Exact Solutions for Buckling and Post-buckling of Functionally-Graded Graphene-Reinforced Composite Beams Postprint

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Abstract

The nonlinear buckling and post-buckling mechanical behaviors of graphene platelet (GPL) reinforced functionally graded beams are investigated using an exact analytical solution method. The study assumes that GPLs are uniformly distributed in each layer of the beam, but their weight fraction varies gradiently or uniformly through the thickness direction, resulting in continuous gradient variation of the structural material properties along the thickness direction. The equivalent material properties are obtained based on the Halpin-Tsai micromechanical model and the rule of mixtures. Simultaneously, the nonlinear governing equations for graphene platelet reinforced functionally graded beams are derived using the energy variational method based on Euler-Bernoulli beam theory and Von Kármán nonlinear strain-displacement relations. Exact analytical solutions of these equations are obtained to derive analytical expressions for the critical load, buckling mode, and post-buckling deformation. Furthermore, a parametric study is conducted to analyze the influence of GPL weight fraction, geometry, size, and distribution pattern on the nonlinear buckling and post-buckling of the composite beam.

Full Text

Preamble

This preamble presents a series of mathematical formulations and technical specifications that establish the foundation for the subsequent analysis. The initial expressions introduce core concepts, followed by publication metadata and structural definitions that frame the problem space.

The problem is formally constrained by mathematical conditions, with additional technical conditions specified through MATH_{0001} . These constraints define the boundaries within which the subsequent analysis operates.

Further mathematical constructs establish key relationships and parameters, systematically developing the theoretical framework required for the study.

Subsequent expressions refine the model specification, introducing progressively more detailed relationships and variables. Later sections address computational aspects, providing the algorithmic foundations necessary for implementation. The preamble concludes with final definitions that complete the technical preliminaries, including MATH_{0004} , thereby establishing a rigorous basis for the research that follows.

Note: Figure translations are in progress. See original paper for figures.