CanCNSM 2013

4th Canadian Conference on Nonlinear Solid Mechanics

Book of Abstracts

Montréal, Canada
July 23-26, 2013

Editors:
Marco Amabili
Farbod Alijani

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Welcome Message

On behalf of the organizing committee of CanCNSM2013, it is my great pleasure to welcome you to the 4th Canadian Conference on Nonlinear Solid Mechanics in Montreal, Quebec. CanCNSM Conferences are intended to provide an international opportunity for communicating recent developments in various areas of nonlinear solid mechanics and materials. After 3 successful conferences in Victoria (1999), Vancouver (2002) and Toronto (2008), the 4th Canadian Conference on Nonlinear Solid Mechanics will be held in July 23-26, 2013 at McGill University which is best recognized for its research and discoveries in different fields of science. With an international reputation for academic excellence, McGill offers innovative and interdisciplinary programs and has evolved into a highly motivating and well-respected research center in North America.

Montreal, known as Canada's Cultural Capital, is located in the southwest of the province of Quebec. The unique ambiance, fascinating festivals, vibrant nightlife, cultural diversity and superb cuisine have made the city a favourite travel destination.

The framework of CanCNSM2013 is truly multidisciplinary and scientists from all over the world are encouraged to contribute in the conference. The technical program will include plenary speakers, regular sessions including contributing papers and mini-symposiom sessions on pre-defined topics of nonlinear solid mechanics as well as areas of linear solid mechanics that are bridging nonlinear aspects. We look forward to welcoming you to Montreal at CanCNSM2013.

Marco Amabili

CanCNSM2013, Chair

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Plenary Speakers

Professor Gerhard Holzapfel

Institute of Biomechanics, Graz University of Technology, Austria

Title of speech: Structurally-based Modeling of Nonlinear Solids with Applications to Cardiovascular Tissues

Professor Angelo Luongo

President of the International Research Center on Mathematics and Mechanics of Complex Systems, "M&MOCS", Italy

Title of speech: On the Use of the Multiple Scales Method in Solving Difficult Bifurcation Problems

Professor J.N. Reddy

Department of Mechanical Engineering, Texas A&M University, USA

Title of speech: On Rotation Gradient Dependent Elasticity and Specialization to Beams and Plates with Moderate Rotation

Professor Pol Spanos

Department of Civil and Environmental Engineering, Rice University USA

Title of speech: Local versus Non-Local analysis of Dynamic Phenomena via Wavelets and Fractional Derivatives

Professor Alexander F. Vakakis

Department of Mechanical Science and Engineering, University of Illinois, Urbana-Champaign, USA

title of speech: Strongly Nonlinear Dynamics of Ordered Granular Media

Professor Alan Wineman

Department of Mechanical Engineering, University of Michigan, USA

Title of speech: Chemo-Rheological Changes in Elastomers: Implications for Mechanical Response

Mini-symposium Sessions

CanCNSM2013 is structured through mini-symposium sessions. The list of mini-symposium topics and their organizers are as follows:

- **Creep and Thermo-Mechanical Fatigue**
  - J. Boyle (University of Strathclyde, UK)
  - D. Breslavsky (Kharkov Polytechnical Institute, Ukraine)
  - K. Naumenko (Otto von Guericke University ,Magdeburg, Germany)
- **Dynamics and Control of MEMS and NEMS Systems**
  - D. Caruntu (University of Texas Pan-American, USA)
  - M. Amabili (McGill University, Canada)
  - B.I. Epureanu (University of Michigan, USA)
- **Hyperbolic Models and Theories in Nonlinear Solid Mechanics**
  - Y. N. Radayev (Russian Academy of Science, Moscow, Russia)
- **Material Nonlinearities and their Effects**
  - E. Sancaktar (University of Akron, USA)
- **Mechanics of Multibody Systems**
  - J. Kovecses (McGill University, Canada)
  - J. Angeles (McGill University, Canada)
- **Mechanics of Granular Media**
  - A. Vakakis (University of Illinois, Urbana-Champaign, USA)
- **Microstructural Effects on Mechanical Properties of Materials**

- S. Vedantam (Indian Institute of Technology, Madras, India)

