A Non-Local Strain Gradient Model for Functionally Graded Nanobeam subjected to Different Thermal loading

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1. INTRODUCTION & OBJECTIVES

Iijima[1] has brought a revolution in the research field with the discovery of Carbon Nanotubes. Their unique physical, chemical, and mechanical properties made researchers from various domains use CNTs in their field. Functionally Graded Materials, which were introduced in 1980, find their applications in civil, mechanical, and aerospace industries because of the gradual variation in their properties, unlike composite materials, which have abrupt variations in their properties[2]. This is because the composition and the volume portions have a continuous variation. Functionally graded carbon nanotubes have the advantages of CNTs and functionally graded materials. Hence, they find their applications in NEMS(Nano Electro Mechanical System) and MEMS(Micro Electro Mechanical System), which deal with micro and nanoscale. Hence, there is a need to understand the behavior of functionally graded materials at nanoscales properly. It was observed from the literature that materials exhibit scale effects at nanoscales. Our classical continuum theories fail to predict the behavior of carbon nanotubes as the scale effects are not taken into consideration. Hence, for the analysis of the carbon nanotubes, we need to adopt a theory that considers scale effects in their formulation. Many researchers developed theories that consider scale effects in their formulation. Lim et al.[3] came up with a higher-order Non-Local Strain Gradient Theory that overcomes the drawbacks of the previous models. The advantage of the NLSGT model is that it can capture both stiffness softening as well as enhancement effects, which were not captured by the previous models. For this, they have introduced two parameters, the nonlocal parameter, and the stain gradient parameter, in the formulation.

The main objectives of this work include developing a model that investigates the buckling behavior of functionally graded carbon nanotubes. To study the influence of strain gradient and nonlocal parameters on the buckling behavior. We have also studied the influence of different boundary conditions and different thermal loading conditions on the critical buckling temperature of the functionally graded carbon nanotube.

2. EQUATIONS

The governing differential equation of our problem is given by

$$\frac{\partial^6 w}{\partial x^6}+\frac{\partial^4 w}{\partial x^4}b+c\frac{\partial^2 w}{\partial x^2}=0 \text{ where } b = \frac{-\gamma}{\beta l^2}, c = \frac{-N_x^T}{\beta l^2}$$

The closed-form solution for the differential equation is given by

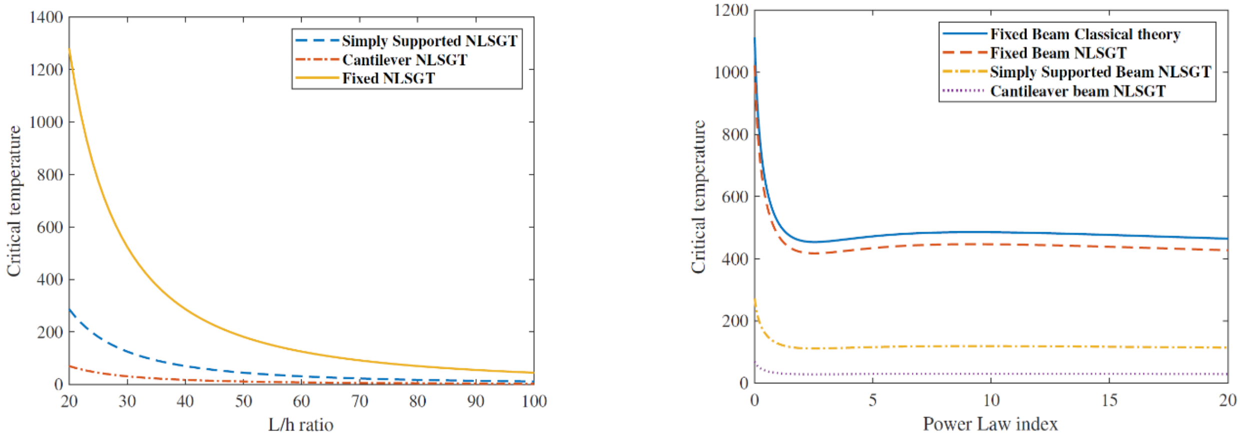
$$w=C_1+C_2x+C_3\cos Fx+C_4\sin Fx+C_5\cos Gx+C_6\sin Gx$$

$$\text{where } F, G=\sqrt{\frac{-b\pm\sqrt{b^2-4c}}{2}}$$

Now, substituting the values of different boundary conditions we get the critical buckling temperature values. For our analysis, we have taken values of elastic modulus, thermal conductivity, and coefficient of thermal expansion as follows$E_c = 380GPa, E_m = 70GPa, K_c = 10.4W/m^{\circ} and\ K_m = 204W/m^{\circ} \alpha_c = 7.4 \times 10^{-6}/℃\ \alpha_m = 23 \times 10^{-6}/℃$ respectively. The indices c and m denotes ceramic and metallic phase respectively[4].

3. RESULTS & HIGHLIGHTS OF IMPOINTANT POINTS

We conclude that the critical buckling temperature of the functionally graded beam increases with the introduction of nonlocal and strain gradient parameters when compared with the classical continuum theory for different boundary conditions as well as different thermal loading conditions. The critical buckling temperature of the beam also varies with respect to end conditions, it is higher for the beam clamped at both ends, followed by simply supported and cantilever end conditions. Also, the proposed model would generate the same results as that of the classical continuum model if the values of strain gradient and nonlocal parameters are kept equal.



Figures 1,2 Variation of Critical buckling temperature w.r.t .L\h ratio &Power law index under different B.C.

Table 1. Critical buckling temperature for a clamped restrained beamfor a nonlinear temperature distribution.

L\h ratio	K=0 Kiani[4]	K=0	K=0.5 Kiani[4]	K=0.5	K=1 Kiani[4]	K=1
10	2212.88	2552.92	1647.78	1901.87	1331.19	1536.82
15	977.95	1038.94	725.02	770.60	584.41	621.29
20	545.72	564.42	402.06	416.02	323.03	334.34
40	128.93	130.06	90.62	91.47	70.99	71.68
75	29.52	29.61	16.34	16.41	10.88	10.93

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