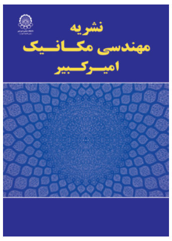

Amirkabir Journal of Mechanical Engineering

Amirkabir J. Mech. Eng., 50(1) (2018) 47-50
DOI: 10.22060/mej.2016.738

Using Green Function Method to Dynamic Analysis of Nanotubes Conveying Fluid Under Moving Load

A. Zandi Baghche Maryam, M. Hosseini*

Department of Mechanical Engineering, Sirjan University of Technology, Sirjan, Iran

ABSTRACT: In this paper, the dynamic response of carbon nanotubes (CNT) conveying fluid under moving harmonic load by using the Green function method is investigated. The results of this analysis are obtained for four different boundary conditions, namely fixed- fixed, fixed- pinned, pinned- fixed and pinned -pinned. The harmonic load is assumed to travel with uniform velocity, accelerating and decelerating types of motion and the internal fluid flow is moved with uniform velocity. The Green function and Laplace transform method is implemented to analysis of force vibrations for achieving exact solutions of dynamic response. In the present work, the effects of various parameters such as viscoelastic coefficient, moving load and fluid flow velocity, length scale parameter, boundary conditions, viscous damping and types of the load motion on the dynamic displacement of the CNT are elucidated. However, the results show that these parameters are vital in investigation of the dynamic displacement of CNT. It is obvious that the dynamic deflection is very sensitive to the material length scale parameter in which structural stiffness of CNT and the dimensionless dynamic displacements, respectively, is decreased and increased with increases in the length scale parameter.

Review History:

Received: 18 March 2016
Revised: 7 June 2016
Accepted: 17 July 2016
Available Online: 15 August 2016

Keywords:

Carbon nanotubes conveying fluid
Moving harmonic loads
Boundary conditions
Types of load motion
Green function method

1- Introduction

The beam-type structures containing flowing fluid and moving load have been widely used in numerous applications such as civil, petrochemical and gas industries. Therefore, it has been the subject of great interest and a challenging research topic over the past few decades. Carbon NanoTubes (CNTs) are regarded as promising for applications in nano-mechanical devices, such as Nano-Eelectro Mechanical Systems (NEMS), nano-biology and nano-mechanics mainly for resonators, actuators, sensors, blood vessel simulator, fluid transport, fluid storage and drug delivery [1-3].

Simsek [4] investigated the vibration of a functionally graded (FG) simply-supported beam due to a moving mass by using Euler–Bernoulli, Timoshenko and the third order shear deformation beam theories. Simsek [5] studied the dynamic behavior of micro-beams under the action of a moving micro-particle based on the modified couple stress theory and presented that the static deflections and free vibration frequencies of the micro-beams is size dependent.

In the present investigation, the vibration analysis of CNT conveying fluid under moving harmonic load by using the Green function method is examined. The Green function and Laplace transform method are used to solve the governing differential equations of motion. The load is assumed to move with uniform motion, accelerating and decelerating types of motion and the internal fluid flow is moved with uniform the motion. Hence, the present article aims to examine the influence of viscoelastic coefficient, moving load and fluid flow velocity, length scale parameter, boundary conditions and types of the load motion on the dynamic displacement of the CNT. The result of this study can be useful for manufacturing smart nanomechanical system in advanced biomechanics applications and design devices under moving load.

2- Governing Equation of Motion

The differential equation of motion for the CNT conveying fluid subjected to a moving harmonic load $\rho(x,t)$ is given by [6]:E

$$EI\frac{\partial^4 w}{\partial x^4}+EI\,g\frac{\partial^5 w}{\partial x^4\partial t}+\left(1-(e_0a_0)^2\frac{\partial^2}{\partial x^2}\right)q(x,t)=\left(1-(e_0a_0)^2\frac{\partial^2}{\partial x^2}\right)p(x,t) \tag{1}$$

E, I, L, e_0a_0 and g are elastic modulus, the second moment of cross-sectional area of the tubes, length of tubes, length scale parameter, and viscoelastic coefficient, respectively. $w(x,t)$ is the flexural displacements of the CNT, x and t are the axial coordinate and time, respectively. The $q(x,t)$ is defined as:

$$q(x,t)=m_f v_f^{\,2}\frac{\partial^2 w}{\partial x^2}+2m_f v_f\frac{\partial^2 w}{\partial x\,\partial t}+(m_f+m_i)\frac{\partial^2 w}{\partial t^2}+\bar{c}\frac{\partial w}{\partial t} \tag{2}$$

m_i, m_f, v_f and $\bar{c}$ represents the mass of CNT per unit length, mass per unit length of fluid, the velocity of fluid and damping coefficient, respectively.

