Composites Part B 94 (2016) 1–10

Contents lists available at ScienceDirect

Composites Part B

journal homepage: www.elsevier.com/locate/compositesb

Determination of critical buckling loads of isotropic, FGM and laminated truncated conical panel

Çiğdem Demir, Kadir Mercan, Ömer Civalek*

Akdeniz University, Engineering Faculty, Civil Engineering Department, Division of Mechanics, 07058, Antalya, Turkey

ARTICLE INFO

Article history:
Received 3 February 2016
Received in revised form
25 February 2016
Accepted 11 March 2016
Available online 24 March 2016

Keywords:
A. Lamina/ply
B. Buckling
C. Computational modelling

ABSTRACT

The present study deals with buckling analysis of simply supported conical panels based on the Donnell's shell theory. Different material properties have been considered such as isotropic, composite laminated and functionally graded (FG). The governing differential equation for buckling of laminated conical panel is derived. These equations are discrete using method of discrete singular convolution (DSC). Shannon's delta kernel is used for trial functions. To check the presented DSC method and computer program, the critical buckling loads for isotropic and composite conical panels are calculated which compare very well with earlier available results. The effect of some geometric parameters and material parameters on critical buckling of panels is also investigated. It is noticed that the present DSC methodology can predict accurately the buckling loads of conical panels.

1. Introduction

Curved structural components such as panels and shells are extensively used in many engineering area such as; civil, aerospace, automobiles, mechanical, piping industries, marine and pressure vessels members. The curved structural members such as circular and conical panels are the main components in these systems. During the past fifty years, different shell theories have been used for modeling of the shell structures [1]. Classical shells theories and different kinds of higher order shear deformation theories are the two-main types of these theories. Related formulations and details on these theories can be found in the literature [1–8]. In addition to this, laminated composite materials have also been generally used because of their positive material and strength properties. Linear and nonlinear vibration and dynamic analysis of plates, panels and shells are extensively studied by researcher via different numerical methods [9–25]. Tornabene [26] presented a good and detailed review on these approaches. During the modeling of the structures, different types of material combinations can be considered. In the past ten years, by using the functionally graded materials (FGM) in different engineering applications, FGM structures such as plates, beams, shells and panels are gaining the considerable importance and find great deal of applications in high temperature applications [27,28]. Mechanical and thermal analysis of FGM structures in the literature is reviewed by Birman and Byrd [29] and Thai and Kim [30].

During the past years, many researchers have interested on buckling of Shell type structures. Axisymmetrical buckling of circular cones under axial compression was studied by Seide [31]. Stability of functionally graded truncated conical shells reinforced by functionally graded stiffeners and surrounded by an elastic medium and buckling of cylindrical and conical shells under compression are investigated by Dung et al. [32,33]. Abediokhchi et al. [34] give a GDQ solution for buckling of laminated conical panels. Shakouri and Kouchakzadeh [35] investigated the buckling problem of conical shells. Low buckling loads of axially compressed conical shells is given by Baruch et al. [36]. A simple solution for buckling of laminated conical shells is given by Tong and Wang [37]. Analytical solutions for bending, buckling and vibration responses of cross-ply circular cylindrical shells using first-order shear deformation theory are presented by Shadmehri et al. [38]. By using the Ritz method, buckling analysis of composite shells is given by Shadmehri et al. [39]. Buckling analyses of conical shells with different material properties have been investigated by Sofiyev [40]. Mercan and Civalek [41] give a DSC solution for buckling of BNNT. Naj et al. [42] and Ajdari et al. [43] have investigated buckling problem of conical shells under different loading conditions. Post-buckling and buckling characteristics of shells are carried out by Patel et al. [44,45]. Static and dynamic buckling and postbuckling of shallow spherical shells are investigated and presented by Nath and

* Corresponding author. Tel.: +90 242 3106319; fax: +90 242 3106306.
E-mail address: civalek@yahoo.com (Ö. Civalek).

http://dx.doi.org/10.1016/j.compositesb.2016.03.031
1359-8368/

Sandeep [46]. Torsional and bending buckling and post-buckling of shells has been given by Shen [47]. Bending, vibration and buckling responses of circular cylindrical shells are analytically investigated and some benchmark results presented by Khdeir et al. [48]. Thermal buckling of functionally graded cylindrical shells has been presented Shahsiah Eslami [49]. Thermal and mechanical instability problem of functionally graded truncated conical shells have been formulated and some results are presented by Naj et al. [42]. Buckling analyses of composite conical shells and CNT reinforced shell elements have been studied by Mirzaei and Kiani [50] and Jam and Kiani [51]. The buckling of truncated conical sandwich panels under axial compression and external pressure is solved by Fard and Livani [52]. Detailed results related to mechanical and thermal buckling of functionally graded conical shell panels have been presented by Zhao and Liew [53].

