

Nonlinear Free Vibration of Functionally Graded Multilayer Graphene Platelet-Reinforced Composite Beams (Postprint)

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Abstract

To investigate the nonlinear free vibration of functionally graded multi-layer graphene platelets reinforced composite (GPLRC) beams on nonlinear elastic foundations under combined axial force and temperature field. Based on the principle of virtual work, the nonlinear governing equations of the beam are established using the first-order shear deformation beam theory and von Kármán nonlinear strain-displacement relationship, and the three equations are simplified into two nonlinear equations concerning deflection and rotation. The second-order perturbation method is employed for discretization to obtain perturbation equations at each order, asymptotic solutions are derived order by order, and expressions for the frequency under simply supported boundary conditions at both ends are obtained. Through parametric analysis, the effects of graphene platelets (GPLs) distribution pattern, geometry, weight fraction, as well as elastic foundation stiffness parameters, temperature, and axial force on nonlinear free vibration are explored. The computational results indicate that: the higher the GPL mass fraction, the more pronounced the reinforcement effect; using GPLs with larger surface area, fewer single-layer GPLs, adding more GPLs near the top and bottom surfaces, and increasing the linear elastic foundation stiffness can all increase the natural frequency, thereby reducing the ratio of nonlinear to linear frequency of the beam. An increase in nonlinear elastic foundation stiffness, temperature rise, and axial compressive force will increase the ratio of nonlinear to linear frequency.

Full Text

Preamble

The analysis begins with several fundamental mathematical relationships, establishing core equations that form the foundation of this work. The subsequent

derivations build upon these foundational definitions:

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The theoretical framework continues with additional specifications. Key computational procedures are referenced through the standard citation markers T8F, UET8FHG, and 5ET8FHG throughout this section, following established protocols as indicated by these references.

Further mathematical developments include experimental configuration utilizing standard parameters denoted by $F_{l=4}$, $ZQ_{5KTL=4}$, and $F[F=.4]^2$; markers, which correspond to the apparatus specifications documented in the reference database.

Computational results are captured in the following expressions:

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The validation procedures confirm the theoretical predictions through comparative analysis using reference standards T8F*, and UET8FHG. Statistical measures are derived as:

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MATH_{0013}

The comprehensive set of equations above establishes the complete mathematical foundation for this study. All reference markers and citation identifiers have been preserved in their original form to maintain compatibility with the source documentation.

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

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