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Study of the behavior of integrated boron nitride nanotube (BNNTs) under the effect of a longitudinal magnetic field

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Abstract

The effect of the longitudinal magnetic field on the mechanical buckling of single-walled boron nitride nanotube (SWBNNT) integrated in the elastic Kerr medium is investigated. The structure is modeled using the non-local Euler-Bernoulli theory. The elastic matrix is described by the Kerr model, which takes into account the normal pressure and the transverse shear strain. Using the nonlocal elastic theory and considering the Lorentz magnetic force obtained from Maxwell relations, the stability equation for buckling analysis of SWBNNT is derived. The effects of the magnetic field, the non-local parameter, the lower spring parameter Kw, the upper spring parameter Kc and the intermediate shear layer parameter Kg are significant in this analysis.

Introduction

Nanosciences and nanotechnologies have known a tremendous growth, owing to the development of new analysis like carbon nanotubes (CNTs), which are sheets of graphene mono or multilayer rolls. These objects which interest many researchers and applications in nanotechnology [1], and other fields of materials science, because CNTs exhibit extraordinary resistance [2]. We have another material that is a structural analogue of a CNTs is the boron nitride nanotube (BNNTs) where B and N atoms completely replacing C atoms in the graphitic sheet with almost no change in atomic spacing. BNNTs have many properties superior to CNT, such as exceptional elastic properties, high mechanical resistance and thermal stability . The critical buckling of a BNNT embedded in Kerr's medium under a longitudinal magnetic field is carried out by the nonlocal Euler Bernoulli beam theory. This study showing the effects of nonlocal parameter, radius and length of BNNTs, as well as the foundation parameters on buckling of BNNT embedded in an elastic medium with influence of magnetic field are investigated.

MATHEMATICAL FORMULATIONS

Considering the elementary Euler–Bernoulli beam theory [3], the axial and transverse displacement fields can be represented as:

$$\boldsymbol{u(x,z) = u_0 - z\frac{dw}{dx}}$$
$$\boldsymbol{w(x,z) = w(x)}$$

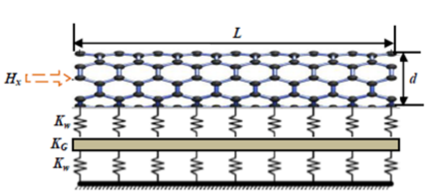

Fig. 1 The SWBNNT under a longitudinal magnetic field embedded in Kerr medium.

Nonlocal elasticity is first considered by Eringen [4]. He proposed a differential form of the nonlocal constitutive relation as :

$$\sigma_x - \mu\frac{d^2\sigma_x}{dx^2} = E\varepsilon_x$$

Virtual work principle is used herein to derive the equations of equilibrium. The principle can be stated in analytical form as [5]:

$$\sigma\int_v (U+V)dv = 0$$

$$\delta U = -\int_0^L M_x\left(\frac{d^2\delta w}{dx^2}\right)dx$$

$$\delta V = -\int_0^L q\delta w dx - \int_0^L P_0\frac{dw}{dx}\frac{d\delta w}{dx}dx$$

Where $\boldsymbol{q}$ and $\boldsymbol{P_0}$ are the transverse and axial loads, respectively.

The following equilibrium equations of the proposed beam theory are obtained:

$$\boldsymbol{\delta w: -\frac{d^2M_x}{dx^2} - K(x) + f(x) - P_0\frac{d^2w}{dx^2} = 0}$$

The nonlocal equilibrium equation can be expressed in terms of displacements (w) as:

$$D\frac{d^4w}{dx^4} + \left(1-(e_0a)^2\frac{d^2}{dx^2}\right)\left[P_0\frac{d^2w}{dx^2} + K(x) + f(x)\right] = 0$$

The closed-form solutions can be obtained from the following equation:

$$P_{cr} = \frac{D\alpha^2}{\lambda\alpha^2} + \eta AH_x^2 + \frac{\frac{\alpha^2DK_G}{K_c} + K_w + K_G\alpha^2}{(1+\frac{K_w}{K_c})\alpha^2}$$

Results and discussions

The parameters used in calculations for the SWBNNTs are: E = 1 TPa, G = E/ [2(1 + ν)], ν = 0.19, rod diameter d = 1 nm and I = πd^4d4/64

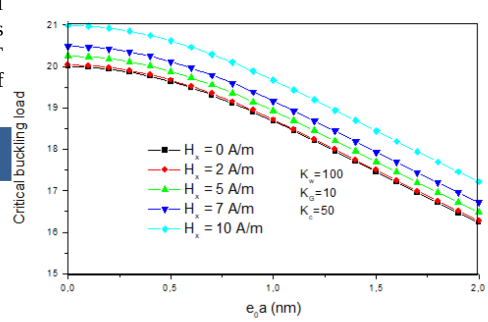

Fig. 2 Variation of the dimensionless critical buckling load of SWBNNT versus the nonlocal parameter for various values of magnetic field.

Figure. 2: For five values of H_x; 0, 2, 5, 7, 10 A/m, the effect of the small-scale parameter is shown in this figure, it is observed that there is significant influence of the magnetic field on the critical buckling response of embedded SWBNNT. Furthermore, it is seen that as small effect parameter increases, the critical buckling load decreases.

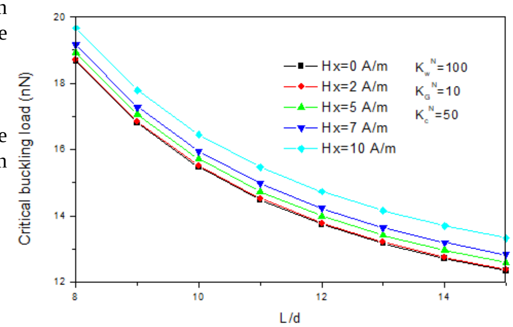

Fig. 3 Variation of the dimensionless critical buckling load of SWBNNT with the length to diameter ratios for various values of a magnetic field.

Figure. 3: Shows the variation of the critical buckling load of SWBNNT as function of aspect ratios L/d for five different magnetic field values (Hx=0, 2, 5, 7 and 10 A/m.), and a constant value of nonlocal parameter (e_0a=1 nm) and Kerr's parameters (Kw=100, KG=10, Kc=50) are used. It is seen that as the aspect ratios (L/d) increase, the critical buckling load decreases. It can be also observed from the obtained curves that the critical buckling load is in direct correlation relation with magnetic field values (Hx).

Conclusion

It can be concluded that the classical elastic model, which does not consider the small-scale effects, will give a higher approximation for the critical buckling load. But the nonlocal continuum theory will present an accurate and reliable result. In addition, an interesting feature that can be deduced is that as the Kerr's parameters increases, the value of critical buckling load decreases irrespective of the nonlocal parameter. Finally, the results show that the critical buckling load of SWBNNTs increases with the increase in the strength of the longitudinal magnetic field for all proprieties studied in this paper. These results are important in mechanical design considerations of the next generation of nanocomposite and others types of structures and materials.

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