

Track 5:

Experimental and Applied Mechanics

Organized by: Carlos E. Ventura, University of British Columbia; Hugh A. Bruck, University of Maryland; Wendy C. Crone, University of Wisconsin–Madison

Experimental and Applied Mechanics covers the wide variety of subjects that are related to the broad field of experimental or applied mechanics. It is SEM's mission to disseminate information on a good selection of subjects. To this end, research and application papers in Track 5 relate to the broad field of experimental mechanics.

Keynote Presentation:

Jay D. Humphrey

Yale University

Monday, June 13 • 10:30 AM • Session 4

Video-based Inverse FEM Estimation of Soft Tissue Properties

Biological soft tissues appear to develop, grow, remodel, and adapt so as to maintain particular mechanical metrics (e.g., stress) near target values. To accomplish this, tissues often develop regionally varying stiffness and anisotropy. The goal of this work is to develop and implement a hybrid experimental - computational method to quantify regional variations in properties in situ in pressure-distended biological membranes. To this end, we combine biplane-video based measurements of the finite displacements experienced by sets of fiducial markers that are placed on the surface of the sample with a custom subdomain inverse finite element method to infer, using nonlinear regression, the best-fit material parameters within a postulated form of the stored energy function. Diverse applications will be noted, but the method will be illustrated primarily for results from the lens capsule of the eye.

J.D. Humphrey received the Ph.D. in Engineering Science and Mechanics from The Georgia Institute of Technology and completed a post-doctoral fellowship in Medicine - Cardiovascular at the Johns Hopkins University. He is currently Professor of Biomedical Engineering at Yale University. He has authored a graduate textbook (*Cardiovascular Solid Mechanics*), an undergraduate textbook (*An Introduction to Biomechanics*), a short handbook (*Style and Ethics of Communication in Science and Engineering*) and has co-edited a research text (*Cardiovascular Soft Tissue Mechanics*), published chapters in numerous other books or encyclopedias, and published 160+ archival journal papers. He serves as founding co-editor-in-chief for the international journal *Biomechanics and Modeling in Mechanobiology*, which recently received the highest impact factor in the field of biomechanics. He currently serves on the World Council for Biomechanics and on the Executive Committee of the US National Committee on Biomechanics; he is a Fellow of the American Institute of Medical and Biological Engineering and a Fellow of the American Society of Mechanical Engineers.

Keynote Presentation:

Frans Spaepen

Harvard University

Monday, June 13 • 4:10 PM • Session 25

Defects and Deformation of Colloidal Crystals Studied by Confocal Microscopy

Colloidal particles in suspension form liquid, crystalline and glassy phases similar to those formed by atoms. The structure of the phase that is formed depends on the nature of the colloids and their interactions (hard sphere, charged, functionalization of the surfaces, monodisperse or alloy) and especially the density. Since the particles have diameters on the order of a micron they can be observed by optical microscopy. In particular, confocal microscopy has made it possible to track the individual particles in time and space and to use colloidal systems as "analog computers" for the study of the dynamics of defects in crystals (stacking faults, dislocations, grain boundaries) and the fundamental mechanisms of the deformation of simple glasses.

Frans Spaepen is John C. and Helen F. Franklin Professor of Applied Physics at Harvard University. He got his undergraduate degree, in Metallurgical Engineering, at the K.U. Leuven in 1971, and a Ph.D. in Applied Physics from Harvard University in 1975. He joined the faculty of the Division of Applied Sciences at Harvard in 1977 as Assistant Professor, was appointed Associate Professor in 1981, and Full Professor in 1983. In 1984 and 2007 he was a Visiting Professor at the University of Leuven, and in 2000-01 a Humboldt visitor in Köln and Jülich. From 1990 till 1998 he was Director of the Harvard Materials Research Laboratory/Materials Research Science and Engineering Center. Since 2002 he is the Director of the Rowland Institute at Harvard. In 2008-09 he was Interim Dean of the School of Engineering and Applied Sciences and in 2009-10 Interim Director of Center for Nanoscale Systems.

