5469

Hierarchical Optimization of Fiber Reinforced Composites for Natural Frequencies

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Hierarchical topology optimization has the purpose of optimally design the material distribution layout of a structure in two distinct levels: one macro-mechanical (or structural, global) and the other micro-mechanical (or material, local), in a simultaneous and integrated way. In the macro level, design in terms of optimal material distribution on the general layout of the structure is taken into account. In the micro level, it is searched the constitutive properties optimal design, in terms of defining the distribution of material phases in microstructure representative unit cells. This general approach is here extended to laminated composites optimization: at the macro level, orientations and fiber volume fractions are defined for unidirectional composite material layers and, at the micro level, it is designed the shape of the reinforcement fibers. The objective is to maximize the first natural vibration frequency in laminated plates subjected to constraints to limit the total fiber volume fraction employed and also to keep the second vibration frequency within a predefined distance from the first. In this problem multiple eigenvalues are possible and this leads to non-differentiability, which requires treatment using non-smooth optimization concepts.

5519

Simultaneous Optimization of Orientation and Concentration in Piezoelectric Composites

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Optimization is applied to the problem of piezocomposites by simultaneously account for the concentration and orientation of the constituents. Existing studies in piezocomposites are confined to independently identifying either the optimal volume fraction or the orientation of the piezoelectric phase. Four different composite configurations of single crystal/polycrystal piezoelectric with polymer are analyzed. Polarization orientation plays a crucial role in the overall piezoelectric properties of such materials. Thus the orientation distribution parameters of a polycrystalline piezoelectric sample in a two-phase composite critical along with the volume fraction of either phases. Nevertheless, this choice is complicated and it is impossible to analyze all possible permutations and combinations of the piezoelectric volume fraction and distribution parameters or the angles themselves. Optimal design variables which would generate single-/poly-crystalline configurations that enhance the macroscopic piezoelectricity

are identified. It is found that juxtaposing a preferentially oriented piezoelectric material with a polymer into a composite would result in increase of piezoelectric figure of merit from constituent phases.

5569

Optimal Design of Composite Structures Subjected to Fatigue Loading in a Fuzzy Environment

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The efficient and effective use of composite materials in design applications is directly connected with the good knowledge of the static and fatigue strengths of the material. However, experimental data, especially for fatigue tests, have ranges of scatter affected by variability in material microstructure from one test specimen to another, of course, if we do not want to mention also about the effects of stacking sequences etc. Typically, the variability in material parameters makes it difficult to accurately predict the response of structural components and significantly affects the reliability of designs see e.g. the monograph [1]. Therefore, commonly the probability theory is employed to characterize variability in material parameters. The materials characteristics are treated as random variables with assumed probability density distributions. However, the critical review (see Yang et al. [2]) of existing probabilistic descriptions of fatigue test demonstrates evidently that: (i) there is no unique approach (or methodology) that may be used for the statistical characterization of fiber composite fatigue life data, (ii) there is lack of one and only one probability density distributions which may describe fatigue tests for composite materials although it is commonly assumed that fiber reinforced materials follow a Weibull distribution, (iii) a construction of probability density distributions requires sufficient (commonly a great number) experimental data.

Composite structures are usually made of many layers. Each of layers may have different thicknesses and fiber orientations. Thus, for various stacking sequences of laminates it is possible to obtain different values of failure loads. The physical nature of the composite material (two-phases structure) results in statistical distributions of failure loads due to the variability of properties. A scatter of properties has a different origin, but, in general, it may be divided and classified in the following manner: (1) geometric properties (imperfections), (2) physical and mechanical properties, (3) environmental effects (exploitation), (4) technology understood in the sense of geometric dimensions but as an origin of local defects, a scatter of fiber directions etc.

The application of the fuzzy set theory [3] is describe on the example of the analysis of rectangular plate subjected to axial load. The variability of the fatigue plate strain is studied. The optimization problem is formulated as the λ-problem in which a maximum of the λ parameter is searched for – see Ref. [4].

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