Centre International des Sciences Mécaniques
International Centre for Mechanical Sciences

Rectors:
E. Guazzelli (Marseille) - F. Pfeiffer (Munich) - F.G. Rammerstorfer (Vienna)

PROGRAMME 2015

In memory of Antonio Venicio Turello,
President of CISM from 1969 to 2013

Udine, Italy

"...The aims of the Centre are: to promote, on a non-profit basis, research in the field of Mechanical Sciences, to favour the exchange, diffusion and application of the most advanced knowledge in the field, to establish active relations with similar national or international institutions, to enlist the cooperation of the most highly qualified scientists and research workers of the various countries of the world, to establish research-laboratories and libraries, to set up courses and seminars at a high scientific level ..."

from the Statute of the "International Centre for Mechanical Sciences".
CISM, Chap. 1, Art. 1.

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The Frans T.M. Nieuwstadt Session

Interaction of Microscopic Structures and Organisms with Fluid Flows

May 25 - 29, 2015

The interaction of fluids and structures is an area of tremendous activity, most notably for low Reynolds number flows which are described by the Stokes equations. This regime, where the suspended structures are microscopic, is especially important to chemical engineering, materials science, soft-condensed matter physics, and biophysics. This course will focus on the interactions of fluids with microscopic objects, such as deformable particles, swimming microorganisms and “active” particles, and the collective behavior of these systems.

Students will first be given a thorough foundation in the physics and mathematical description of the Stokesian flow regime as well as relevant matter on material elasticity. On the theoretical side it will include mathematical aspects such as singularity, boundary integral, and approximate treatments of the Stokes equations, as well as Faxen relations and treatment of many-body interactions. The classical elastica will be described with emphasis on “extreme mechanics” of buckling and opening. On the experimental side, material will include basic methods and modern microfluidic techniques for fabrication.

Students will then learn many different aspects of the dynamics of flexible structures suspended in viscous flows. The viscous forces acting upon flexible objects can deform them, say through continuous bending or an abrupt buckling, and these deformations in turn modify the flow, leading to a highly non-linear coupling. This arises in modeling the flagellae or cilia involved in micro-organismal locomotion and mucal transport, in determining the shape of biofilm streamers, and in new methods of structure self-assembly. Micro-organisms locomote in a variety of ways, singly and collectively, and in many kinds of environments. This example of fluid-structure interaction is a central example of “active matter”. Lectures will cover both theoretical and experimental aspects, discussing classical results as well as modern advances in understanding collective hydrodynamics, and the effects of confinement and complex media on motility.

This course will give the possibility to the students to learn the state of the art of this still developing area. We have designed a program for the courses in which both experimental and theoretical aspects will be treated and that will provide students with a strong background on the fundamentals of the field as well as recent developments on open questions. The course is addressed to doctoral students and postdoctoral researchers in hydrodynamics, mechanics, materials science, applied physics and applied mathematics, academic and industrial researchers and practicing engineers.

Invited Lecturers:

Basile Audoly (Université Pierre et Marie Curie and CNRS, Paris, France), Kenneth Breuer (Brown University, Providence, RI, USA), Darren Crowdy (Imperial College, London, UK), Anke Lindner (ESPCI, Paris, France), Michael Shelley (New York University, NY, USA), Howard Stone (Princeton University, NJ, USA).

Coordinators: O. Du Roure (France), M. Shelley (USA).

Dynamics of Bubbly Flows

June 8 - 12, 2015

In many practical situations, bubbles are dispersed in a liquid phase. The understanding and the modeling of bubbly flows is therefore a major issue for many applications including chemical engineering (bubble columns), water treatment (oxygenation and purification), nuclear industry (steam generators, accidental depressurizations), naval transport (skin drag reduction) and medicine (contrast agent, micro-bubbles bursting).

Bubbly flows result from the two-way coupling between a liquid and bubbles that are randomly distributed over space. The specific properties of the bubbles make their dynamics very rich. Bubbles are inertialess and deformable, which complicates the expression of the hydrodynamic forces that act on them. They are compressible, which causes bubbly flows to be complex media for pressure waves and allows cavitation to occur. The interface properties are influenced by the presence of surfactant molecules that may be adsorbed at the bubble surface. In addition, the size of the bubbles is often not small compared to the characteristic length scales of the flow and buoyancy forces play a significant role. This implies to consider a large range of length scales and causes the generation of a strong agitation known as pseudo-turbulence.

