GERMANY/HONG KONG JOINT RESEARCH SCHEME
THE PROJECT REPORT
(for Project Completion)

Project Number: G_HK005/11

Title

Nonlinear Size Effects of Micro- and Nano-Structures

Particulars

	Hong Kong team	German team
Name of Project Co-ordinator (with title)	Prof. C.W. Lim	Prof. Ch. Zhang
Name of Co-Investigator (if any)		Dr. T.Q. Bui
Institution or Institutional affiliation	✓ CityU; ☐ HKU; ☐ CUHK; ☐ HKUST; ☐ HKBU; ☐ LU; ☐ HKIEd; ☐ PolyU	✓ University of Siegen; ☐ Others: _____
Other project team members (if any)		

Funding Period

	1st year	2nd year (if applicable)
Start Date	1 January 2012	1 January 2013
Completion Date	31 December 2012	31 December 2013

Objective(s) as per original application

- Development of a new nonlinear model for investigating the size effects of micro- and nano-structures
- Investing the influences of long-range forces on nonlinear large deformation
- Preparation for new research proposals

Details of Report [Please attach relevant document(s)]

i) Outline of proposed research and results obtained

The project aims to promote intensive research collaboration between two partnering research institutions: University of Siegen and City University of Hong Kong. Specifically, it aims to develop a new nanomechanical nonlinear model which considers the size effects large deformation of micro- and nano-structures including micro- nano-beams, arches, etc. Both research parties also worked on the preparation of new research proposals in the future.

As a result of mutual visits, discussions and close collaboration in the last two years, two research seminars [1,2] were organized and three research papers [3-5] were published. Specifically, during a research visit to City Univ of Hong Kong, the Principal Investigator from Univ of Siegen (Prof Ch. Zhang) presented a seminar to the host investigator, academic and research staff and a group of graduate students. In a different research visit, the Principal Investigator from City Univ of Hong Kong (Prof. C.W. Lim) presented a seminar to the partner investigators and a group of research staff and graduate students in University of Siegen on a topic in nonlocal theory and modelling in nanostructures. Following various discussions intensive collaboration, a new FG model and computational method with numerical analysis on Lamb wave propagation in micro-sized functionally graded materials (FGMs) by a 2D time-domain spectral finite element method using high-order Chebyshev polynomials were developed [3]. Different excitation frequencies in a wide range of 28-350kHz were investigated, and the dispersion properties obtained were verified with reference results. Furthermore, a new symplectic elasticity method for stability and dynamic buckling of structures in any size in general were also established [4,5] where Paper [4] deals with a symplectic approach within the perspective of stress wave propagation to study theoretically the localization of dynamic buckling of a cylindrical shell subjected to an axial impact while Paper [5] reported dynamic buckling of cylindrical shells subjected to the combined action of axial impact load, torsion and pressure. Although the partner investigators are not among the authors of these two paper [4,5], they were consulted during the preparation of these papers provided much criticism to improve these papers.

ii) Significance of research results

The close collaboration and research papers as described above have significant research values. Although not specifically targeting nanostructures, the new FG model and computational method [2] and symplectic elasticity dynamic stability analyses [3,4] are applicable to structures of all sizes including micro- and nano-structures. These papers have developed new theoretical, analytical approaches and computational methodologies for structures which undergo wave propagation and stability problems. The new models and results will provide original research insights into the relevant issues and the solutions will provide new understanding and guidelines for designing experiments for verification and also in designs of micro- and nano-structural components.

iii) Research output

[1] Ch. Zhang, *Static and Dynamic Analyses of Interface Cracks in Piezoelectric Laminates*, City Univ of Hong Kong, Hong Kong, 1 March 2013.

[2] C.W. Lim, *On Nonlocal Strain Gradient Theory of Elasticity*, Univ of Siegen,Germany,29 Nov 2013.

[3] Saeid Hedayatrasa, Tinh Quoc Bui, Chuanzeng Zhang and C.W. Lim, Numerical modeling of wave propagation in functionally graded materials using time-domain spectral Chebyshev elements, *J. Computational Physics*, **258**, 381-404, 2014. (**Grant acknowledged**).

[4] Jiabin Sun, Xinsheng Xu and C.W. Lim, Localization of dynamic buckling patterns of cylindrical shells under axial impact, *I. J. Mech. Sci.*, 66, 101-108, 2013. (**Grant acknowledged**).

[5] Jia-Bin Sun, Xin-Sheng Xu and C.W. Lim, Symplectic method for dynamic buckling of cylindrical shells under combined loading, I. J. Appl. Mech., 5(4), 1350042, 2013. (**Grant acknowledged**).

iv) Potential for or impact on further research collaboration

The original proposal proposed research interaction and collaboration with Prof. Ch. Zhang and Dr T.Q. Bui of University of Siegen. Subsequent collaboration with the partner investigations led to extensive interaction with graduate students at both institutions [1,2] and in addition, three research papers with significant research outcomes [3-5]. From various discussions and communications, the investigators have begun to nurture a new research project and a proposal is currently in preparation. Further close research interaction has been going continuously. 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 size-dependent micro- and nano-structures based on the new FG model, symplectic methodology and FE numerical method will be established and reported in international research journals.