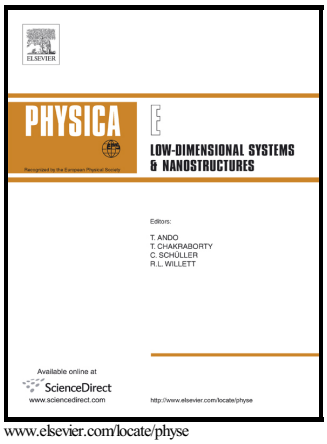
# Author's Accepted Manuscript



www.elsevier.com/locate/physe

## Free vibration of an embedded single-walled carbon nanotube with various boundary conditions using the RMVT-based nonlocal Timoshenko beam theory and DQ method

Chih-Ping Wu, Wei-Wen Lai

PII: S1386-9477(14)00432-9
DOI: http://dx.doi.org/10.1016/j.physe.2014.12.004
Reference: PHYSE11795

To appear in: *Physica E: Low-dimensional Systems and Nanostructures*

Received date: 25 October 2014
Revised date: 3 December 2014
Accepted date: 4 December 2014

Cite this article as: Chih-Ping Wu and Wei-Wen Lai, Free vibration of an embedded single-walled carbon nanotube with various boundary conditions using the RMVT-based nonlocal Timoshenko beam theory and DQ method, *Physica E: Low-dimensional Systems and Nanostructures,* http://dx.doi.org/10.1016/j.physe.2014.12.004

# Free vibration of an embedded single-walled carbon nanotube with various boundary conditions using the RMVT-based nonlocal Timoshenko beam theory and DQ method

Chih-Ping Wu* and Wei-Wen Lai

Department of Civil Engineering, National Cheng Kung University, Tainan 70101, Taiwan, ROC

*Corresponding author.
*E-mail*: cpwu@mail.ncku.edu.tw

**ABSTRACT**

The nonlocal Timoshenko beam theories (TBTs), based on the Reissner mixed variation theory (RMVT) and principle of virtual displacement (PVD), are derived for the free vibration analysis of a single-walled carbon nanotube (SWCNT) embedded in an elastic medium and with various boundary conditions. The strong formulations of the nonlocal TBTs are derived using Hamilton's principle, in which Eringen's nonlocal constitutive relations are used to account for the small-scale effect. The interaction between the SWCNT and its surrounding elastic medium is simulated using the Winkler and Pasternak foundation models. The frequency parameters of the embedded SWCNT are obtained using the differential quadrature (DQ) method. In the cases of the SWCNT without foundations, the results of RMVT- and PVD-based nonlocal TBTs converge rapidly, and their convergent solutions closely agree with the exact ones available in the literature. Because the highest order with regard to the derivatives of the field variables used in the RMVT-based nonlocal TBT is lower than that used in its PVD-based counterpart, the former is more efficient than the latter with regard to the execution time. The former is thus both faster and obtains more accurate solutions than the latter for the numerical analysis of the embedded SWCNT.

***Keywords:*** Reissner's mixed variation theorem; Free vibration; Nonlocal Timoshenko beams; Various boundary conditions; Winkler foundations; Pasternak foundations.