Owing to their complexity, different approaches have to be combined to deal with the different aspects of bubbly flows. Numerical simulations are particularly well suited to investigate phenomena at the bubble scale. In this course, the fundamentals of the numerical simulation of bubbles will be presented and, in particular, the hydrodynamic loads acting on a bubble will be discussed in detail. Collective effects are better addressed by experimental investigations. A review of advanced experimental techniques (High-speed imaging, Particle Image Velocimetry, 3D Particle Tracking Velocimetry…) will be proposed and the dynamics of a swarm of rising bubbles will be described for both Newtonian and non-Newtonian liquids. Theoretical methods are also of great help in the study of bubbly flows. Theoretical expression of hydrodynamic forces on a single bubble will be presented for large or small Reynolds numbers. Averaged equations will be derived to handle the stochastic character of flows involving many bubbles.

The objective is to provide state-of-the-art information on bubbly flow. The principal methods of investigations will be exposed and illustrated. The flow will be considered at different scales, from that of a single bubble to that of a bubble swarm. Major results concerning the dynamics of bubbly flows will be presented as well as several modern applications. The course is addressed to PhD students, young and senior researchers, or practicing engineers, involved in Chemical Engineering, Mechanical Engineering or Fluid Dynamics. Since it does not focus on a particular technique (numerical, experimental or theoretical), it should be of interest for a large audience.

Invited Lecturers:

Dieter Bothe (Technische Universität Darmstadt, Germany), Chao Sun (University of Twente, The Netherlands), Jacques Magnaudet (Université de Toulouse, France), Andrea Prosperetti (Johns Hopkins University, Baltimore, MD, USA), Frédéric Risso (CNRS and Université de Toulouse, France), Shu Takagi (The University of Tokyo, Japan), Roberto Zenit (Universidad Nacional Autónoma de México, Mexico).

Coordinators: F. Risso (France), C. Sun (The Netherlands).

Bone Cell and Tissue Mechanics

June 22 - 26, 2015

Bone is a remarkable material: it is strong yet lightweight, can adapt itself to changes in mechanical loading, lasts for a lifetime and can repair itself after a fracture. Although biology has revealed many secrets of how bone cells can form and remove bone tissue, the mechanisms that control these processes, and the role of mechanical loading in this, are still not well understood. The goal of this course is to provide state-of-the-art information on this topic. To do so, the course will review the entire area of bone cell and tissue mechanics at all three commonly distinguished levels of structural organization of bone: the bone organ level, the bone tissue level and the bone cell level. The course will be of a multi-disciplinary nature and include topics like bone biology, imaging and computational modeling.

At the bone organ level, the focus will be on the diagnosis of bone strength using imaging and computational techniques. Bone remodeling at this level is often considered as an optimization process that adapts bone density and shape to the mechanical loading conditions. Hypothetical models that are developed to describe such adaptations of bone are discussed.

At the bone tissue level, bone can form remarkably complex porous architectures. This capability provides bone with the possibility to form bone with mechanical properties in a wide range. Methods to visualize and model such structures in 3D have become available only over the last two decades. Hypothetical models describing how these structures evolve, how they can adapt to mechanical loading and how they can be affected by bone diseases are discussed.

At the level of the cell, promising candidates for the mechanosensory system will be discussed, as well as possible signaling pathways for the communication between bone cells. At this level, the porosity of the bone tissue itself also becomes an important factor since it is assumed that fluid flow plays an important role in the mechanosensory system. The visualization and modeling at this level still is a challenging field of research.

Besides being informative, it is hoped that the course will function as a forum for the exchange of data, philosophy, and ideas across disciplinary divides and so provide further stimulus for a comprehensive approach to the problems of bone mechanics.

The target audience is graduate students, PhD candidates and young faculty members. We expect an audience as diverse in background as the lecturers, that is to say spanning across the professional spectrum from biomedical and structural engineers, to biologists, veterinarians and orthopaedic and dental surgeons.

Invited Lecturers:

Georg Duda (Charité - Universitätsmedizin, Berlin, Germany), Peter Fratzl (Max Planck Institute of Colloids and Interfaces, Potsdam, Germany), Jenneke Klein-Nulend (University of Amsterdam, The Netherlands), Ralph Müller (ETH, Zürich, Switzerland), Bert van Rietbergen (Eindhoven University of Technology, The Netherlands), Tim Skerry (University of Sheffield, UK).

Coordinator: B. van Rietbergen (The Netherlands).

Mixing and Dispersion in Flows Dominated by Rotation and Buoyancy

July 6 - 10, 2015

Rotation and buoyancy play an essential role in many astrophysical, geophysical, environmental and industrial flows. They influence the transition to turbulence, strongly affect large-scale (turbulent) flow properties by inducing anisotropy, and also affect boundary-layer dynamics and inertial-range turbulence characteristics. Moreover, rotation and buoyancy may have a strong impact on the dispersion of passive and active tracers and of (inertial) particles and droplets in such flows. The impact of buoyancy or rotation on transport may be direct (gravitational, centrifugal or Coriolis forces on fluid parcels or particles/droplets) or indirect by the modified flow characteristics. These impact significantly heat and mass transfer in many natural systems. Examples are (large-scale) convection processes, transport of sediment in coastal flows, dispersion of suspended particulate matter in estuarine flows, in lakes and reservoirs, and dispersion of aerosols and pollutants in the atmospheric boundary layer. Increasing computational capabilities and the rapid development of advanced experimental measurement tools, for example optical diagnostics and particle tracking, provide highly resolved temporal and spatial data sets.

