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Three dimensional static and dynamic analysis of thick functionally graded plates by the meshless local Petrov–Galerkin (MLPG) method

A. Rezaei Mojdehi [a,c,*], A. Darvizeh [b], A. Basti [c], H. Rajabi [d]

[a] Wind Turbines Technology Development Center, Niroo Research Institute, Tehran, Iran
[b] Department of Mechanical Engineering, Faculty of Engineering, Islamic Azad University, Anzali Branch, Bandar-e-Anzali, Iran
[c] Department of Mechanical Engineering, Faculty of Engineering, The University of Guilan, Iran
[d] Department of Mechanical Engineering, Faculty of Engineering, Islamic Azad University, Lahijan Branch, Lahijan, Iran

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ABSTRACT

In this paper, three dimensional (3D) static and dynamic analysis of thick functionally graded plates based on the Meshless Local Petrov–Galerkin (MLPG) is presented. Using the kinematics of a three-dimensional continuum, the local weak form of the equilibrium equations is derived. A weak formulation for the set of governing equations is transformed into local integral equations on local sub-domains using a Heaviside step function as test function. In this case, governing equations corresponding to the stiffness matrix do not involve any domain integration or singular integrals. Nodal points are distributed in the 3D analyzed domain and each node is surrounded by a cubic sub-domain to which a local integral equation is applied. The meshless approximation based on the three-dimensional Moving Least-Square (MLS) is employed as shape function to approximate the field variable of scattered nodes in the problem domain. The Newmark time integration method is used to solve the system of coupled second-order ODEs. Effective material properties of the plate, made of two isotropic constituents with volume fractions varying only in the thickness direction, are computed using the Mori–Tanaka homogenization technique. Numerical examples for solving the static and dynamic response of elastic thick functionally graded plates are demonstrated. As a result, the distributions of the deflection and stresses through the plate thickness are presented for different material gradients and boundary conditions. The effects of the volume fractions of the constituents on the centroidal deflection are also investigated. The numerical efficiency of the proposed meshless method is illustrated by the comparison of results obtained from previous literatures.

1. Introduction

In recent years, functionally graded materials (FGMs) have gained special importance and notably increased applications in a wide variety of engineering structures. Material properties of an FGMs vary continuously according to a predetermined profile. In contrast to laminated composites, FGMs have no sudden change in material properties across the interface between discrete materials, which can result in large interlaminar stresses leading to delamination. Generally, FGMs are composed of two ceramic and metal phase in which the material properties such as the Young's modulus vary from the metallic side to the ceramic one. These materials have been introduced to attain the ideal performance of its constituents, e.g. high heat and corrosion resistance of ceramics on one side, and large mechanical strength and toughness of metals on the other side. FGMs with material properties varying only in one direction can be manufactured either by high speed centrifugal casting [1,2] or by depositing ceramic layers on a metallic substrate [3,4]. An FGM with properties changing in the plane of a sheet can be produced by ultraviolet irradiation to alter the chemical composition [5]. A directed oxidation technique has also been employed [6,7] to deposit a ceramic layer on the outside surfaces of a structure.

Several analytical solutions have been presented for the analysis of FG plates. Mian and Spencer [8] established a class of exact three dimensional solutions for functionally graded plates with traction-free surfaces. Reddy [9] presented solutions for rectangular FG plates based on the third-order shear deformation theory (TSDT). Cheng and Batra [10] have related deflections of a simply supported functionally graded polygonal plate given by a TSDT and the first-order shear deformation theory (FSDT) to that of an equivalent homogeneous Kirchhoff plate. Vel and Batra [11] provided an exact solution for the three dimensional thermoelastic

* Corresponding author at: Wind Turbines Technology Development Center, Niroo Research Institute, End of Poonak Bakhtari (Dadman) Blvd., Shahrak Ghods, Tehran 14686, P.O. Box 14665/517, Iran. Tel./fax: +98 21 88364616.
E-mail addresses: ARMojdehi@nri.ac.ir, A.R.Mojdehi@gmail.com (A.R. Mojdehi).

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