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Large displacement static and transient analysis of functionally graded deep curved beams with generalized differential quadrature method

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Abstract

In this article, large displacement static and transient behavior of moderately thick deep functionally graded curved beams with constant curvature are investigated using generalized differential quadrature method. Equilibrium equations for static and dynamic responses are obtained using the virtual work principle. Spatial derivatives in the equilibrium equations are expressed with the generalized differential quadrature method. Large displacements are taken into account using Green-Lagrange nonlinear strain-displacement relations that are derived from elasticity theory equations. Transverse shear effect is considered through the first-order shear deformation theory. Static and dynamic equilibrium equations are solved using Newton and Newmark methods respectively. Several curved beam problems with different level of deepness is solved with the proposed method. Effect of functionally graded material properties on the behavior of curved beam is investigated using various ceramic and metal combinations such as Zirconia/Aluminum, Alumina/Aluminum, Zirconia/Monel, Silicon Nitride/Steel and Alumina/Steel materials in analyses.

Keywords: Generalized differential quadrature, Large displacement, Functionally graded, Curved beam

1. Introduction

Functionally graded materials (FGMs) were invented by Japanese scientists in 1984 to overcome problems such as high thermal residual stresses and stress concentrations at the interface of conventional composite materials. FGMs are formed by combining different sets of materials commonly metal with ceramic. In FGMs desired mechanical properties are achieved by changing volume fraction gradually through the thickness. FGMs have important applications in aerospace, biomedical, defense, energy, and optoelectronics areas. If manufacturing technique can be improved, FGMs are promising and can be used in wider areas.

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