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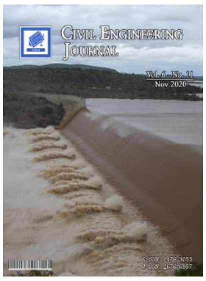

Finite Element Analysis of Functionally Graded Beams using Different Beam Theories

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Abstract

The present study deals with buckling, free vibration, and bending analysis of Functionally Graded (FG) and porous FG beams based on various beam theories. Equation of motion and boundary conditions are derived from Hamilton's principle, and the finite element method is adopted to solve problems numerically. The FG beams are graded through the thickness direction, and the material distribution is controlled by power-law volume fraction. The effects of the different values of the power-law index, porosity exponent, and different boundary conditions on bending, natural frequencies and buckling characteristics are also studied. A new function is introduced to approximate the transverse shear strain in higher-order shear deformation theory. Furthermore, shifting the position of the neutral axis is taken into account. The results obtained numerically are validated with results obtained from ANSYS and those available in the previous work. The results of this study specify the crucial role of slenderness ratio, material distribution, and porosity condition on the characteristic of FG beams. The deflection results obtained by the proposed function have a maximum of six percent difference when the results are compared with ANSYS. It also has better results in comparison with the Reddy formulae, especially when the beam becomes slender.

Keywords: Functionally Graded Materials; Finite Element Method; Buckling Analysis; Free Vibration.

1. Introduction

A composite material is made of two or more constituent material with different mechanical properties. This new material has physical and chemical characteristics, unlike that of the individual components. In laminate composite structures, isotropic elastic layers are joined together to provide mechanical and advanced material properties. The typical problem with laminate composite is the concentration of stress at the site of separation of the different layers, which causes cracks and the delamination phenomenon. In functionally graded materials (FGMs), because the changes from one material to another are trivial, there is no delamination [1]. FGMs are categorized as composite materials that have contiguous conversion in the properties of materials from one plane to another, thus reducing the stress concentration existed in conventional composites [2]. FGMs have several potential advantages that made their use more common in comparison with laminated composites [3]. These advantages are including reducing in-plane and transverse stresses along with thickness, proportional distribution of residual stress, improved thermal properties, greater fracture and corrosion resistance, and reducing stress concentration factors [1].These features have led to their widespread use in various scientific and engineering applications, such as mechanical, structural, aerospace, nuclear, armory and, etc. FGMs are typically made of isotropic components (e.g., metals and ceramics). FGMs are also used as

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