3- Method of Solution

The method of Green functions is more efficient than the

Corresponding author, E-mail: hosseini@sirjantech.ac.ir

series methods because this method yields exact solutions in closed forms. This is in particular essential to calculate dynamic stresses and determine the dynamic response of beams other than simply supported. Also by the use of the Green functions method, the boundary conditions are embedded in the Green functions of the corresponding beams. Furthermore, by using this method, it is unnecessary to solve the free vibration problem in order to obtain the eigenvalues and the corresponding eigenfunctions, which are required while using series solutions [8]. When $p(x,t)$ is harmonic, the solution of Eq. (1) can be represented as [9]:

$$w(x,t) = W(x)\exp(i\bar{\Omega}t) \qquad (3)$$

where $\bar{\Omega}$ is the harmonic frequency of the moving load $p(x,t)$. After substituting Eq. (3) for Eq. (1), we can obtain the solution of displacement as [9]:

$$W(x) = \int_0^L p(l)G(x,l)dl \qquad (4)$$

where $G(x,l)$ is the Green's function.

4- Results and Discussion

In the present study, the vibration analysis of CNT conveying fluid under moving harmonic load is investigated. In this section, the effects of viscoelastic coefficient, moving load velocity, length scale parameter and types of the load motion on the vibration response are studied.

Fig. 1 displays the dynamic displacement as a function of the load velocity for fixed- fixed CNT. In this diagram, η is the displacements, while is related to the dimensionless times. It is found that the non-dimensional dynamic displacement increases as the dimensionless velocity increases.

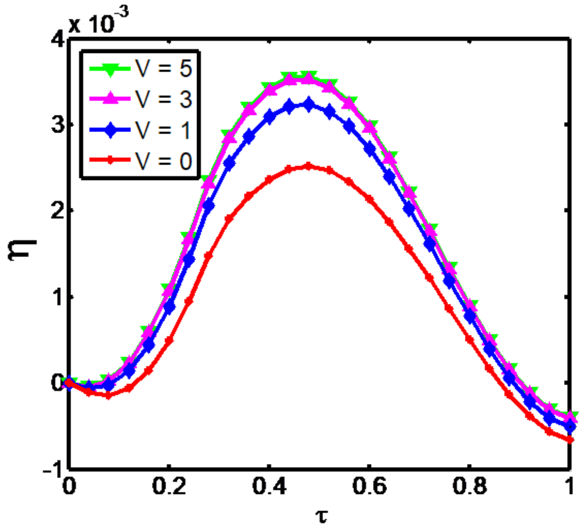

Figure 1. The non-dimensional deflection of CNT at ξ=0.3 versus the dimensionless velocity for fixed- fixed boundary condition

The effect of length scale parameter of fixed- fixed CNT on the dimensionless dynamic displacements is illustrated in Fig. 2. It is found that the dynamic deflection is very sensitive to the material length scale parameter on the vibration response. Also, it is found that the stiffness of CNT and the dimensionless dynamic displacements, respectively, decrease and increase with the increases in the length scale parameter. To examine the effect of types of the load motion on the non-dimensional dynamic displacements of fixed- fixed CNT, the result is shown in Fig. 3. Also, based on the results plotted in this figure, the types of the load motion, from lowest to the highest values of dimensionless dynamic displacements, can be ordered as uniform motion, decelerated motion and accelerated motion, respectively.

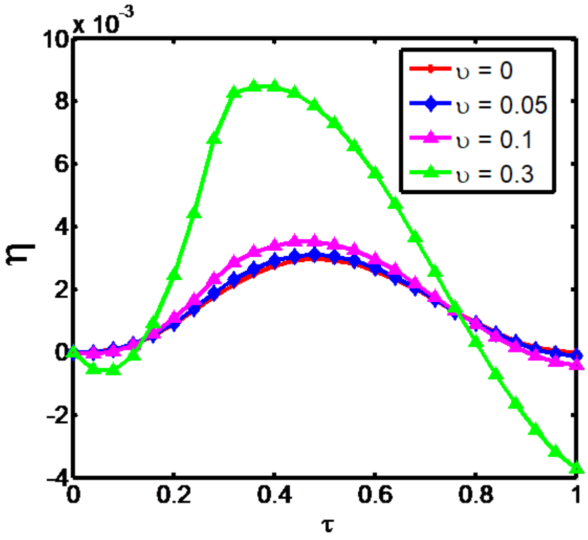

Figure 2. The non-dimensional deflection of CNT at ξ=0.3 versus the length scale parameter for fixed- fixed boundary condition