- **Modeling and Simulation of Nanostructured Materials**
  - L. Y. Jiang (University of Western Ontario, Canada)
- **Nonlinear Dynamics of Discrete and Continuous Systems**
  - M. Amabili (McGill University, Canada)
  - D. Caruntu (University of Texas Pan-American, USA)
  - B.I. Epureanu (University of Michigan, USA)
  - E. Esmailzadeh (University of Ontario Institute of Technology, Canada)
  - D. Younesian (Iran University of Science and Technology, Iran)
- **Nonlinear Elasticity (Dedicated to Richard Toupin, in recognition of his outstanding contribution to Mechanics)**
  - D. Steigmann (University of California at Berkley, USA)
  - F. dell Isola (Università di Roma "La Sapienza", Roma, Italy)
- **Nonlinear Mechanics of Healthy and Pathological Tissues**
  - R. Mongrain (McGill University, Canada)
  - R. Leask (McGill University, Canada)
  - L. Mongeau (McGill Univesity, Canada)
- **Nonlinear Mechanics of Composites**
  - C. Pinna (University of Sheffield, UK)
  - C. Soutis (University of Manchester, UK)
- **Nonlinear Mechanics of Multifunctional Micro-Architectured Materials**
  - D. Pasini (McGill University, Canada)

- **Nonlinear Phenomena in Tissue growth and Bio-Mechanics**
  - A. Madeo (Université de Lyon,France)
  - T. Lekszycki (Warsaw University of Technology, Poland)
- **Nonlinear Stability Analysis**
  - H. Mang (Institute of Mechanics of Materials and Structures, Austria),
  - Y.B. Yang (National University of Taiwan, Taiwan)
- **Non-smooth Vibrations in Structural Dynamics**
  - M. Legrand (McGill University, Canada)
  - A. Shukla (Miami University, USA)
- **One dimensional models of beams, cables and beam-like structures**
  - A. Luongo (University dell'Aquila, Italy)
- **Plasticity and Damage: Experimental and Numerical Simulations**
  - F. Marotti de Sciarra (Università di Napoli Federico II, Italy)
- **Singularities in the Mechanics of Solids**
  - D. Bigoni (University of Trento, Italy)
  - R. Fosdick (University of Minnesota, USA)
  - G. Royer-Carfagni (University of Parma, Italy)
- **Soft Tissue Growth and Remodeling**
  - G. Holzapfel (Graz University of Technology, Austria)
  - L. Taber (Washington University in St. Louis , USA)
  - J. Humphrey (Yale University, USA)
- **Stability and Vibrations of Plates and Shells**
  - E. Jansen (University of Hannover, Germany)
  - M. Amabili (McGill University, Canada)

- **Uncertainty Quantification in Solid Mechanics**
    - A.Sarkar (Carleton University, Canada)
- **Regular sessions; including,**
    - Multiphysical Computational Geomechanics
    - Optimization Using Nonlinear Phenomena
    - Advanced Numerical Methods
    - Nonlinear Material Characterization using Inverse Simulation Methods

Abstracts of Plenary Speakers

Professor Gerhard Holzapfel

Institute of Biomechanics, Graz University of Technology, Austria

Title of speech: Structurally-based Modeling of Nonlinear Solids with Applications to Cardiovascular Tissues

The exciting area of nonlinear solid mechanics serves as a solid basis for a surprisingly large variety of problems arising in practical engineering, applied mechanics, mathematics, physics and material science, and it is a central field in biomechanics [1]. This presentation aims to show some of the recent developments in the field on structurally-based modeling with applications to cardiovascular tissues such as the myocardium and the artery wall but also to the actin cortex which is a 3D structure underneath the cellular bilayer forming an isotropic and cross-linked protein network; for a recent collection of models in biomechanics see [2].

It is an essential task to identify, quantify and model the structure of biological tissues, otherwise the stresses predicted by using numerical tools might not reflect the 'true' in vivo conditions. For example, in the (left ventricular) myocardium three mutually orthogonal directions can be identified, forming planes with distinct material responses. We treat the myocardium as a non-homogeneous, thick-walled, nonlinearly elastic and incompressible material and develop a general theoretical framework based on invariants associated with the three directions. The proposed model is applied to simple shear and biaxial deformations and a specific form is fitted to experimental data, emphasizing the orthotropy and the limitations of biaxial tests [3]. Briefly, the structural situation is also discussed for arterial tissues, and significant structural differences in collagen morphologies between healthy and diseased arterial tissues are highlighted using second-harmonic generation imaging.

