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Concurrent Multi-scale Optimization of Composite Frame Structure

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Abstract

The paper aims to discuss the problem of concurrent multi-scale optimization design of composite frame structure which is widely used in aerospace industry for its advantages of lightweight and large spatial span. The concurrent optimization model based on the minimum structural compliance or maximum structural fundamental frequency are established. The fiber winding angle and the tube's inner radius are chosen as the independently design variables defined on two geometrical scales (material micro- and structural macro- scales) respectively. Then the optimization of macro structural topology and micro fiber orientation can be realized simultaneously with respect to their coupling effects. Considering manufacturing and cost requirements, the design variables(winding angle of the fiber) in micro-scale are constrained with discrete characters, that is to say, only limited values can be chosen from a predefined allowable set. To overcome the difficulty due to the discrete characters for the gradient based optimization algorithm, the improved Heaviside penalization discrete material optimization (HPDMO) interpolation scheme is adopted. The sensitivity analysis are also deduced with respect to the design variables defined on the two geometrical scales. The optimal results from the different optimization models (single-scale, concurrent multi-scale) are presented and compared via to some numerical examples. It is shown that the concurrent optimization can further explore the potential of composite frame structures and to achieve better structural performances. The novel concurrent two-scale optimization model provides a new choice for the design of the composite frame structures in aerospace and other industries.