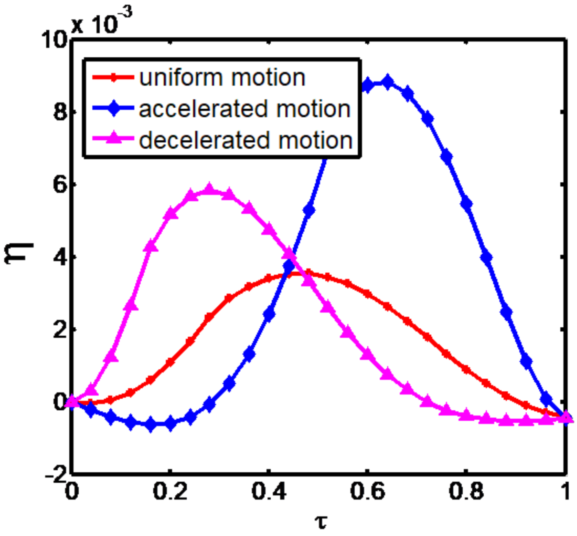

Figure 3. The non-dimensional deflection of CNT at ξ=0.3 versus types of the load motion for fixed- fixed boundary condition

5- Conclusions

In the present study, the vibration analysis of CNT conveying fluid under moving harmonic load by using the Green function method has been investigated. Effects of moving load and fluid flow velocity, length scale parameter, boundary conditions and types of the load motion on the dynamic displacement of the CNT are demonstrated.

Our results indicate that the non-dimensional dynamic displacement increases with the increase in the dimensionless velocity. It has shown that, by increasing the value of length scale parameter, the stiffness of CNT and its displacements will be decreased and increased, respectively. Also, the results show that the accelerated motion produces higher displacements than the decelerated and uniform motion.

References

[1] R. Rafiee, Analysis of Nonlinear Vibrations of a Carbon Nanotube Using Perturbation Technique, *Modares Mechanical Engineering*, 12(3) (2012) 60-67.

[2] M. Foldvari, M. Bagonluri, Carbon nanotubes as functional excipients for nanomedicines: II. Drug delivery and biocompatibility issues, Nanomedicine: Nanotechnology, *Biology and Medicine*, 4(3) (2008) 183-200.

[3] N. Khosravian, H. Rafii-Tabar, Computational modelling of a non-viscous fluid flow in a multi-walled carbon nanotube modelled as a Timoshenko beam, *Nanotechnology*, 19(27) (2008) 275703.

[4] M. Şimşek, Vibration analysis of a functionally graded beam under a moving mass by using different beam theories, *Composite Structures*, 92(4) (2010) 904-917.

[5] M. Şimşek, Dynamic analysis of an embedded microbeam carrying a moving microparticle based on the modified couple stress theory, *International Journal of Engineering Science*, 48(12) (2010) 1721-1732.

[6] Z.K. Maraghi, A.G. Arani, R. Kolahchi, S. Amir, M. Bagheri, Nonlocal vibration and instability of embedded DWBNNT conveying viscose fluid, *Composites Part B: Engineering*, 45(1) (2013) 423-432.

[7] M. Abu-Hilal, M. Mohsen, Vibration of beams with general boundary conditions due to a moving harmonic load, *Journal of Sound and Vibration*, 232(4) (2000) 703-717.

[8] M. Abu-Hilal, Forced vibration of Euler–Bernoulli beams by means of dynamic Green functions, *Journal of sound and vibration*, 267(2) (2003) 191-207.

[9] D.G. Duffy, *Green's functions with applications*, CRC Press, 2015.

Please cite this article using:

A. Zandi Baghche Maryam and M. Hosseini, Using Green Function Method to Dynamic Analysis of Nanotubes Conveying Fluid Under Moving Load, *Amirkabir J. Mech. Eng.*, 50(1) (2018) 137-150.

DOI: 10.22060/mej.2016.738