His research interests span a wide range of experimental and theoretical topics in materials science, such as amorphous metals and semiconductors (viscosity, diffusion, mechanical properties), the structure and thermodynamics of interfaces (crystal/melt, amorphous/crystalline semiconductors, grain boundaries), mechanical properties of thin films, the perfection of silicon crystals for metrological applications, and colloidal systems as models for the study of dynamics and defects in crystals and glasses.

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Keynote Presentation:

Keith Runge

University of Florida

Tuesday, June 14 • 10:50 AM • Session 33

Consistent Embedding: A Theoretical Framework for Multiscale Modeling

A fundamental framework for the undertaking of computational science provides clear distinctions between theory, model, and simulation. Consistent embedding provides a set of principles which when appropriately applied can create multi-scale models that capture the physical behavior of more computationally challenging methods within methods that are more easily computed. The consistent embedding methodology is illustrated within the context of brittle fracture for two serial and one concurrent multi-scale modeling examples. The examples demonstrate how predictive modeling hierarchies can be established.

Keith Runge is an adjunct assistant professor at the Quantum Theory Project of the University of Florida and an adjunct professor in the Materials Science and Engineering department of the University of Arizona. He is the founder and owner of BWD Associates, LLC since 2004. He received his B.A. (*summa cum laude*) in physics, chemistry, and math from Thiel College in Greenville, PA and Ph.D. in physics (*ab initio* Molecular Dynamics) from the University of Florida. His research interests include the application of physical modeling to biological architectures, the physics of warm, dense matter, atmospheric and surface chemistry, phononic crystals, and new approaches to molecular dynamics modeling.

Keynote Presentation:

José Pontes

Federal University of Rio de Janeiro

Tuesday, June 14 • 1:30 PM • Session 41

Numerical Solution of the Walgraef-Aifantis for Simulation of Dislocation Dynamics Using the Walgraef-Aifantis Model

Strain localization and dislocation pattern formation are typical features of plastic deformation in metals and alloys. Glide and climb dislocation motion along with accompanying production/annihilation processes of dislocations lead to the occurrence of instabilities of initially uniform dislocation distributions. These instabilities result into the development of various types of dislocation microstructures, such as dislocation cells, slip and kink bands, persistent slip bands, labyrinth structures, etc., depending on the externally applied loading and the intrinsic lattice constraints. The Walgraef-Aifantis (WA) model is an example of a reaction-diffusion model of coupled nonlinear equations which describe microstructure formation of forest (immobile) and gliding (mobile) dislocation densities in the presence of cyclic loading. This paper briefly discusses the WA model and focus on a finite differences, second order in time Crank-Nicholson semi-implicit parallel scheme, with internal iterations at each time step, for solving the model evolution equations in two dimensions.

José Pontes is Assistant professor at the Metallurgy and Materials Engineering Department of the Federal University of Rio de Janeiro, Brazil. Graduated in Aeronautical Engineering at the Technological Institute of Technology (Brazil, 1970), he worked as a project engineer for almost 20 years in the design of thermal systems for a Nuclear Power Plant and a major Direct Current Transmission System in Brazil. In 1989 he moved to Brussels, where he obtained a Doctor degree in Physics (1994) at the Free University of Brussels, under the supervision of Prof. Daniel Walgraef. From 1994 to 1996 he had a post-doctoral position at the Complutense University of Madrid, working with Prof. Manuel Garcia Velarde. In 1996 he returned to Brazil and was appointed to his current position at the Federal University of Rio de Janeiro. His research interests are in Hydrodynamic Stability, Finite Differences, Finite Element Methods and Nonlinear Systems. He is Emeritus Member of the Brazilian Society of Mechanical Sciences and Engineering.

