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Boundary conditions effect for buckling analysis of porous functionally graded nanobeam

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Abstract. This paper is concerned with the buckling behavior of 2D and quasi-3D problem of functionally graded nanobeam founded on high order shear deformation beams theory and made by two different types of porous distribution materials in Nano- and micro-scales. The used Quasi-3D formulation takes into account the transverse shear effect and uses only three variables. Both formulations do not include the correction factor that is required in the first shear deformation theory proposed by Timoshenko. Governing equations are derived using the principle of virtual work. Analytical resolutions for buckling of FG nanobeam are introduced under tow different boundary conditions, and the results obtained are compared to those proposed in literatures.

Keywords: buckling; functionally graded material; porous materials; nanobeam

1. Introduction

For the analysis of micro and nano-rods/tubes (such as nano-probes made from carbon nanotubes), it goes back to applying classical beam theories where one distinguishes the theory of Euler-Bernoulli or simple beam in 18th century then the Timoshenko theory beam that allows the effect of transverse shear deformation was formulated in the early 20th century.

Further, many numerical, analytical and 3D elasticity method are used to study static and dynamic behavior of functionally graded carbon nanotube reinforced composite structures such as (Murmu and Pradhan 2009, Formica *et al*. 2010, Janghorban and Zare 2011, Ke *et al*. 2012, Lei *et al*. 2013, Rokni *et al*. 2015, Mehar *et al*. 2016, 2017, 2018a, b, 2019, 2020, Mehar and Panda 2016, 2017, 2018, 2020, Mahapatra *et al*. 2017, Khiloun *et al*. 2020, Khadimallah *et al*. 2020, Rabhi *et al*. 2020, Al-Maliki *et al*. 2020, Al-Furjan *et al*. 2021).

Shown invalidity the classical theories of beams to determine the decrease in phase velocities of wave propagation in a carbon nanotube when the number of waves is large as the microstructure has a significant influence on wave dispersion.

Since 1972, the concept of non-local elasticity for the analysis of different bending, buckling and vibration stresses of microbeams/rods/tubes (Wang and Hu 2005, Peddieson *et al*. 2003, Zhang *et al*. 2005, Wang and Varadan 2006, Lu *et al*. 2006), has been applied through research following Eringen's pioneering work (Eringen 1972, 1983, Eringen and Edelen 1972), strain gradient theory (Lam *et al*. 2003) and the like, which could predict size effect by considering material length scale parameters.

On the other hand, the small-scale effect in mechanical properties was not taken up by these theories, those proved inadequate, being at the free scale. For example, Wang and Hu (2005) have shown invalidity the classical theories of beams to determine the decrease in phase velocities of wave propagation in a carbon nanotube when the number of waves is large as the microstructure has a significant influence on wave dispersion.

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Many researchers have applied the nonlocal elasticity concept for bending, buckling and vibration analyses of nano-sized structures such as beams (Aranda-Ruiz *et al*. 2012, Aydogdu 2009, De Sciarra 2014, Ghannadpour *et al*. 2013, Loya *et al*. 2009, Lu 2007, Miandoab *et al*. 2014, Murmu and Pradhan 2009, Reddy and El-Borgi 2014, Wang *et al*. 2006, Yang *et al.* 2010, Semmah *et al*. 2019, Hussain *et al*. 2019, Matouk *et al*. 2020, Asghar *et al*. 2020, Taj *et al*. 2020, Gafour *et al*. 2020), rods (Murmu and Pradhan 2009, Khosravi *et al*. 2020) and plates (Ansari *et al*. 2016, Daneshmehr *et al*. 2015, Ke *et al*. 2015, Boutaleb *et al*. 2019, Balubaid *et al*. 2019, Bellal *et al*. 2020, Abdulrazzaq et al. 2020).

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