This allows the exploration and analysis of more complex flow phenomena and the associated transport processes in more depth.

The aim of the course is to present a state-of-the-art overview of current developments in this exciting field in a way accessible to attendees coming from a variety of fields. Relevant example are, turbulence research, (environmental) fluid mechanics, lake hydrodynamics and atmospheric physics.

Topics to be discussed during the lectures range from the fundamentals of rotating and stratified flows, mixing and transport in stratified or rotating turbulence, transport in the atmospheric boundary layer, the dynamics of gravity and turbidity currents eventually with effects of background rotation or stratification, mixing in (stratified) lakes, and the Lagrangian approach in the analysis of transport processes in geophysical and environmental flows. We have composed a team of lecturers who are able to address these topics from fundamental, experimental and numerical points of view. Moreover, part of the lectures cover fundamental aspects including a number of the basic dynamical properties of rotating and or stratified (turbulent) flows, the mathematical description of these flows, some applications in the natural environment, and the Lagrangian statistical analysis of turbulent transport processes and turbulent transport of material particles (including, for example, inertial and finite-size effects). Four lectures are dedicated to specific topics such as transport in (stratified) lakes, transport and mixing in the atmospheric boundary layer, mixing in stratified fluids and dynamics of turbidity currents.

The course is addressed to doctoral students and postdoctoral researchers, but also to academic and industrial researchers and practicing engineers, with a background in mechanical engineering, applied physics, civil engineering, applied mathematics, meteorology, physical oceanography or physical limnology.

Invited Lecturers:
Damien Bouffard (Ecole Polytechnique Fédérale, Lausanne, Switzerland), Mickael Bourgoin (Université de Grenoble, France), Herman Clercx (Eindhoven University of Technology, The Netherlands), GertJan van Heijst (Eindhoven University of Technology, The Netherlands), Paul Linden (University of Cambridge, UK), Eckart Meiburg (University of California at Santa Barbara, CA, USA), James Riley (University of Washington, Seattle, WA, USA).

Coordinators: H. Clercx and G.J. van Heijst (The Netherlands).

Mechanics of Liquid and Solid Foams

July 13 - 17, 2015

This course will focus on the relationships between the cellular microstructure and the nonlinear mechanical behavior of liquid and solid foams, and foam-like biological and synthetic materials. Consequently, this survey of foam mechanics will explore numerous topics in applied mechanics ranging from traditional fluid mechanics to solid mechanics. Theoretical analysis, numerical simulations, and experiments will be used to unravel the complex relationships between cell-level structure, local deformation mechanisms, and macroscopic mechanical behavior.

The cells in liquid foams, such as soap froth, are polyhedral gas bubbles separated by thin liquid films that are stabilized against rupture by surfactants. Many commercially important cellular solids, such as polymer, food and metal foams, are formed when liquid foams solidify into structures that can have open or closed cells. The growth of spherical gas bubbles in a liquid and their evolution to form the polyhedral cells in low-density foam are key features of foam manufacturing processes, and illustrate the interplay between the mechanics of liquid and solid foams. The cell-level architecture of low-density foams can be viewed as polyhedra that fill space, forming networks of surfaces or edges, that can be random or regular. Similar networks are characteristic of biological materials, such as trabecular bone, the cytoskeleton, and cells in animal tissues such as the eye of the drosophila fruit fly.

Liquid foams are used in firefighting, mineral ore separation, drilling fluids and mobility control in the petroleum industry, and a wide range of consumer products, foods and beverages. Natural and synthetic cellular solids are lightweight materials with unique and advantageous combinations of properties involving stiffness- and strength-to-weight ratio, energy absorption, thermal insulation and acoustics, all of which can be tuned by controlling density and cell morphology.

Despite significant progress in understanding foam rheology and mechanics over the last few decades, the complex nonlinear phenomena that occur at all length scales remain poorly understood. Whether the structure is two-dimensional and ordered or three-dimensional and highly disordered the fluid mechanics and solid mechanics is very challenging when taking a micromechanical point of view. For solid foams connecting the microstructure and the mechanical properties of the base material to the macroscopic behavior of the material remains a challenge. Models involving idealized ordered microstructures, such as the Kelvin foam, and realistic random microstructures with different cell sizes will be presented, and the strengths and weaknesses in predicting all aspects of mechanical behavior will be discussed. Taken as a whole, the participants will be presented with the state of the art in the mechanics of liquid and solid foams and will be exposed to many open questions.