Buckling of shell structures have also been analyzed by this time in many of articles mentioned above. However, relatively less studies have been devoted on buckling analysis of conical panels especially panel with FG material [52–54]. The motivation for performing the present study is to give a simple and efficient method for determination of critical axial buckling loads of conical panels with different material composition. For this purpose, a relatively new method, discrete singular convolution (DSC) is used for numerical simulations. The governing differential equations of buckling of the conical panel are derived via Donnell's shell theory. Then, the method of discrete singular convolution (DSC) has been used for discretization of governing differential equations for axial buckling.

2. Formulations

Laminated composite conical panel and geometric properties are shown in Fig. 1. Conical shell panel with length L in related direction, semi-vertex angle α, thickness of the shell h, subtended angle φ. The radii at the two ends are defined as R_1 and R_2, respectively. The conical panel is referred to a coordinate system (x,θ,z). The components of the deformation of the conical shell with references to this given coordinate system are denoted by u, v, w in the x, θ and z directions, respectively.

By using the Donnel's shell theory, the strain components can be written as

$$\bar{\varepsilon}_x = \varepsilon_x + z\kappa_x \tag{1a}$$

$$\bar{\varepsilon}_\theta = \varepsilon_\theta + z\kappa_\theta \tag{1b}$$

$$\bar{\gamma}_{x\theta} = \gamma_{x\theta} + 2z\kappa_{x\theta} \tag{1c}$$

where ε_x, ε_θ and $\gamma_{x\theta}$ are the strain components, and κ_x, κ_θ and $\kappa_{x\theta}$ are the curvature components, respectively. These are defined as:

$$\varepsilon_x = \frac{\partial u}{\partial x}, \tag{2a}$$

$$\varepsilon_\theta = \frac{1}{R(x)}\frac{\partial v}{\partial \theta} + \frac{u \sin\alpha}{R(x)} - \frac{w\cos\alpha}{R(x)}, \tag{2b}$$

$$\gamma_{x\theta} = \frac{1}{R(x)}\frac{\partial u}{\partial \theta} + \frac{\partial v}{\partial x} - \frac{v\sin\alpha}{R(x)} \tag{2c}$$

$$\kappa_x = -\frac{\partial^2 w}{\partial x^2}, \tag{3a}$$

$$\kappa_\theta = -\frac{1}{R^2(x)}\frac{\partial^2 w}{\partial \theta^2} + \frac{\cos\alpha}{R^2(x)}\frac{\partial v}{\partial \theta}, \tag{3b}$$

$$\kappa_{x\theta} = \left[-\frac{1}{R(x)}\frac{\partial^2 w}{\partial x \partial \theta}\right]. \tag{3c}$$

The displacement fields given in Eqs. (2) and (3) are defined by the following relations:

$$\bar{u}(x,\theta,z) = u(x,\theta) - z\cdot w(x,\theta)_{,x} \tag{4a}$$

$$\bar{v}(x,\theta,z) = v(x,\theta) - z\frac{1}{R(x)}w(x,\theta)_{,\theta} \tag{4b}$$

$$\bar{w}(x,\theta,z) = w(x,\theta) \tag{4c}$$

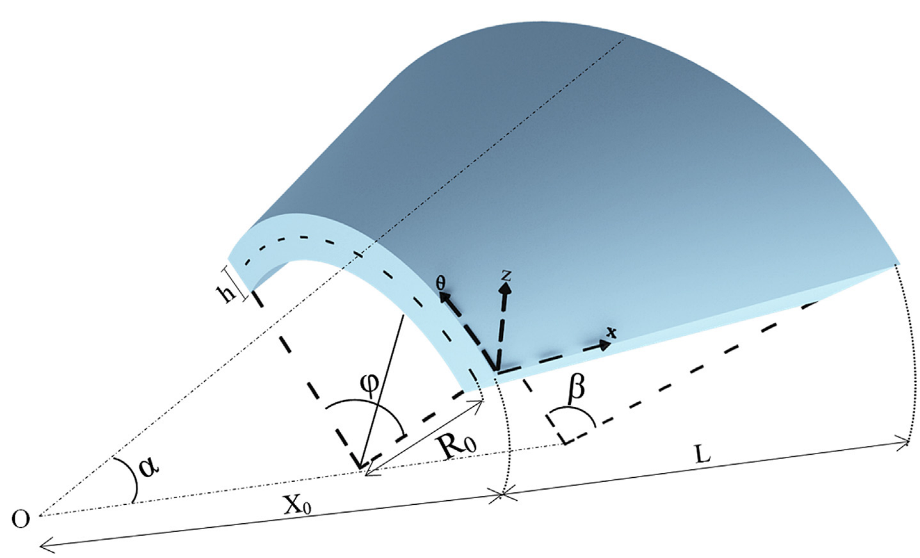

Fig. 1. A typical conical panel and related parameters.