Accepted Manuscript

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PII: S0263-8223(15)00111-7
DOI: http://dx.doi.org/10.1016/j.compstruct.2015.02.032
Reference: COST 6217

To appear in: *Composite Structures*

Please cite this article as: Wali, M., Hentati, T., Jarraya, A., Dammak, F., Free vibration analysis of FGM shell structures with a discrete double directors shell element, *Composite Structures* (2015), doi: http://dx.doi.org/10.1016/j.compstruct.2015.02.032

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Abstract

Free vibration response of functionally graded material (FGM) shell structures is studied by using an efficient 3d-shell model based on a discrete double directors shell element. With this element, the vanishing of transverse shear strains on top and bottom faces is considered in a discrete form. The mechanical properties of the shell structure are assumed to vary continuously in the thickness direction according to the general four-parameter power-law distribution in terms of the volume fractions of the constituents. The fundamental equations for the FGM shell structures are derived using principle of virtual work. Performance and accuracy of the present discrete double directors shell model (DDDSM) are confirmed by comparing the present solutions obtained from finite element analyses with the existing results in the literature.

Keywords: Free vibration, Third-order theory, FGM, Shell element

1. Introduction

Functionally graded materials (FGM) are a kind of composite structures in which the properties vary continuously in one or more directions. Typical FGMs are made from a mixture of ceramic and metal, or a combination of different metals or different ceramics that are appropriate to achieve the desired objective. The continuous change of material properties from one surface to other existing in FGM gives an important advantage when compared to laminate structure. The advantage of using this material is that it eliminates the interface problem due to smooth surface. These FGM shell structures have been widely used in many engineering fields such as aerospace and other industries because of their high heat-resistance.

Typically functionally graded shell structures have been analyzed with shear deformation theories by using the first-order shear deformation theory (FSDT) [1-3] or higher-order shear deformation theories (HSDT) [4-6]. The FSDT gives acceptable results but depends on a shear correction factor to adjust the transverse shear stiffness and the accuracy of solutions will be strongly dependent on the correction factors. There is no need of a shear correction factor when using a HSDT but equations of motion are more complicated to obtain than those of the FSDT [7].

Several studies have been devoted for the analysis of functionally graded shells and plates. For free vibration, computational methods can be classified as analytical and numerical methods. In general analytical methods require less CPU-Time than the finite element methods. However, these analytical methods are not convenient when compared to FE methods in the cases of application to complex geometrical problems. Therefore, to obtain accurate numerical results by the finite element method one needs to use a small mesh size to minimize the truncated error [8]. Patel et al. [9] are studied free vibration characteristics of functionally graded material elliptical cylindrical shells using finite element procedure using the higher-order displacement model including variable transverse displacement through the thickness. In their finite element model, they are adopted an eight-noded quadrilateral shell finite element having 11 degrees of freedom/generalized displacements per node. Talha and Singh [10] are studied the free vibration and static analysis of