The broad course topics are: cell-level foam structure (including a tutorial Surface Evolver simulations), rheology and aging of liquid foam, and the mechanics of solid foams and biological cellular materials. Both liquid and solid foams exhibit linear elasticity, yielding and plasticity, and the onset and propagation of instabilities.

The target audience for this course is PhD students and postdocs in engineering, physics, and materials science, as well as young and senior researchers in academia and industry.

Invited Lecturers:

Stavros Gaitanaros (MIT, Cambridge, MA, USA), Sascha Hilgenfeldt (University of Illinois, Urbana-Champaign, IL, USA), Reinhard Höhler (Université Pierre & Marie Curie, Paris, France), Andrew Kraynik (Sandia National Laboratories, Albuquerque, NM, USA and University of Erlangen-Nuremberg, Erlangen, Germany), Stelios Kyriakides (University of Texas at Austin, TX, USA), Patrick Onck (University of Groningen, The Netherlands).

Coordinators: A. Kraynik (USA and Germany), S. Kyriakides (USA).

The Art of Modeling Mechanical Systems

CISM-AIMETA Advanced School

Course sponsored by AIMETA and GAMM

July 27 - 31, 2015

Engineering and Physics cannot be thought of without models; models, which represent the real world to the best of our knowledge. And, before starting with any mathematical description, we must establish something like a phenomenological picture, a symbolic map of the real world's structures with elements like masses, springs, dampers, fluid system, thermodynamic elements and so forth and with elements of interconnections.

This first step of mechanical modeling is mostly underestimated, but it decides very substantially about the success of all following activities like mathematical modeling, numerical algorithms and finally computer codes. Therefore, it is worth looking at that more systematically, in spite of the fact that there do not exist systematic approaches to these problems. Establishing models includes very strong phenomenological issues. Models should be as simple as possible and so complex as necessary, not more and not less. And all this is still more an art than a science.

Good modeling requires a deep insight into the performance of the real world's objects, may it be a machine, a building, an airplane or human walking. We must understand how it works, in terms of operations, functions, dynamics, kinematics, stability and deformation, noise and wear under given leading conditions. But this is only one important precondition. Other aspects are the goals and requirements of models.

Firstly, very simplified models might nevertheless represent the main features of a problem in such a way that they provide some physical insight, especially with regard to parameter influences. Secondly, we may establish models by considering as many details as possible. Such models are large, costly and sometimes leading to cloudy results. But done in a skillful way such models are the basis for physical understanding and for improving design. Thirdly, we may find models with similar features as our real world case, but only in a more qualitative sense. This might help sometimes to understand the physical background of a problem.

From all this we know, that modeling mechanical systems requires insight and intuition. The course concerned with such a topic aims at presenting some rules for mechanical models in a more general systematic way, always in combination with small and large examples, many from industry, able to illustrate the most important features of modeling. It will be not a course presenting mathematical solution algorithms, but discussing the best way to a good solution. The course has a strong focus on the art of modeling.

The course is addressed to researchers and engineers from academia and from industry, to doctoral students and to postdocs, working in the fields of mechanical, civil and electrical engineering as well as in fields like applied physics or applied mathematics.

Invited Lecturers:

Hartmut Bremer (Johannes Kepler Universität Linz, Austria), Friedrich Pfeiffer (Technical University of Munich, Germany), Michel Raous (Lab. de Mécanique et d'Acoustique, Marseille, France), Ahmed Shabana (University of Illinois at Chicago, IL, USA), Steven Shaw (Michigan State University, East Lansing, MI, USA), Peter Wriggers (Leibniz Universitaet Hannover, Germany).

Coordinators: F. Pfeiffer (Germany), H. Bremer (Austria).

The Piero Villaggio Session

Similarity, Symmetry and Group Theoretical Methods in Mechanics

September 7 - 11, 2015

The aim of the course is to bring together researchers in mechanics, applied physics and applied mathematics who use similarity and symmetry analysis of engineering problems in both solid and fluid mechanics, researchers who are developing significant extensions of these methods implement, and numerical analysts who develop and use such methods in numerical schemes.

The powerfulness of the Lie group symmetry analysis has been extensively utilized, essentially to support the finding of analytic solutions to partial differential equations. For a given DE problem, one can algorithmically calculate its admitted point symmetries – transformations of dependent and independent variables that map a problem intoItself. Knowledge of admitted symmetries allows one to construct mappings relating DE systems, find out whether or not a given nonlinear DE system can be mapped into a linear system by an invertible transformation, and find exact (group-invariant or symmetry-generated) solutions. Lie group analysis is of further interest in setting up numerical schemes preserving the group properties of an initial boundary value problem (BVP).

