3nd International workshop of young researchers in the mechanics of materials and structures.

Organizers: Maurizio Angelillo* & Antonio De Simone**

*Laboratorio di Strutture, Dipartimento di Ingegneria Civile,
Università di Salerno
** International School for Advanced Studies (SISSA) Trieste

The meetings are held on a annual base with alternate location SISSA Trieste and University of Salerno.
The third meeting will be held at the Laboratory of Structural Mechanics of the University of Salerno from October 6 to October 8, 2010

Local organizers: Maurizio Angelillo, Antonio Fortunato, Dipartimento di Ingegneria Civile, Universita' di Salerno, via ponte don Melillo, 84084 Fisciano (SA) Italy.
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At this third meeting will participate as a teacher of a mini-course of three days on “Frontiers in Vascular Continuum Biomechanics and Mechanobiology”, Jay D. Humphrey from the “Department of Biomedical Engineering, Yale University” (formerly“Texas A&M” University).

These are the names of the young researchers (PhD graduates presenting their thesis in 2010) selected for the presentation of their PhD work at this third meeting:

Massimiliano Cremonesi, Politecnico di Milano,
Antonino Favata, Università di Roma 2,
Enrico Masoero, Politecnico di Torino, currently MIT,
Kim Pham, UPMC Univ Paris 06 and CNRS,
Marco Ribezzi, Università di Roma 3, currently Universitat de Barcelona,
Sara Roccabianca, Università di Trento.

Workshop schedule

Wednesday, Oct 6
9.00 - 10.00
Humphrey, Lecture 1A

10.15 - 11.15
Humphrey, Lecture 1B

11.30 - 13.15
PhD presentation 1

14.15 - 16.00
PhD presentation 2

Thursday, Oct 7

8.30 - 9.30
Humphrey, Lecture 2A

9.45 - 10.45
Humphrey, Lecture 2B

11.00 - 12.45
PhD presentation 3

13.45 - 15.30
PhD presentation 4

Friday, Oct 8

8.30 - 9.30
Humphrey, Lecture 3A

9.45 - 10.45
Humphrey, Lecture 3B

11.00 - 12.45
PhD presentation 5

13.45 - 15.30
PhD presentation 6

NOTICE
English is the official language of the workshop.
The rule for the presentations is that they must be done with chalk and blackboard, with a minimum support of images (no ppt or similar presentation).

Summaries.

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A Lagrangian finite element method for the interaction between flexible structures and free surfaces fluid flows

Abstract
The numerical simulation of fluid-structure interaction phenomena is increasingly important because this problems occurs in many fields of engineering. The computational treatment of the free surface and of the interface between solid and fluid in fluid-structure interaction is always critical. The Arbitrary Lagrangian Eulerian method (ALE) in which the movement of the fluid particles is independent from that of the mesh nodes, is often used to solve these kind of problems.
Other possible methods are based on the volume of fluid or level set algorithms. Meshfree and meshless methods are often used for their ability to recover the free-surfaces and the interfaces. A possibility to overcome the difficulties concerning the tracking of the interfaces is to adopt a Lagrangian approach for both fluid and structure. In the present work a fluid-structure interaction algorithm is presented based on a staggered approach in which the fluid is treated in a Lagrangian framework using a new implementation of the so called Particle Finite Element Method (PFEM),first proposed by Oñate, Idelsohn and coworkers, and the structure using a classical finite element method.
An advantage of the Lagrangian approach for the fluid flow is that the convective terms in the momentum conservation disappear. The difficulty is however transferred to the necessity to frequently regenerate the mesh. In fact, if a fixed finite element mesh is used and the position of element nodes is updated as a consequence of the fluid flow, very soon the element distortion becomes excessive. A remedy which allows to avoid these distortions consists of systematically remeshing the volume of the problem. To this purpose, an efficient Delaunay triangulation has been adopted. Moreover to define the integration domain and to correctly impose the boundary conditions a method to identify the external boundary is necessary. This has been achieved using a criterion based on the mesh distortion called alpha shape method. The same method allows to define the inclusion and the separation of the individual particles. When remeshing is performed, data have to be transmitted from the old mesh to the new one. In this approach, to avoid interpolation from mesh to mesh, only degrees of freedom of particles located at the vertices of triangles are used, so that only linear shape functions can be used for both velocity and pressure. However, it is well known that this type of discretization does not satisfy the LBB inf-sup compatibility condition and so a stabilization method is required. To this purpose a pressure-stabilizing Petrov-Galerkin (PSPG) stabilization is used. The proposed Lagrangian PFEM is particularly suited for the solution of fluid-structure interaction problems in the presence of free-surfaces, in conjunction with a classical finite element method for the solid part. A critical issue of fluid-structure interaction schemes is the identification of the contact interfaces between the solid and fluid domains. The evolution of the interaction surfaces is tracked using a novel algorithm which exploits the features of the Lagrangian approach based on the continuous remeshing introduced for the fluid solution. The proposed algorithm is based on the superposition of a set of fictitious fluid particles to the nodes of the solid domain, which can come in contact with the fluid domain. When the Delaunay triangulation is performed, the alpha-shape criterion selects those parts of the interface where the fluid particles can possibly come into contact with the structure. If the two discretized domains are not in contact, the fluid and the solid analyses are performed separately without any interaction. If instead parts of the two discretized domains are in contact, a coupled analysis is performed with a Dirichlet-Neumann iterative approach.
The proposed scheme has been applied to both Newtonian and non-Newtonian fluids. Comparisons with numerical benchmarks and with experimental results are presented to show its potentialities and to find possible defects. The non-Newtonian solver has been also used to

