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PII: S1359-8368(18)30117-3

DOI: 10.1016/j.compositesb.2018.05.037

Reference: JCOMB 5707

To appear in: *Composites Part B*

Received Date: 11 January 2018

Revised Date: 20 April 2018

Accepted Date: 24 May 2018

Mechanical buckling analysis of functionally graded power-based and carbon nanotubes-reinforced composite plates and curved panels

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Abstract

The main aim of this paper is to investigate the mechanical buckling behavior of functionally graded materials and carbon nanotubes-reinforced composite plates and curved panels. The governing equations are established using a double directors finite element shell model which induces a high-order distribution of the displacement field and takes into account the effect of transverse shear deformations. The effective material properties of functionally graded materials are estimated using a power law distribution and those of nanocomposites by an extended rule of mixture with some efficiency parameters. Uniform and four profiles of carbon nanotubes are considered to describe the distribution of these reinforcements through the thickness of the nanocomposite shell structure. A comparison study of the present results with those available in the literature is carried out for the isotropic case in order to prove the validity as well as the accuracy of the present model. Then, the results are extended to functionally graded materials and nanocomposites. The results reveal that the critical buckling load of plates and curved panels can be significantly increased as a result of a functionally graded reinforcement. They also show that the mechanical buckling behavior of such structures is significantly influenced by the plate aspect ratio, the length-to-thickness ratio, radius-to-thickness ratio, boundary conditions, power law index as well as the carbon nanotubes profiles and their volume fractions.

Keywords:
Mechanical buckling, FGM, FG-CNTRC, High-order, Double directors shell model.

1. Introduction

The buckling load of a shell structure is a key factor in design considerations for many industries such as aerospace, aeronautic, aircraft, civil engineering and automobiles. In fact, when a shell structure is subjected to a compressive load along its edge, the shell is deformed but remains flat as a long as the edge forces are adequately small and there is no initial imperfection in geometry of the structure. As the load increases, an unstable state reaches as a result of which the shell structure bends slightly. The minimum in-plane edge compressive load required just to initiate such instability is called critical buckling load parameter. The determination of such factor has also attracted the attention of many researchers which have developed many analytical and numerical methods to analyze as well as to predict the buckling behavior of plate and shell structures. Three mainly theories are often used for mechanical analysis of shell structures which are: The classical plate theory (CPT), the first order shear deformation theory (FSDT) and the high-order theories (HSDT). The detailed information on these theories can be found in the literature [1, 2, 3].

Recently, a new class of materials known as functionally graded materials (FGMs) has emerged due to their high performances. These novel materials were first introduced by a group of scientists in Sendai, Japan

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