Symmetries have been historically relied upon to construct Lagrangian formulations in field theory. In the context of continuum solids mechanics, Lie groups have been applied to solve the Navier and the Lame equations, or, in a similar spirit and extending this view to dissipation, to partially solve the ideal plasticity equation, to formulate conservation laws and invariance relations, to analyze the kinematics of mechanisms, and more recently to formulate the constitutive laws and master response of materials with complex rheological behaviors. Symmetry methods have a fundamental role in Lagrangian mechanics, Eshelbian mechanics, and nonlinear elasticity. The field of Eshelbian Mechanics (so called in the honor of the works of Eshelby, but also known as Configurational Mechanics), relies on translational symmetries in the material space, for writing field equations in terms of Eshelby stresses. Those symmetries extended to rotations and dilatations have been intensively used to construct the well known J-integrals. The concept of nonlocal symmetries allows to construct novel BVP in continuum mechanics (and group invariant solutions), involving potential variables, thereby extending the classical picture relying on the traditional Lagrangian and Eulerian viewpoints.

Symmetry methods are at the basis of methodologies for finding invariance relations of the BVP of continua obeying non dissipative and dissipative behaviors, including nonlinear elasticity, plasticity and creep. Lie symmetries are useful to find conservation laws in the analysis of Euler and Navier-Stokes equations for incompressible fluids: this particularly includes very recent results on new vorticity related conservation laws for Euler and Navier-Stokes equations and others which only exist in reduced dimensions such for as for plan or helically symmetric flows. The three “complete approaches” to statistical turbulence theory are an immediate consequence of Navier-Stokes equations. Beside the classical Lie symmetries stemming from Navier-Stokes equations, these sets of equations admit more Lie symmetries, named statistical symmetries.

The involvement of Lie groups as a new predictive and systematic methodology to obtain invariance properties of materials is more recent. From the knowledge of the constitutive law of a given material, Lie symmetries are able to predict its response under various control conditions, and inversely to formulate a material’s constitutive law exploiting a postulated Lie group structure satisfying the symmetries involved in the experimental data.

The proposed course will reflect the organization of the Summer School on the same topics that took place in Varna, Bulgaria (June 7-12, 2013), jointly organized by I. Mladenov and J.F. Ganghoffer. Those topics were dealt with by three main speakers, leaders in the field, who made a pedagogical introduction and laid out key issues and concepts: G. Bluman (UBC, Vancouver, Canada), N. Ibragimov (Blekinge Institute of Technology, Karlskrona University, Sweden), and C-M. Marle (Univ. Pierre et Marie Curie and French Academy of Sciences, Paris). Two of these lecturers will deliver courses during the CISM session.

The course is mostly intended for Master students in mechanics or applied mathematics (or in physics, but having a sufficiently good level in mechanics, defined by the prerequisites), for PHD students, post-doctoral students, industrial researchers and engineers interested in the more practical use of symmetry methods. Permanent researchers willing to get an overview of the field are also welcome.

Invited Lecturers:
George Bluman (University of British Columbia, Vancouver, BC, Canada), Jean-François Ganghoffer (Université de Lorraine, Nancy, France), Ivailo Mladenov (Bulgarian Academy of Sciences, Sofia, Bulgaria), Andreas Müller (Shanghai Jiao Tong University Joint Institute, China), Jan J. Slawianowski (University of Warsaw, Poland), Martin Oberlack (Technical University, Darmstadt, Germany).

Coordinators: J-F. Ganghoffer (France), I. Mladenov (Bulgaria).

Particles in Wall-Bounded Turbulent Flows: Deposition, Re-Suspension and Agglomeration

Course sponsored by EDF

September 14 - 18, 2015

Particle transport in near-wall turbulent flows involves challenging phenomena, such as deposition, re-suspension and agglomeration, which cover a wide range of situations from single-particle deposition to the formation of deposited aggregates that modify fluid flows. These issues have implications in many processes ranging from power-generation industries to electronics, food industry, water treatment, micro-mechanics and micro-biology and are also found in environmental or medical contexts.

What is referred to as ‘particle deposition’ is best addressed by introducing a coupling between the underlying phenomena (deposition, re-suspension, agglomeration, clogging) which reveals that three fundamental physical interactions are at play: particle/fluid, particle/surface and particle/particle interactions. There are thus two major mechanisms: the hydrodynamic transport, describing particle/fluid interactions and how particles are transported and dispersed by turbulent flows, and the attachment mechanism, describing particle/surface and particle/particle interactions and how particles adhere to surfaces.

The related phenomenology has often been addressed from two separate points of view using: either a hydrodynamic approach but with a poor description of attachment forces or a physico-chemical standpoint but with no proper account for particle transport. However, new descriptions have emerged with the development of multi-scale models. Furthermore, new insights have been provided by Direct Numerical Simulation (DNS) and by fine experimental techniques (such as PIV/PTV or AFM), leading to an improved understanding of particle deposition. With respect to this context, the course has a three-fold objective: -To provide an in-depth presentation of the phenomenology involved in particle dynamics in wall-bounded turbulent flows and of the basic physical interactions; -To introduce unified models of particle deposition (which combine hydrodynamic and physico-chemical approaches) that are helpful to achieve a comprehensive description of the complete phenomenon; -To discuss open experimental/modelling issues, for example multi-layer deposition and re-suspension.