simulate typical tests on fresh concrete, mortar and cement pastes showing a good agreement between numerical and experimental results.

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On certain constitutive issues in continuum mechanics

Abstract
The thesis consists in a collection of some research arguments in continuum mechanics, general and structural, all of them of constitutive nature.
The work is organized as follows. In the first chapter, we consider the so-called *simple materials*, those for which the stress is determined by the history of the first spatial gradient of the deformation; in particular, we focus on two classes of simple materials, with *fading memory* and with *internal variables*, and for each class, we propose a theorem of splitting of the total energy into internal and kinetic parts.
In the second and third chapter, we consider *transversely isotropic* and thin material bodies in shape of right cylinders. In chapter 2, we consider plate- and shell-like such bodies. For the former, we investigate the implications of isolating the *null-lagrangian* part of the total energy so as to evaluate it in terms of the given boundary conditions. For the latter, we derive a *membrane theory*, in general and as appropriate when the base surface is ruled.
In the final chapter 3, we deal with the issue of the *identification* of constitutive parameters for rod-like bodies, whose governing equations are obtained by a direct one-dimensional approach. In fact, with such an approach, there is a need to gather the geometric and material information necessary to choose the stiffness parameters in a manner consistent with a parent three-dimensional theory. In the cases of shear and torsion stiffnesses, this is done on the basis of a fairly general notion of cross-section shape factors.

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Progressive collapse and robustness of framed structures

Abstract.
Progressive collapse of buildings with framed structure is a topic raising widespread interest, especially after catastrophic collapse events occurred in the last decades.
Many improvements have been made for what concerns evaluating and providing structural robustness, i.e. collapse resistance after local damage. Nevertheless, a clear framework and the corresponding tools to investigate and understand the physics of the phenomenon are still missing. The approach proposed in this thesis consists first of an exploration stage, aimed at identifying the possible collapse mechanisms that local damage can trigger, pointing out the influence of geometric and mechanical properties of the structure. This stage requires extended parametric studies based on numerical simulations, since there are few experimental data available in literature and since campaigns of progressive collapse tests are expensive and complicated from a technical point of view. The observed collapse mechanisms are successively analysed with theoretical models and energy-based considerations, which permits to evaluate structural robustness and, under opportune simplifying assumptions, express it in closed form.

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Construction and analysis of gradient damage models

Abstract
This work is concerned with the modeling of softening material by regularized damage models. First we propose a rigorous construction of the underlying local model by justifying its formulation within the framework of Generalized Standard Materials. Accordingly, the strain work becomes a state function whose convexity properties are directly related to the hardening or softening properties and the quasi-static evolution problem admits a variational form. As the modeling of softening material can deal with non-uniqueness and time discontinuities, we propose to reinforce the classical evolution problem by integrating stability concepts and energy conservation principle. The local model is then enhanced by inserting gradient of damage into the energy expression. The merits of this new approach are emphasized throughout the study of homogeneous damage states.
Secondly, a bifurcation and stability analysis is carried out for a bar submitted to a tensile test. It permits us to construct homogeneous as well as localized damage solutions in closed form and to illustrate the concepts of loss of uniqueness and stability, of damage localization and structural failure. Additionally, by enforcing the energy balance, we provide an explicit construction to overcome the issue of time discontinuities.
Finally we proceed to the identification of the model parameters in the case of concrete. On the one hand, by an energetic analogy with fracture mechanics, the internal length of the model is linked to the surface energy density of a crack. On the other hand, the laws of rigidity and dissipation of the underlying local damage model are identified by using stability diagrams and the PIED experiment as this latter allows to stabilize homogeneous damage states in a tensile test. An analytical analysis of this experimental procedure through a reduced model obtained by an asymptotic expansion shows under which conditions the homogeneous states can really gain stability. Moreover, depending on the choice of material parameters, numerical experiments in 1D and 2D highlight the existence of surprising phenomena such as damage phase transition.

