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Buckling Load Optimization of Variable stiffness composite Plate Using FEM and Semi-analytical method

By

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Abstract

The advent of new composite manufacturing techniques like Automated Fiber Placement (AFP) offers greater flexibility in structural designs by allowing curvilinear fiber paths. Hence, it is now possible to change laminate stiffness locally, thereby enabling Variable Stiffness (VS) composite structures. Such structures demonstrate superior buckling performance over traditional constant stiffness structures. However, obtaining the optimum fiber paths to improve buckling performance remains an open area of research due to the complexity of determining such fiber paths. This research investigated two approaches for optimizing fiber paths; First, a Finite Element Method (FEM) approach that utilizes linear shape functions to interpolate local fiber angle variation within the plate when given angle values at global manufacturing mesh nodes. Second, a new semi-analytical formulation for calculating in-plane load distribution and stability of a composite laminated plate, with spatial variation in ply-by-ply fiber angles. Double Fourier series approximation is used to achieve variable fiber angle distribution. Ritz method is used to find the approximate solution for the boundary value problem. Using the developed methods, optimization studies were conducted on uniaxially compressed, eight-ply symmetric composite laminate plate, with univariate and bivariate fiber angle distribution. The study used Genetic-Algorithm(GA) and Quasi-Newton method of Broyden, Fletcher, Goldfarb, and Shanno (BFGS) as optimization formulation. The results not only show an 87% and 67% improvement in buckling load for a VS plate using FEM and Semi-analytical method respectively but also provides a better understanding of the influence of fiber angle distribution.