The general terminology of ‘particles’ does not mean that the course will be strictly limited to solid (colloidal or inertial) spherical particles. Indeed, specific lectures will also discuss droplets (coalescence/breakup) and non-spherical particles, such as fibre suspensions in turbulent flows. The course is organised so as to cover the different aspects of the physics involved in particle behaviour in turbulent flows (thus, the transport/attachment mechanisms) and the variety of points of view (experimental/ numerical/modelling).

The present course will be attractive to graduate and doctoral students, to young researchers as well as to practicing engineers in the fields of mechanical, nuclear, environmental, medical, chemical and process engineering. Since the course includes presentations of up-to-date progress as well as open questions that remain to be addressed, it will be also of interest for senior researchers.

Invited Lecturers:

Jean-Pierre Minier (EDF R&D, MFEE, Chatou, France), Jacek Pozorski (IMP, Polish Academy of Sciences, Gdansk, Poland), Christophe Henry (IMP, Polish Academy of Sciences, Gdansk, Poland), Fredrik Lundell (Linné FLOW Centre & Wallenberg Wood Science Centre, KTH, Royal Institute of Technology, Stockholm, Sweden), Cristian Marchioli (Università di Udine, Italy), René van Hout (Technion-Israel Institute of Technology, Haifa, Israel), Greg Voth (Wesleyan University, Middletown, CN, USA).

Coordinators: J-P. Minier (France), J. Pozorski (Poland).

Modelling, Simulation and Characterization of Multi-Scale Heterogeneous Materials

CISM-ECCOMAS International Summer School

September 28 - October 2, 2015

A central topic in mechanics consists in building “virtual laboratories” to optimise heterogeneous materials so as to achieve specific targets. This requires building constitutive models on one or more scales, devising and verifying well-suited numerical schemes to solve the resulting mathematical problems numerically and, most importantly, to design and optimise experimental techniques to ensure the observability of relevant quantities, and validate the models.

Materials are heterogeneous or even discrete at some scale. Those heterogeneities can be accounted for either by averaging properties at smaller scales, or by considering explicitly the micro/meso structures of the materials. However, when failure occurs, it is no longer possible to separate micro from macro effects and more advanced strategies are required, such as error-controlled adaptive model order reduction or adaptive hybrid multi-scale methods.

Discretising the heterogeneities, cracks, dislocations and defects can be cumbersome using standard finite element methods (FEM). Enrichment and implicit boundary strategies can be applied to deal with complex and evolving boundaries/geometries, whereas other approaches aim at completely abolishing the need for finite element meshes. This class of mesh-free methods can be particularly appealing, since full-field monitoring techniques typically measure data on scattered sets of points that can be directly used for simulation purposes. Sharing some appealing properties with mesh free methods, isogeometric methods were recently introduced with the aim to simplify the design-through analysis concept and were recently used for digital image correlation.

Such full-field techniques, used to measure material deformation, have brought up a revolution in mechanical testing of materials. The visualisation of deformation maps enables researchers to naturally address heterogeneities. In particular, the Digital Image Correlation (DIC) and grid-based methods are particularly appealing thanks to their simplicity and reasonably low cost. There are also techniques to measure deformation in the bulk of materials, such as Digital Volume Correlation (DVC). The identification of material parameters from such full-field kinematic measurements can be done using finite element model updating for material parameter identification. An alternative technique called the Virtual Fields Method (VFM) relies on global equilibrium equations and efficiently deals with parameter identification of non-linear constitutive laws or heterogeneous materials. Furthermore, this approach relaxes strong constraints on specimen shape and load, opening the possibility of a very large design space for novel experimental procedures.

The course will include carefully crafted presentations covering in detail all these aspects, providing a comprehensive overarching framework for experimental, numerical and theoretical mechanics of heterogeneous materials. After the course the participant will be able to: (1) select suitable models, implement discretisation techniques and solution algorithms for non-linear multi-scale problems for heterogeneous materials; (2) verify the numerical methods and validate the material models by a combination of a posteriori error estimation and advanced experimental techniques for heterogeneous materials; (3) develop and optimise suitable experimental techniques to observe phenomena of interest, identify material properties and characterise heterogeneous materials.

The course is addressed to doctoral students and postdoctoral researchers in mechanical, civil, material science, applied physics and applied mathematics, academic and industrial researchers.

Invited Lecturers:

Stéphane Bordas (University of Luxembourg, Luxembourg and Cardiff University, UK), Daniel Dias-da-Costa (The University of Sydney, Australia and University of Coimbra, Portugal), Timon Rabczuk (Bauhaus-Universität Weimar, Germany), Pierre Kerfriden (Cardiff University, UK), Fabrice Pierron (University of Southampton, UK), Pascal Lava (KU Leuven, Belgium).

