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Geometrical nonlinear bending characteristics of SWCNTRC doubly curved shell panels

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Abstract. In this paper, geometric nonlinear bending characteristics of single wall carbon nanotube reinforced composite (SWCNTRC) doubly curved shell panels subjected to uniform transversely loadings are investigated. The nonlinear mathematical model is developed for doubly curved SWCNTRC shell panel on the basis of higher-order shear deformation theory and Green– Lagrange nonlinearity. All nonlinear higher order terms are included in the mathematical model. The effective material properties of SWCNTRC are estimated by using Eshelby-Mori-Tanaka micromechanical approach. The governing equation of the shell panel is obtained using the total potential energy principle and a Newton-Raphson iterative method is employed to compute the nonlinear displacement and stresses. The present results are compared with published literature. The effect of SWCNT volume fraction, width-to-thickness ratio, radius-to-width ratio (R/a), boundary condition, linear and nonlinear deflection, stresses and different types of shell geometry on nonlinear bending response is investigated.

Keywords: SWCNTRC shell panel; micromechanics; nonlinear bending; green-lagrange nonlinearity; HSDT; newton-raphson method

1. Introduction

Wide application of reinforced composite shells in mechanical, civil, aeronautical, automotive, biomedical, nuclear, petro-chemical and marine engineering has created the necessity of the analysis of their responses precisely. It is well known that the shell structures are much stronger and stiffer than other structural forms due to their geometrical form (three-dimensional curvatures). Some researchers are reported in literature review as follow: Lal *et al.* (2011) investigated nonlinear bending response of laminated composite spherical shell panel with system randomness subjected to hygro-thermo-mechanical loading. Sadowski and Michael (2013) presented solid continuum finite elements and shell finite elements in the modeling of the nonlinear plastic buckling behavior of cylindrical shells. Jin *et al.* (2013) reported vibration analysis of moderately thick composite laminated cylindrical shells with arbitrary boundary conditions. Song *et al.* (2016) expressed nonlinear vibration analysis of CNT-reinforced

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$$[S]_{30,18} = 3\beta_y \ ; \ [S]_{31,15} = \frac{1}{2}\frac{\partial \beta_x}{\partial x} \ ; \ [S]_{31,17} = \frac{1}{2}\frac{\partial \beta_y}{\partial x} \ ; \ [S]_{31,23} = \frac{1}{2}\frac{\beta_x}{R_1^2} \ ; \ [S]_{32,16} = \frac{1}{2}\frac{\partial \beta_x}{\partial y} \ ;$$

$$[S]_{32,18} = \frac{1}{2}\frac{\partial \beta_y}{\partial y} ; [S]_{32,24} = \frac{1}{2}\frac{\beta_y}{R_2^2} ; [S]_{33,15} = \frac{\partial \beta_x}{\partial y} ; [S]_{33,17} = \frac{\partial \beta_y}{\partial y} ; [S]_{33,23} = \frac{\beta_y}{R_1 R_2}$$