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Carbon Nanotube Beam Model and Free Vibration Analysis

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Abstract

Thanks to their superior properties, the interest on nanostructures has increased. Among the nanostructures, carbon nanotubes have an important place. In this study, the free vibration of Carbon Nanotubes is investigated. CNT is modeled as a beam. Four different cross-sections are selected such as circular, rectangular, triangular and quadratic for use in the solution. The frequency values of the first five modes of these 4 different cross-sections with the same area have been gained by using Euler-Bernoulli Beam Theory for simply supported boundary condition. The results are compared. In this study, it is aimed to understand how the mode number and cross-section change the frequency values.

Keywords: Carbon nanotube, free vibration, Euler-Bernoulli, frequency.

1. Introduction

As a result of rapid developments in technology, nanotechnology emerged and has become one of the most important issues of today. Nanotechnology is mainly concerned with particles smaller than 100 nm. The nanostructures are defined as structures having at least one dimension between 1 and 100 nm [1-2]. One of the most important subjects of nanotechnology is carbon nanotubes. Carbon nanotube was discovered by Iijima in 1991 [3]. The CNT is the cylindrical shape of the graphene and can be single-layered or multi-layered. There are also 3 types of nanotubes depending on the direction of rolling of the graphene layer. These are armchair, zigzag and chiral. The properties of CNT vary depending on the geometry. The very interesting properties such as mechanical, electrical, optical exhibited by CNT attract a lot of attention. It has high Young's modulus and low mass density [4-8]. Analyzes such as buckling, vibration, bending of structures are important. Analysis results help to understand the behavior of structures. Analyzes of macro and nano-sized structures are studied in various methods [9-14]. In this paper, the vibration of CNT is studied by using Euler-Bernoulli Beam Theory. Frequency values of CNT are carried out for 4 different cross-sections and simply supported boundary condition.

2. Vibration of Euler-Bernoulli Beam

The vibration equation of a beam whose material and cross-sectional properties are unchanged is expressed as [15,16]:

$$EI\frac{\partial^4 w(x,t)}{\partial x^4}+\rho A\frac{\partial^2 w(x,t)}{\partial t^2}=f(x,t) \tag{1}$$

Where E is Young Modulus, I is moment of inertia, ρ is mass density, A is cross-sectional area, $w(x,t)$ is transverse deflection of beam and $f(x,t)$ is external force. When the equation is solved for free vibration and the simple supported boundary condition by using separating of variables equations, we obtain the frequency equation

$$\omega_n=\frac{n^2\pi^2}{L^2}\sqrt{\frac{EI}{\rho A}} \tag{2}$$

Where n is mode number, L is length of beam and ω shows the frequency.

3. Numerical Examples

In this study, the free vibration of CNT with simple supported boundary condition is investigated by using Euler-Bernoulli Beam Theory. Four different cross-sections with same area are used. For a better comparison, the width/height (b/h) ratio is taken as the same for triangle and rectangle. The Young modulus used in calculations is 1054 GPa and mass density is 1.4 g/cm^3. The results are shown in table 1 and figure 1.

Table 1. Frequency values for 20 nm length (10^9 rad/sn)

A=12.6 nm², L=20 nm				
mode numbers	*circular r=2 nm*	*rectangular b=3 nm h=4.2 nm*	*triangular b=4.24 nm h=5.93 nm*	*quadratic b=3.55 nm h=3.55nm*
1	677.0115	820.8328	946.2678	693.8005
2	2708.046	3283.3313	3785.0712	2775.2018
3	6093.1034	7387.4953	8516.4102	6244.2041
4	10832.184	13133.325	15140.285	11100.807
5	16925.287	20520.820	23656.695	17345.012

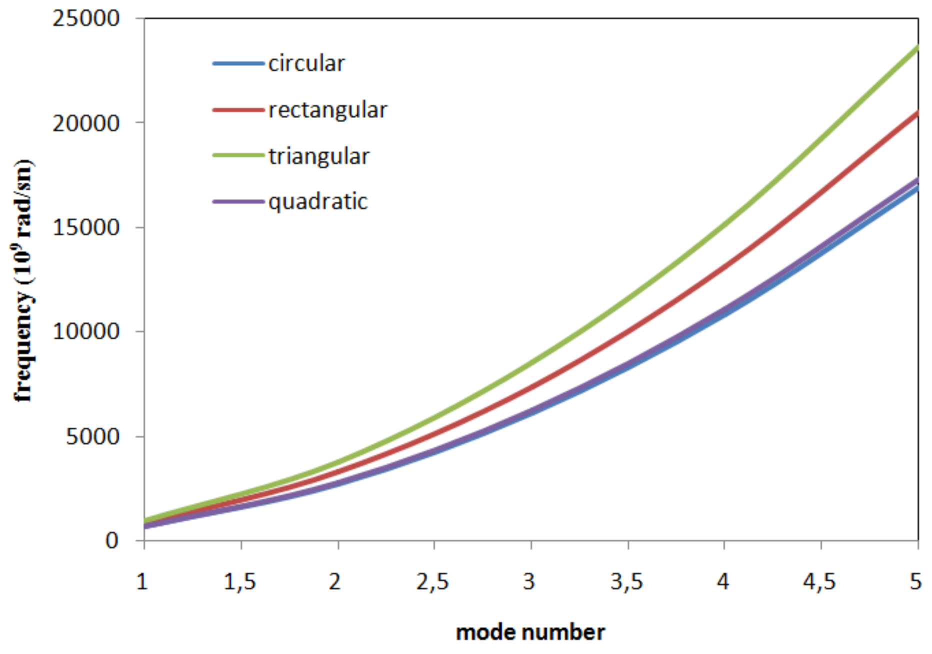

Fig. 1. Frequency values for different cross-sections

4. Conclusions

In this paper, free vibration analysis of CNT is presented. The frequency values of the first five modes of four different cross-sections have been gained by using Euler-Bernoulli Beam Theory for simply supported boundary condition. As can be seen from the results, the frequency values increase with the mode numbers. Using same cross section area, the highest frequency value is seen on the triangular cross-section. Circular cross section has the lowest frequency value.

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