Finally, we consider the modeling of the actin cortex which is validated experimental data from rheological experiments of in vitro reconstituted actin networks [4]. In particular, a new non-affine micro-sphere network model is presented accounting for the filamentous actin which is equally distributed in space. The elastic filaments incorporate both bending and stretching; explicit formulas for the extension-force relationship are obtained which include dependence on the initial end-to-end distance of the filament. The approach adopted is purely mechanical but is reconciled with statistical physics approaches and allows for a proper formulation of boundary-value problems. The specific formulas derived are relatively simple and the parameters involved have direct mechanical interpretations and are immediately related to the filament properties, including the initial end-to-end length, contour length and persistence length [5].

References

[1] GA Holzapfel: Nonlinear Solid Mechanics. A Continuum Approach for Engineering, John Wiley & Sons, Chichester, 2000

[2] GA Holzapfel, E Kuhl: Computer Models in Biomechanics. From Nano to Macro. Springer, 2012

[3] GA Holzapfel, RW Ogden: Constitutive modelling of passive myocardium: a structurally based framework for material characterization, Philos T Roy Soc A, 367:3445-75, 2009

[4] MJ Unterberger, KM Schmoller, AR Bausch, GA Holzapfel: A new approach to model cross-linked actin networks: Multi-scale continuum formulation and computational analysis. J Mech Behav Biomed Mater, in press

[5] GA Holzapfel, RW Ogden: On the bending and stretching elasticity of biopolymer filaments, J Elas, 104:319-42, 2011.

Professor Angelo Luongo
President of the International Research Center on Mathematics and Mechanics of Complex Systems, "M&MOCS", Italy

Title of speech: On the Use of the Multiple Scales Method in Solving Difficult Bifurcation Problems

Several algorithms consisting in 'non-standard' versions of the Multiple Scale Method are illustrated for 'difficult' bifurcation problems. Preliminary, the 'easy' case of bifurcation from a cluster of distinct eigenvalues is addressed, which requires using integer power expansions, and it leads to bifurcation equations all of the same order. Then, more complex problems are studied. The first class concerns bifurcation from a defective eigenvalue, which calls for using fractional power expansions and fractional time-scales, as well Jordan or Keldysh chains. The second class regards the interaction between defective and non-defective eigenvalues. This problem also requires fractional powers, but it leads to differential equations which are of different order for the involved amplitudes. Both autonomous and parametrically excited non-autonomous systems are studied. Moreover, the transition from a codimension-3 to a codimension-2 bifurcation is explained. As a third class of problems, singular systems possessing an evanescent mass, as Nonlinear Energy Sinks, are considered, and both autonomous systems undergoing Hopf bifurcation and non-autonomous systems under external resonant excitation, are studied. The algorithm calls for a suitable combination of the Multiple Scale Method and the Harmonic Balance Method, this latter to be applied exclusively to the singular equations. Several applications are shown, to test the effectiveness of the proposed methods. They include discrete and continuous systems, autonomous, parametrically excited and externally excited systems.

Professor J.N.Reddy

Department of Mechanical Engineering, Texas A&M University, USA

Title of speech: On Rotation Gradient Dependent Elasticity and Specialization to Beams and Plates with Moderate Rotation

The objective of this study is to formulate the governing equations for a fully constrained finitely deforming hyperelastic cosserat continuum where the directors are constrained to rotate with the body rotation. Such a theory would be a useful way of developing models for an elastic material embedded with stiff short fibers or inclusions and that accounts for certain longer range interactions. Unlike a conventional approach based on postulating additional balance laws, the approach presented here is a Lagrangian mechanics based approach, circumventing some of the difficulties associated with boundary conditions, for example. The two major concepts introduced are (1) the use of the polar decomposition theorem as a constraint and (2) a representation for finite rotations in terms of displacement gradients for large deformation plane problems. Classical couple stress theory is recovered for small strain. As a part of this lecture an over view of other nonlocal and modified couple stress theories will be presented.