Coordinators: D. Dias-da-Costa (Australia and Portugal), S. Bordas (Luxembourg and UK).

Material Parameter Identification and Inverse Problems in Soft Tissue Biomechanics

October 12 - 16, 2015

There are many fields in medicine and in biomedical engineering where accurate measurements of local soft tissue properties are needed. In general it is difficult to measure the mechanical properties of these materials directly and some kind of inverse approach is needed, where an experiment has to be simulated and the material parameters are adjusted until the model matches the experiment.

Several open questions are raised by inverse approaches in soft tissue biomechanics:

- Experimental measurements on biological tissues present many practical and theoretical difficulties. Experimental and numerical errors also increase the uncertainty, as do inadequate constitutive models.
- An inverse problem requires a computational model that can be solved repeatedly with different material parameters. This requires a model that can be solved quickly and reliably; these are not attributes one usually associates with computational models of biological tissues.
- Biological tissue mechanical behaviour exhibits special characteristics that may affect the mechanical response and disturb material identification, such as visco-elasticity, multi-scale properties, variability of properties and remodelling. Tissues often develop regionally varying stiffness, strength and anisotropy. Important challenges in soft tissue mechanics are now to develop and implement hybrid experimental - computational methods to quantify regional variations in properties in situ.
- Once the necessary experimental data and computational models are in place, it is essential to implement an appropriate optimisation strategy to adjust the material parameters to give the best match with the experimental results, and to consider issues of uniqueness of the identified parameters.
- The question of uniqueness can be tackled by increasing the quantity of experimental data. To this purpose, tracking the full-field deformation of tissues using optical measurements or medical imaging techniques becomes quite commonplace but these novel measurement approaches have only been recently applied to material identification of biological tissues and they still have to be well calibrated and validated for them.
- It has also been identified that in certain situations useful patient-specific results can be obtained without precise knowledge of patient-specific properties of tissues. This situation arises for instance in image-guided surgery and modelling and analysis of thin-walled biological organs.

Learning skills in this multidisciplinary environment is challenging, and rarely addressed to a sufficient level within classical degree programs. The advanced school will gather the best worldwide specialists in hybrid experimental - computational methods applied to soft tissues, to teach a focused and highly original course in this area. The course is addressed to doctoral students and postdoctoral researchers in mechanical and biomedical engineering, materials science, biophysics and applied mathematics, academic and industrial researchers and practicing engineers. Attendees should have an engineering background with reasonable knowledge of mathematics; the necessary biology from will be taught from scratch.

Invited Lecturers:

Stéphane Avril (Ecole des Mines, Saint-Etienne, France), Sam Evans (Cardiff University, UK), Christian Gasser (Royal Institute of Technology, Stockholm, Sweden), Cees Oomens (Eindhoven University of Technology, The Netherlands), Hazel Screen (Queen Mary University of London, UK), Jeff Weiss (The University of Utah, Salt Lake City, UT, USA).

Coordinators: S. Avril (France), S. Evans (UK).

International Advanced Professional Training

CO_2 Capture Technologies to Mitigate Climate Change

July 20 - 24, 2015

Scientific evidences linking the upraise of CO_2 emissions and anthropogenic climate change are overwhelming, which makes it necessary to urgently develop CO_2 capture and storage (CCS) technologies scalable to a commercial level in order to allow the continuous use of fossil fuel as a reliable source of energy on demand. Leading CO_2 capture technologies which are expected to be available in the short and long term will be reviewed in the proposed course. More specifically, a detailed update will be outlined on leading technologies such as solvent scrubbing, oxyfuel combustion, chemical looping and calcium looping. This will include a critical review of the wide diversity of materials which are being investigated as potential CO_2 sorbents such as conventional solvents, solvent blends, biphasic solvents, ionic liquids, Metal-Organic Frameworks (MOFs), Zeolitic Imidazolate Frameworks (ZIFs), solid sorbents, low-temperature sorbents and membranes. Experience shows that the performance of these materials must be assessed taking into account the conditions and constraints imposed by each specific application, which may play a critical role on proposed techniques for process intensification or sorbent reactivation. It is thus of paramount importance to focus theoretical and lab-scale studies on analyzing the material behavior at conditions closely mimicking those to be found at practice and to pursue a fundamental understanding on the physical-chemical processes that govern the behavior of the materials. These points will be a main focus in the Course. The course will consider also modeling and thermodynamics of the integration of CCS and power plants, which is a critical issue to help system-scale network design and optimize post-combustion capture efficiency. Integration of CCS in gasification and steam reforming plants for pre-combustion capture as well as integration of CCS with other CO_2 pollutants industrial processes, most notably cement manufacture, iron and steel making will also be a relevant subject of the course. An important matter of concern that will be further considered regards energy penalties in CCS. Methods to reduce inefficiencies and increase overall performance in thermal systems will be discussed with an emphasis on currently developing techniques for their specific application to CCS.

