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Free vibration of functionally graded porous cylindrical shell using a sinusoidal shear deformation theory

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Abstract: The present study focuses on performing a free vibration analysis of a functionally graded (FG) porous cylindrical shell subject to different sets of immovable boundary conditions. It is assumed that the modulus of elasticity of the porous composite is graded in the thickness direction. The open-cell metal foam provides a typical mechanical feature to determine the relationship between coefficients of density and porosity. A sinusoidal shear deformation theory (SSDT) in conjunction with the Rayleigh–Ritz method is employed to derive the governing equations associated with the free vibration of the circular cylindrical shell. Two types of graded porosity distributions in the thickness direction are considered. The study investigates the effects of FG porosity, boundary conditions, and geometrical parameters on free vibration characteristics of the FG porous cylindrical shell.

Keywords: functionally graded porous material; cylindrical shell; free vibration; sinusoidal shear deformation theory; Rayleigh–Ritz method.

1. Introduction

Circular cylindrical shells are widely applied as common structural components in several engineering fields including aerospace engineering, aircraft engineering, and nuclear reactors. Previous studies investigated the mechanical properties of isotropic and laminated composite cylindrical shells [1–5]. Functionally graded materials (FGMs) are microscopically inhomogeneous, since their mechanical property vary smoothly and continuously from one surface to another in the preferred direction, and this is achieved by gradually varying the volume fraction of the constituent materials [6-7]. Functionally graded (FG) porous material is a novel FGM in which porous materials are characterized by the graded distribution of internal pores in the microstructure, thereby enabling the local density to act as a design variable to achieve improved structural performance [8]. Recently, FG porous materials have received increasing attention owing to their advantages, such as low specific weight and efficient capacity of energy [9–13].

The free vibration behavior of an FGM cylindrical shell is of considerable interest for engineering design and manufacture and was extensively examined by extant studies [14–17]. Pradhan et al. [18] and Loy et al. [19] calculated the natural frequencies of an FGM circular cylindrical shell using Love's shell theory. Kim Y.-W. [20] analyzed free vibration characteristics of FGM cylindrical shells that partially rested on an elastic foundation with an oblique edge. Kadoli, R. et al. [21] investigated free vibration and linear thermal buckling for functionally graded cylindrical shells with a clamped–clamped boundary condition based on temperature-dependent material properties. Matsunaga, H. [22] studied natural frequencies and buckling stresses of FGM shallow shells by considering the effects of transverse shear, normal deformations, and rotatory inertia. Thang P. T. et al. [23] conducted an investigation on the effect of stiffeners on the nonlinear buckling of cylindrical shells with FGM coatings under a torsional load. Isvandzibaei M.R. et al. [24] presented a study on the vibration of a supported thick-walled FGM cylindrical shell that was subject to pressure loading.

In contrast to beam and plate structures [9–13], limited studies investigate the mechanical properties of FG porous cylindrical shells. Tomasz Belica et al. [25] investigated the dynamic stability of FG porous cylindrical shells subjected to combined loads. Majia G. et al. [26] considered an FGM cylindrical microshell