites

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