PROCORE - FRANCE/HONG KONG JOINT RESEARCH SCHEME
COMPLETION REPORT

Project Reference Number

9052006 (RGC Ref No: F-HK03/11T)

Project Title

Wave Propagation in Carbon Nanotubes Based on A New Nonlocal Cylindrical Shell Model
基于一种新的非局部圆柱壳模型的碳纳米管的波传播

Particulars

	Hong Kong team	French team
Name of Project Co-ordinator (with title)	English: Dr C.W. Lim Chinese: 林志华	Prof. Noël Challamel
Name of Co-Investigator (if any)	English: NA Chinese:	NA
Institution or Institutional affiliation	✓ CityU; ☐ HKU; ☐ CUHK; ☐ HKUST; ☐ HKBU; ☐ LU; ☐ HKIEd; ☐ PolyU	☐ CEA; ☐ INRA; ☐ CNRS No.; ☐ INRIA; ☐ INFREMER; ☐ INSERM No.; ☐ University of; ✓ Others: Université de Bretagne Sud, Université Pierre et Marie Curie (Paris 6)
Other project team members (if any)	NA	NA

Funding Period

	1st year	2nd year (if applicable)
Start Date	1 January 2012	Nil
Completion Date	31 December 2012	Nil

Objective(s) as per original application

- Develop a cylindrical shell model for carbon nanotubes based on a nonlocal elasticity model.
- Investigate dynamical and wave propagation characteristics in carbon nanotubes
- Forge close research collaboration between Hong Kong and France institutions
- Dissemination and publication of new research models and results.
- Preparation for new research proposals.

[Please attach relevant document(s)]

i) Outline of proposed research and results obtained

A new elastic nonlocal stress model and analytical solutions has been developed for torsional dynamic behaviors of circular nanorods/nanotubes [1]. The new model begins with the derivation of strain energy using the nonlocal stress and it considers the nonlinear history of straining. The variational principle is applied to derive an infinite-order differential nonlocal equation of motion and the corresponding higher-order boundary conditions which contain a nonlocal nanoscale parameter. Some examples for free torsional vibration of nanorods/nanotubes and axially moving nanorods/nanotubes are investigated in detail. Unlike the previous conclusions of reduced vibration frequency, the analysis indicates that natural frequency for free torsional vibration increases with increasing nonlocal nanoscale. Furthermore, the critical speed for torsional vibration of axially moving nanorods/nanotubes is derived and it is concluded that this critical speed is significantly influenced by the nonlocal nanoscale.

In addition to research and analytical results, the PI managed to consolidate the ideas from various discussions during the trip and a new research proposal submitted to City University of Hong Kong has successfully attracted the CityU Seed Grant [2].

ii) Significance of research results

The research is significant because the new approach presents is different from previous methods where, instead of directly replacing the stress terms in the classical equations of motion by the corresponding nonlocal stress terms, new higher-order governing equations of motion and the higher-order boundary conditions are derived by considering nonlinear straining with reference to an undeformed state. The conclusion that the nonlocal nanoscale induces higher torsional stiffness and hence causes increased free vibration frequency is significant for giving new insights to the theory of nonlocal elasticity. In addition, the results for critical velocity of axially moving nanorods/nanotubes obtained will be useful for comparison and reference in the future. In conclusion, the research result presents a new avenue for the theory and analysis and the approach could be extended to other relevant fields of research in nonlocal elasticity and strain gradient theory.

iii) Research output

[1] **C.W. Lim**, C. Li and J.L. Yu, Free torsional vibration of nanotubes based on nonlocal stress theory, *J. Sound Vib.*, **331**(12), 2798-2808, June 2012. (Paper attached and grant acknowledged)

[2] CityU Seed Grant 2013-2014, Study of mechanical properties of multilayer graphene sheets controlled by ion irradiation, HK$100,000. (grant successfully awarded)

iv) Potential for or impact on further research collaboration

The original proposal proposed research interaction and collaboration with Prof. Noël Challamel of Université de Bretagne Sud. Subsequent collaboration with Prof. Challamel led to research interaction with Dr Thomas Michelitsch of Université Pierre et Marie Curie (Paris 6). From various discussions with the two parties, the PI has extended research on a relevant and a research paper has been published [1] and a research proposal has received research funding [2]. Close research interaction with these two parties is currently being forged. There is great potential for significant research outputs with impact through further research collaborations in the future. In particular, the theory, model and new analytical solutions in nonlocal elasticity will be established and reported in international research journals.