Stability of micro-beam including Higher-Order Beam Theories under thermal and mechanical forces

E.Mokhtari [1,*] - Amir hoessin yosefi [2]

[1] Islamic azad university Shahin shahr branch–faculty member of civil engineering

[2] Islamic azad university Shahin shahr branch– faculty member of civil engineering

Abstract

This paper investigatesthe effects of thermal load and shear force on the buckling of nanobeams.Higher-order shear deformation beam theoriesare implementedand their predictions of the critical buckling load and post-buckled configurations are compared to those ofEuler-Bernoulli and Timoshenkobeam theories.The Eringen model for nonlocal elasticity is adopted to account formaterial discontinuity at the nano-scale and analytical solutionsfor critical buckling loads and post-buckling configurations are derived for each beam theory.Results show that thermal loadhas a more significant impact on the buckling behavior ofsimply-supported beams (S-S) than it has onclamped-clamped (C-C)beams. However, the nonlocal effect has more impact on C-C beams that it does on S-S beams.Moreover, it was found that the predictions obtained fromTimoshenko beam theoryare identical to those obtained using all higher-order shear deformation theories, suggesting that Timoshenko beam theory is sufficientto analyze buckling in nanobeams.

Keywords: micro-beam,stability,Higher-order beam theories, Thermal loads.

1. Introduction

Classical continuum mechanics approaches arecommonly adopted in the analysis of nano devices because of their low computational cost,compared to molecular dynamics, and theirability to explainexperimental results. Nonlocal elasticity [1, 2]has also been adoptedwithin this framework to account for lattice structurediscontinuities, which become significant at nano-scale. Whereas continuum mechanics assumes a continuous material distribution and a point-to-point mapping between the stress and strain fields, nonlocal elasticity assumes that the stress field at a point is a function of the strain field at all pointsin the domain.

The classical Euler-Bernoulli beam theory (CBT) augmented with Eringen nonlocal elasticity model has been widely deployed to study the stability of nanobeams. Adali [3] and Sudak[4]used this approach to study the buckling ofmulti-walled carbon nanotubes (MWCNTs).Ghasemi et al. [5] used it to studybuckling and post-buckling of fluid-conveyingMCNTs.Setoodeh et al. [6] presented exact analytical solutions for the post-buckling configurations of single-walled carbon nanotube (SWNTs) subject to various support conditions.Ansari et al. [7] studied post-buckling behavior of SWCNTsunder thermal loads for various boundary conditions. Wang et al. [8],Zhen and Fang [9], andChang [10, 11] developed modelsincluding thermal effects to studythestability of fluid-conveying SWNTs.Murmuand Pradhan[12]investigated the thermal stability of CNTs embedded in an elastic medium. Janghorban[13]comparedthe static response of nonlocal microbeamsunder thermal loadsobtained using two differential quadrature methods.Lim et al. [14] investigated buckling of nanobeams, nanorods, and nanotubes in a temperature field.Eltaher et al. [15] studied the static stability of nanowires with initial curvature under thermal loads.

Adali[16]introduced nonlocal elasticity into Timoshenko beam theory (TBT) to analyze the buckling of MCNTs.Benguediab et al. [17]used the same theory to investigate theeffects of scale and chirality on buckling of zigzag CNTs.Narendar and Gopalakrishnan[18],Pradhan and Mandal [19], andAmirian et al. [20] applied it to the buckling and vibrations of SWCNTs underthermal loads.

Reddy [21]augmented CBT, TBT, Reddy shear beam theory (RSBT), and Levinson beam theorywith nonlocal elasticity to studybuckling, static and dynamic behaviors of nanostructures.Emam[22]compared static stability predictions fornanobeamsobtained fromCBT, TBT, and RSBT.Tounsi et al. [23]studiedbuckling of nonlocal nanobeams under thermal loads basedon a six-ordershear deformation theory.A review onthe state-of-the-art on nonlocal analysis for the static stability of CNTs is given in Wang et al. [24].

Thus far,the literature lacksa comprehensive study for the significance of implementing nonlocal elasticity models into the variousavailable beam theories. The present work tries to fill this gap by comparing the results obtained for the static stability of nanobeams using six different beam theories adapted with Eringen nonlocal elasticity model, namely CBT,TBT, RSBT, Touratier shear beam theory (TSBT), Soldatos shear beam theory (SSBT), and Karama shear