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Hygro-thermal vibration analysis of graded double-refined-nanoplate systems using hybrid nonlocal stress-strain gradient theory

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Abstract

A new dynamic modeling and free vibrational analysis of double-layered nanoplates made of functionally graded (FG) materials in hygro-thermal environments is presented for the first time. A better description of size-dependent phenomena is presented using a nonlocal stress-strain gradient theory. The double-layered nanoplate is subjected to hygro-thermal loading and it is resting on elastic medium. The gradation of material properties is considered using power-law model. Modeling of double-layered nanoplate is conducted according to a refined four-variable plate theory with fewer field variables than first order plate theory. The governing equations and related classical and non-classical boundary conditions are derived based on Hamilton's principle. These equations are solved for hinged nanoplates via Galerkin's method. It is indicated that type of vibration, moisture rise, temperature rise, nonlocal parameter, strain gradient parameter, material gradation, elastic foundation and side-to-thickness have a remarkable influence on vibration behavior of double-layered nanoscale plates.

Keywords: Double-layered nanoplate, Hygro-thermal environment, Nonlocal strain gradient theory, Four-variable plate theory

1. Introduction

Excessive stresses due to drastic moisture and temperature gradients make the engineering structures susceptible to failure. The influence of temperature is known as thermal effect and the influence of moisture absorption from the atmosphere is known as hygroscopic effect. Since functionally graded (FG) structures are usually exposed to environmental conditions, analysis of combined effect of moisture and temperature on their mechanical behavior is of great importance