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Design and optimization of a variable stiffness composite laminate

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Abstract

With the wide use of fiber-reinforced composite laminates in aerospace industry, structural instability is one of the most key aspects for flight vehicles. Hence, the research on structural instability mechanisms of composite laminates, especially buckling characteristics, is of great significance. In this paper, the buckling characteristics analysis and design optimization of the variable stiffness composite (VSC) panel with given geometry and material properties are studied. Pagano's three layer constant stiffness laminate is investigated as the baseline case. The method of layered modeling and numerical structural analysis of VSC panel in the commercial package ABAQUS is described. The design optimization of the VSC panel aims to maximize the critical buckling load with the fiber orientation angles at the center and end as design variables, which is solved by the sequential quadratic programming method. It is found that with the same weight, the optimal critical buckling load of the designed VSC panel is increased up to 67.9% compared to the baseline laminate. To further verify the accuracy of the optimal design solution, based on the first von Karman equation, critical buckling load differential equation of a rectangular laminate is deduced, and the fiber orientation angle corresponding to the optimal critical buckling load is derived by theoretical analysis, which is compared with the optimal critical fiber angle by optimization. It is noticed that the two critical fiber angles show great agreement to each other. Therefore, the finite element analysis in conjunct with optimization method is proved to be accurate for solving buckling issues of VSC laminates, which thus could be used in further study of the performance of VSC laminates. It is concluded that, compared to the traditional fiber-reinforced composite laminates, the VSC laminates can be designed with more flexibility to achieve better load redistribution, resulting in great improvements of the structural performance.

Keywords: variable stiffness composites; buckling analysis; design optimization; finite element analysis.