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Analytical solution for nonlinear postbuckling of functionally graded carbon nanotube-reinforced composite shells with piezoelectric layers

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Abstract. This paper presents an analytical solution procedure for the nonlinear postbuckling analysis of piezoelectric functionally graded carbon nanotubes reinforced composite (FG-CNTRC) cylindrical shells subjected to combined electro-thermal loadings, axial compression and lateral loads. The carbon nanotubes are assumed to be aligned and straight with uniform and functionally graded distributions in the thickness direction. The kinematics and constitutive relations are written on the basis of the classic theory and the von Kármán nonlinear strain–displacement relations of large deformation. Applying the Ritz energy approach, analytical solutions are proposed for the nonlinear critical axial load, lateral pressure as well as the load-shortening ratio of the piezoelectric FG-CNTRC shell. Numerical results are presented to study the effects of dimensional parameters, CNT volume fraction, distribution type of the reinforcement and piezoelectric thickness on the nonlinear buckling behavior of the piezoelectric nanocomposite shell. It is revealed that the carrying capacity of the structure increases as the shell is integrated by the piezoelectric layers and reinforced by higher CNT volume fraction. Furthermore, FGX- and FGO- CNTRC piezoelectric shells are indicated to have higher and lower carrying capacities compared to UD-CNTRC piezoelectric shells, respectively.

Keywords: A. Carbon-carbon composites; A. Smart materials; A. Nano-structures; B. Buckling; C. Analytical modelling.

1. Introduction

In recent years, carbon nanotubes as the reinforcement materials in the composite structures have attracted a lot of attention [1, 2]. This is due to the promising thermo-mechanical properties of CNTs such as low density, high strength and stiffness-to-weight ratio. So, replacing the traditional carbon fibers by carbon nanotubes in a matrix can effectively improve composite properties and consequently brings about their application in reinforcing the composites, electronic devices and etc [3-6]. However, the volume fraction of carbon nanotubes in a polymer is limited so that, a more amount may lead to deterioration of their mechanical properties [7]. To overcome this shortcoming, Shen [8] combined the concept of the functionally graded material with CNTs through a nonuniform distribution of CNTs along the thickness

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