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Li Li*, Xiaobai Li, Yujin Hu

State Key Laboratory of Digital Manufacturing Equipment and Technology, School of Mechanical Science and Engineering, Huazhong University of Science and Technology, Wuhan 430074, China

Abstract

A novel beam model is derived to investigate the nonlinearized bending behaviors of a two-dimensionally functionally graded (FG) beam based on the Euler–Bernoulli beam kinematic theory. The geometric nonlinearity due to the mid-plane stretching is only taken into account. For the considered two-dimensionally FG material, we assume the Young's modulus varying along the length or axial direction obeys an exponential distribute function, and the Young's modulus varying along the thickness direction obeys a power-law function. A generalized differential quadrature method (GDQM) is developed to calculate the linearized and nonlinearized displacements of two-dimensionally FG beams. Some illustrative examples are given to study the effects of the value of force and various material compositions on the linearized and nonlinearized deflections as well as the nonlinear deflection ratio.

Keywords: Two-dimensionally functionally graded material, Nonlinear bending, Geometric nonlinearity

1. Introduction

Functionally graded (FG) materials, as a new class of composites, have many better properties than conventional laminated composites, such as improved stress spreading, enhanced fracture toughness, and enhanced corrosion resistance. The FG materials can vary their physical properties (including Young's and shear moduli [1], material density, thermal conductivity [2–12], electrical conductivity [6], hygroscopic rate [2, 9, 10], to name a few) continuously in the body, just like many structures in nature (such as pomelo peel, bones and sea shells).

The FG materials have been gaining great interest mainly due to the fact that the rapid development of nano/micro-technologies allows us to design their microstructures. Bouafia et al. [13] and Bedia et al. [14] studied the mechanical and dynamical behaviors of micro FG material made of carbon nanotubes. Besides, many publications reported the bending, thermo-buckling and vibration characteristics of functionally graded micro/nano beams [15–27], plates [28–30] and shells [31]. Because a good comprehension of the mechanical and physical characterizations of FG structural components may be helpful for synthesizing new advance materials, a lot of recent papers discussing the statical and dynamical characterizations of FG continuous components have been published [16, 18, 32–44]. Except for studies on beam like structures, there are also plenty of papers discussing the behaviors of FG plates [45–51]. These works are focused on the static and dynamic characterizations of continuous components made of one-dimensionally FG material.

In many advanced machines, some structural components may be expected to have their material properties changing in more than one directions. Because the working environment, such as temperature field and mechanical loading distribute in more than on directions. For example, aerospace crafts and shuttles

*Corresponding author
Email address: `lili_em@hust.edu.cn` (Li Li)