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Keynote Presentation:

François Hild

LMT–Cachan

Wednesday, June 15 • 9:00 AM • Session 57

Local and Global Approaches to Digital Image Correlation

There are different approaches being currently developed and utilized to measure displacement fields, strains and even mechanical properties when resorting to digital image correlation (DIC). Local DIC is the most classical technique. Many correlation codes, be they industrial or academic, consist in the registration of (small) interrogation windows. They lead to measurement uncertainties well below the pixel level that depend on the texture of the analyzed zone, the displacement interpolation and amplitude. Global DIC is an alternative route that generally consists in a multiscale registration of different types of kinematic fields. Finite element discretizations are a first option. They can be used for 2D and 3D applications. DIC itself can also be regularized by prescribing mechanical constraints to the measured fields. For instance, it allows for direct measurements of mechanical parameters such as Young's modulus, Poisson's ratio or stress intensity factors. All these cases will be illustrated, and the advantages and drawbacks of the various approaches will be discussed.

Dr. François Hild graduated from École Normale Supérieure de Cachan in 1989. He received his Ph.D. in mechanical engineering from the University of Paris 6 in 1992, and from the University of California in 1995. He received his habilitation from the University of Paris 6 in 1998. Since 2003, he is a Research Professor at the Laboratory of Mechanics and Technology in Cachan (France), and is the current head of the Mechanics and Materials division. Dr. Hild has worked in the field of experimental mechanics for about fifteen years and advised 20 Ph.D. students with whom he has published more than 140 papers on subjects that include moiré interferometry, digital image and volume correlation, identification and validation techniques for damage and fracture models. He is an associate technical editor of *Experimental Mechanics* and a member of the editorial board of the *Journal of Strain Analysis for Engineering Design*.

Keynote Presentation:

Cesar Sciammarella

Northern Illinois University

Wednesday, June 15 • 10:50 AM • Session 65

Optical Techniques That Measure Displacements: A Review of the Basic Principles

There are a number of optical techniques that can be used to measure displacements on the surfaces of non transparent bodies or inside transparent bodies to some kind of electromagnetic radiation. Typically, these techniques were developed separately in the range of visible light. Although occasionally connections among these techniques were pointed out, they practically evolved independently from one another. In chronological order, moiré was the first technique to be developed. It was followed by holography, speckle photography, speckle interferometry and numerical correlation of speckles.

The purpose of using these techniques is to find displacements fields and through displacements get the necessary information to compute strain tensors. Concurrently with the measurement of displacements, all the above mentioned optical techniques are used to perform metrological measurements on surfaces both on light reflecting and light diffusing surfaces, and slopes on reflecting surfaces.

The first step in the process of generating displacement or contour data in all these different techniques is to have a carrier on the surface under observation. A carrier is a signal that is intrinsic to the surface or is projected on the surface that upon changes of the surface will be modified. The comparison between two states of this signal yields the sought information.

Behind the processing of the data is the theory information that provides the common mathematical framework that supports all the different techniques. In the presentation of the evolution of these techniques emphasis has been on particular aspects that form the body of knowledge of each one of them. Taking a more general approach, these techniques can be looked upon as a system of methods with many common components that play similar roles and provide the required information utilizing very closely related procedures. The emphasis in this presentation is a formal approach to a system analysis applied to techniques that measure displacements and the advantages of disadvantages of the different approaches in particular fields of application.

Cesar Sciammarella was the Director of the world renowned Experimental Mechanics Laboratory at the Illinois Institute of Technology for more than 30 years. This year he became Professor Emeritus in the MMAE Dept at IIT. He is currently doing research at Northern Illinois University as Adjunct Professor. He recently completed a five year project funded by the Italian government to help the Politecnico of Bari develop its experimental mechanics lab and increase its future talent. In this time he has taken his pioneering developments in applying moiré, holography, and speckle interferometry methodologies as an experimental tool down to the nanometric level. This effort has taken him beyond the Rayleigh limit that traditionally was considered as the maximum resolution that could be obtained in optics in far field observations. His recent work has yielded measurements in the far field of nano crystals and nano spheres with accuracies on the order of ± 3.3 nm. His recent discoveries will no doubt lead this field as he has done in the past. He has received many awards, including the Hetényi, Lazan, and Frocht awards and the William M. Murray Medal from the Society for Experimental Mechanics.