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Abstract

In this paper a new non-iterative computational technique referred to as the symbolic-numeric method of initial parameters (SNMIP) is proposed. The SNMIP represents a modification of the iterative numeric method of initial parameters in differential form known in the literature. The SNMIP is applied to study free vibrations of Euler-Bernoulli axially functionally graded tapered, stepped, and continuously segmented rods and beams with elastically restrained end with attached masses. Both the longitudinal vibration of rods and transverse vibration of beams are considered. The influence of the attached masses and springs on the natural frequencies of vibration of axially functionally graded rods and beams is examined. The validity and accuracy of the method are proven through the comparison with the known results in the available literature.

Keywords: axially functionally graded beams, longitudinal vibration, transverse vibration, variable cross-section, numerical analysis

1. Introduction

Beams made of functionally graded materials can be classified into two major groups. The first group includes beams whose mechanical properties vary through thickness, whereas the second group involves beams whose mechanical properties vary along their longitudinal axes. In the literature, considerations involved for the most part static and dynamic behavior of beams from the first group. For more details refer to [1–7] and the references cited in these papers. The reason for this is the fact that static and dynamic analysis of axially functionally graded (AFG) beams is based on differential equations with variable coefficients whose closed-form solution is hard or even impossible to obtain. In this sense, for some closed-form solutions see e.g. [8–10]. In recent years non-uniform AFG beams have gained considerable attention in engineers and researchers works. Furthermore, non-uniform beams may occur in the form of stepped, tapered, and continuously segmented straight beams as well as circular arches (for more details on non-uniform circular arches refer, e.g., to [11–13]). Further considerations will involve only straight beams. Various numerical methods have been developed for determining natural frequencies and mode shapes of AFG non-uniform beams. Let us mention some of them: the complementary functions method [14], the finite element method [7, 15, 16], the approach based on using power series for the representation of mode shapes [17], the approach based on the Chebyshev polynomials theory [18], the integrated spectral collocation approach [19], the Ritz method [20], the differential quadrature method with domain decomposition technique [21], the method of initial parameters in differential form [22, 23], the differential transform element method and the differential quadrature element method of lowest-order [24], the Fredholm integral equations approach [25].

The analysis of mentioned references indicates that the most investigated problem is that of transverse vibration of tapered AFG beams. The stepped AFG beams were considered only in [21] ,whereas the longitudinal vibration

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