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A Finite Element Analysis to Assess the Piezoelectric Non-linearity in Composite Laminated Plate

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Abstract

Piezoelectric actuators have been widely used in structural control applications of automotive and aerospace engineering. The numerical and experimental tests show that the linear model applies only to the low electric field where piezoelectric material properties are independent of the electric field whereas at the high electric field the performance of the actuator deviates from the linear model. Investigating the effects of the nonlinear piezoelectric parameters is crucial for the accurate analysis, design, and operation of piezoelectric structures operating under high electric fields. This paper provides a finite element model based on higher-order shear deformation theory to analyse the effect of considering higher-order nonlinear piezoelectric constitutive equations on the static analysis of

composite laminated plates at high electric fields. The composite laminated plate bonded with piezoelectric actuators at the top and bottom is used to determine the effect of considering electrostriction and elastostriction coefficients in the piezoelectric constitutive equation. The applied electric potential in the piezoelectric composite plates is taken to be a linear function across the piezoelectric layer. To determine the non-linear effect in the piezoelectric composite laminated plate under a high electric field, a static analysis is performed by varying the orientation of composite layers and boundary conditions of the plate. The accuracy of the present finite element formulation is validated by comparing it with existing results from the literature. The results of static analysis highlight the importance of considering both higher-order non-linear piezoelectric coefficients in finding the deflection and stresses of composite laminated plates. © 2025 The Aeronautical and Astronautical Society of the Republic of China. All rights reserved.

Author keywords

Composite plate; Elastostriction; Electrostriction; Finite element model; Piezoelectric structure

Indexed keywords

Engineering controlled terms

Constitutive equations; Constitutive models; Electrooptical effects; Electrostriction; Laminated composites; Piezoelectric ceramics; Piezoelectricity; Plates (structural components); Shear deformation; Structural analysis

Engineering uncontrolled terms

Composite laminated plates; Composite plates; Elastostriction; Electrostriction; Finite element modelling (FEM); High electric fields; High-order; Linear modeling; Piezoelectric; Piezoelectric structures

Engineering main heading

Piezoelectric actuators

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