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Single Molecule Mechanics in a dual optical tweezers set up.

Abstract
I will give a brief introduction to optical tweezers, an experimental technique which allows the manipulation of micro and sub micron sized objects, with sub-nanometer spatial resolution.
In particular I will focus on the possibility of measuring the mechanical response of bio-polymers to an applied tension. The mathematical models describing this experimental set up nicely combines features form continuum and statistical mechanics. In the lecture much attention will be given to these models, with particular emphasis on the case of the dual trap set up developed in Barcelona.
The discussion will cover the stretching of double stranded DNA, which is reasonably accounted for by the Worm Like Chain Model, and the unzipping of
short DNA hairpins, which is well suited to introduce the role of thermal noise in such small systems.
If time permits some now classical results in non-equilibrium statistical mechanics, such as the Jarzynski equality, will be introduced. Such results are extremely useful in this field, because they connect mechanical manipulation experiments to thermodynamic properties.
For each of these topics a theoretical treatment will be presented and then compared to the experimental results that I obtained in the Small Biosystems lab in Barcelona.

References:

Smith SB, Cui Y, Bustamante C., Optical-Trap Force Transducer that Operates by Direct Measurement of Light Momentum Methods in Enzymology (2003), 361:134-162
Bruinsma R., Protein DNA interactions: Physics of bio-molecules and cells,
Les Houches, Session LXXV, 2-27 July 2001 edited by H. Flyvbjerg ... [et al.]
F. Ritort, Nonequilibrium fluctuations in small systems: from physics to biology, Advances in Chemical Physics, vol. 137, 31-123 (2008)

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Plane strain finite solution and incremental bifurcation analysis of elastic layered structures subject to bending

Abstract
Finite plane strain bending is solved for a multilayered elastic–incompressible thick plate. This solution –previously known only in the simple case of homogeneity– is *per se* interesting and reveals the complex stress states –which evidences for certain geometries more than one neutral axis–developing in multilayers as the result of large strains.
Finite bending of plates is a phenomenon common in nature and in technological processes. Although *plates suffering finite bending are normally made up of layers*, the theory of finite elastic bending has been developed only under the assumption of homogeneity (see [3]; [2]). Moreover, while certain elastic multilayers can be bent until the tubular shape is reached without any appearance of inhomogeneities, crazes develop for other systems (Fig. 2), so that the deformational capability of an elastic structure may result strongly penalized.
Therefore, the aims of the present work are (see also [4]):
(i.) to provide an analytical solution to finite bending of an elastic multilayered thick plate deformed under the plane strain constraint;
(ii.) to analyse and solve the problem of two-dimensional bifurcations possibly occurring during bending, solved by a numerical method (see [1] and [4]);
(iii.) to validate our theoretical approach with experiments.
The bending solution is employed to investigate possible incremental bifurcations and this analysis reveals that a multilayered structure can behave in a completely different way from the corresponding homogeneous plate. For a thick plate of neo-Hookean material, for instance, the presence of a stiff coating strongly affects the bifurcation critical angle (Fig. 3). We studied the case of a bilayered structure with a stiffer coating at the tensile or at the compressive side of the specimen.
Experiments have been designed and performed to substantiate our theoretical findings. These demonstrate that the theory can be effectively used as a design tool for predicting the capability of an elastic multilayered structure to be subject to a finite bending without suffering localized crazing.

References
[1] Dryburgh, G. and Ogden, R.W. (1999). *Bifurcation of an elastic block subject to bending.* Z. angew. Math. Phys. 50, 822-838.
[2] Green, A.E. and Zerna, W. (1968). *Theoretical Elasticity*. Oxford University Press.
[3] Rivlin, R.S. (1949). *Large elastic deformations of isotropic materials. V. The problem of flexure.*
Proc. R. Soc. Lond. 195, 463-473.
[4] Roccabianca, S. and Gei, M. and Bigoni,D. (2010). *Plane strain bifurcations of elastic layered structures subject to finite bending: theory vs. experiments.* IMA J. of Appl. Math., in press.