A promising technology that will be addressed is the integration of Bioenergy and CCS (BECCS). It is believed that capture and long term storage of CO_2 produced by combustion of biomass, which matches approximately the CO_2 consumed during biomass growth, would effectively result in net removal of atmospheric CO_2 yet bringing about new serious environmental and social issues stemming from the escalating demand for biomass. A further critical aspect for reducing carbon emissions is the utilization of CO_2 as feedstock for industrial applications. In this regard, a number of emerging technologies in petrochemical, biochemical, fuel, and power energy sector are expected to play a leading role in minimizing carbon pollution from industrial facilities. Current progress on the mature Enhanced Oil Recovery (EOR) technology will be discussed in the course.

An additional relevant subject to be considered in the course concerns current policy and economics issues which hinder large-scale CCS deployment in the EU. The necessity of adopting new and more effective strategies will be examined.
Participation in the course is open to doctoral students, young and senior researchers, technologists and engineers having in common an interest on CCS technologies and policy.

Invited Lecturers:
Paul S. Fennell (Imperial College London, UK), Fausto Gallucci (Eindhoven University of Technology, The Netherlands), Evgenia Mechleri (Imperial College London, UK), Matteo C. Romano (Politecnico di Milano, Italy), Luis M. Romeo (CIRCE, Zaragoza, Spain), Jose-Manuel Valverde (University of Seville, Spain).

Coordinator: J-M. Valverde (Spain).

21th CISM-IUTAM International Summer School

Measurement, Analysis and Passive Control of Thermoacoustic Oscillations

June 29 - July 3, 2015

When Yuri Gagarin was launched into orbit in 1961, the probability of a rocket blowing up on take-off was around 50%. In those days, one of the most persistent causes of failure was a violent oscillation caused by the coupling between acoustics and heat release in the combustion chamber. If more heat release than average occurs during moments of high pressure and less heat release than average occurs during moments of low pressure then, over a cycle, more work is done during the expansion phase than is absorbed during the compression phase, causing oscillations to grow. These thermoacoustic oscillations have caused countless rocket engine and gas turbine failures since the 1930s and have been studied extensively. Nevertheless, they are still one of the major problems facing rocket and gas turbine manufacturers today.
The ultimate goal of rocket and gas turbine manufacturers is to eliminate or control thermoacoustic oscillations, either through feedback control or passive control. Feedback control works well in simple thermoacoustic systems but is challenging in industrial systems because the sensors and actuators have to withstand very harsh environments. Furthermore, feedback control is unacceptably risky in some applications, such as aircraft. For these reasons, passive control is preferable, either by good initial design, or by adding a passive device to an existing system.
In order to control a thermoacoustic system passively, it is necessary to understand why the system oscillates. It is well known that acoustic perturbations to the velocity or pressure cause heat release perturbations some time later, and that these lead to the feedback loop described above. Other mechanisms, such as the reflection of entropy waves at a sonic throat, are also known. However, experiments show that even small changes to a system can significantly alter its stability, showing that the details of these processes are very influential. The aims of this course are: to describe how thermoacoustic oscillations arise, to show the flame dynamics that cause fluctuating

heat release, to show how these details are uncovered through experimental measurements, to introduce linear and nonlinear methods of analysis, to introduce methods that can reveal which details of a thermoacoustic system are most influential, and to give examples of these processes in industrial thermoacoustic systems.
The course is aimed at doctoral students in an early stage of a PhD in thermoacoustics; researchers with a background in flow stability who are interested in a new area; and practicing engineers in a closely-related area such as gas turbine or rocket engine research.

Invited Lecturers:
Matthew Juniper (University of Cambridge, UK), Tim C. Lieuwen (Georgia Tech, Atlanta, GA, USA), Thierry Schuller (Ecole Centrale Paris, France), Wolfgang Polifke (Technical University, Munich, Germany), Raman I. Sujith (IIT, Madras, India), Bruno Schuermans (Alstom Power, Baden, Switzerland).

Coordinator: M. Juniper (UK).

National Advanced Professional Training

National APT courses in the fields of Structural and Geotechnical Engineering, Surveying, Environmental, Bioengineering and Industrial Engineering will be given in Italian. For all activities and meetings, please refer to our website.

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Applications should reach CISM Secretariat no later than one month before the course. Name, degree, current address and course to be attended should be specified.
A limited number of academic participants, not supported by their own institutions, can be granted board and/or lodging upon application. Application for support must reach CISM Secretariat no later than two months before the course.
Detailed programmes, admission rules and on-line forms are available from the website.

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