819. Nonlinear vibration of fluid-conveying double-walled carbon nanotubes under random material property

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Abstract. In this study, one performs the stochastic dynamic analysis of nonlinear vibration of the fluid-conveying double-walled carbon nanotubes (DWCNTs) by considering the effects of the geometric nonlinearity and the nonlinearity of van der Waals (vdW) force. Based on the Hamilton's principle, the nonlinear governing equations of the fluid-conveying DWCNTs are derived. In order to truly describe the random material properties of the DWCNTs, the Young's modulus of elasticity of the DWCNTs is assumed as stochastic with respect to the position. By adopting the perturbation technique, the nonlinear governing equations of the fluid-conveying can be decomposed into two sets of nonlinear differential equations involving the mean value of the displacement and the first variation of the displacement separately. Then one uses the harmonic balance method in conjunction with Galerkin's method to solve the nonlinear differential equations successively. Some statistical dynamic response of the DWCNTs such as the mean values and standard deviations of the amplitude of the displacement are calculated. It is concluded that the mean value and standard deviation of the amplitude of the displacement increase nonlinearly with the increase of the frequencies for both cases of coupling between longitudinal displacement and transverse displacement and uncoupling between them. However, the coefficients of variation of the amplitude of the displacement remain almost constant and stay within certain range with respect to the frequency. The calculated stochastic dynamic response plays an important role in estimating the structural reliability of the DWCNTs.

Keywords: nonlinear vibration, fluid-loaded double-walled carbon nanotubes, random material properties, Galerkin's method.

Introduction

A landmark paper regarding Carbon nanotubes (CNTs) by Iijima [1] has attracted worldwide attention due to their potential use in the fields of chemistry, physics, nano-engineering, electrical engineering, materials science, reinforced composite structures and construction engineering. Carbon nanotubes (CNTs) are used for a variety of technological and biomedical applications including nanocontainers for gas storage and nanopipes conveying fluids [2-4]. The single-elastic beam model [5-6] were widely adopted to study the dynamic behaviors of fluid-conveying single-walled carbon nanotubes (SWCNTs) and multi-walled carbon nanotubes (MWCNTs). Normally speaking, the beam models mentioned above are linear; however, the vdW forces in the interlay space of MWCNTs are essentially nonlinear. Furthermore, the slender ratios are normally large if the beam models are adopted, that is, the large deformation will occur. Therefore, it is quite essential to consider two types of nonlinear factors, namely, the geometric nonlinearity and the nonlinearity of vdW force in investigating the dynamic behaviors of fluid-conveying MWCNTs. Salvetat et al. [7] measured the flexural Young's modulus and shear modulus using AFM test on clamped–clamped nanoropes, getting values with 50 % of error. Information related to statistical distributions of experimental data is also rare, and the important study from Krishnan et al. [8] provides one of the few examples available of histogram distribution of the flexural Young's modulus derived from 27 CNTs. The Young's modulus was estimated observing free-standing vibrations at room temperature using transmission electro-microscope (TEM), with a mean value of 1.3 TPa -0.4 Tpa / +0.6 TPa.