International Journal of Non-Linear Mechanics 46 (2011) 1195–1204

Contents lists available at ScienceDirect

International Journal of Non-Linear Mechanics

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

Non-linear axisymmetric response of functionally graded shallow spherical shells under uniform external pressure including temperature effects

Dao Huy Bich [a], Hoang Van Tung [b,*]

[a] Vietnam National University, Ha Noi, Viet Nam
[b] Faculty of Civil Engineering, Hanoi Architectural University, Ha Noi, Viet Nam

ARTICLE INFO

Article history:
Received 5 April 2011
Received in revised form
23 May 2011
Accepted 26 May 2011
Available online 6 June 2011

Keywords:
Nonlinear response
Functionally graded materials
Imperfection
Temperature effects
Shallow spherical shells

ABSTRACT

This paper presents an analytical approach to investigate the non-linear axisymmetric response of functionally graded shallow spherical shells subjected to uniform external pressure incorporating the effects of temperature. Material properties are assumed to be temperature-independent, and graded in the thickness direction according to a simple power law distribution in terms of the volume fractions of constituents. Equilibrium and compatibility equations for shallow spherical shells are derived by using the classical shell theory and specialized for axisymmetric deformation with both geometrical non-linearity and initial geometrical imperfection are taken into consideration. One-term deflection mode is assumed and explicit expressions of buckling loads and load–deflection curves are determined due to Galerkin method. Stability analysis for a clamped spherical shell shows the effects of material and geometric parameters, edge restraint and temperature conditions, and imperfection on the behavior of the shells.

1. Introduction

Shallow spherical shells constitute an important portion in many engineering structures. They can find applications in the aircraft, missile and aerospace components. These shell elements also be widely used in other industries such as shipbuilding, underground structures and building constructions. As a result, the problems relating to buckling and postbuckling behaviors bring major importance in the design of this type of shell structure and have attracted attention of many researchers. Huang [2] reported an investigation on unsymmetrical buckling of thin isotropic shallow spherical shells under external pressure. He pointed out that unsymmetrical deformation may be the source of discrepancy in critical pressures between axisymmetrical buckling theory and experiment. Tillman [3] investigated the buckling behavior of clamped shallow spherical caps under a uniform pressure load. He also considered the effect of shell geometric parameters on the axisymmetric and asymmetric post-bifurcation behavior of a clamped perfect and imperfect isotropic shallow spherical cap under uniform external pressure both theoretically and experimentally. Uemura [4] employed a two-term approximation of deflection to treat axisymmetrical snap buckling of a clamped imperfect isotropic shallow spherical shell subjected to uniform external pressure. This work also assessed the effect of shell shallowness on the non-uniqueness of solution by using the second variation of total potential energy. Non-linear static and dynamic responses of spherical shells with simply supported and clamped immovable edge have been analyzed by Nath and Alwar [5] by making use of Chebyshev series expansion. Non-linear free vibration response, static response under uniformly distributed load, and the maximum transient response under uniformly distributed step load of orthotropic thin spherical caps on elastic foundations have been obtained by Dumir [6]. Static and dynamic axisymmetric snap-through buckling of orthotropic shallow spherical shells subjected to uniform pressure have also been investigated by Chao and Lin [7] using the classical thin shell theory and finite difference method. Buckling and postbuckling behaviors of laminated spherical caps subjected to uniform external pressure have been analyzed by Xu [8] and Muc [9]. The former employed non-linear shear deformation theory and a Fourier-Bessel series solution to determine load–deflection curves of spherical shell under axisymmetric deformation, whereas the latter applied the classical shell theory and Rayleigh–Ritz procedure to obtain upper and lower pressures and postbuckling equilibrium paths without considering axisymmetry. Alwar and Narasimhan [10] used method of global interior collocation to study axisymmetric non-linear behavior of laminated orthotropic annular spherical shells. Subsequently, a static and dynamic non-linear axisymmetric analysis of thick shallow spherical and conical orthotropic caps has been reported by Dube

* Corresponding author.
E-mail address: hoangtung0105@gmail.com (H. Van Tung).

0020-7462/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.ijnonlinmec.2011.05.015