Centre International des Sciences Mécaniques
International Centre for Mechanical Sciences

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

PROGRAMME 2017

Udine, Italy

" ...The purpose of the Centre is to promote, on a non-profit basis, research in the Mechanical Sciences and related multidisciplinary sciences, favour the exchange, diffusion, and application of the most advanced knowledge in this field, establish active relations with similar national, or international institutions, enlist the cooperation of the most qualified scientists and researchers throughout the world, set up research laboratories and libraries, organize courses and seminars of a high scientific level ..."

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

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The Sándor Kaliszky Session

Computational Methods for the Analysis, Design, and Failure of Composites

April 3 - 7, 2017

This course aims at providing fundamental and advanced concepts for the analysis and design of composite materials and structures. In particular, lectures cover the following main topics: structural theories and finite element modelling, failure and damage analysis, optimization and tailoring, multiscale approaches, impact problems, manufacturing, and applications. The lecturers have strong professional backgrounds in material science and structural mechanics. They are currently involved in many international research projects on composites, and industrial partnerships, including Airbus, Boeing, Embraer, and NASA. Most of the Lecturers are currently involved in Marie Curie European Training Network projects on composite materials and structures, FULLCOMP (www.fullcomp.net) and COACH (http://www.coach-etn.eu/).

The first module of the course provides basic concepts related to laminated structures, the theory of anisotropic bodies, and the peculiarities of advanced composite materials. Then, the course continues with a review of classical and advanced theories and computational models for laminated structures. Particular attention is paid to beams, plates, and shells, and including guidelines and recommendations for a proper finite element modeling.

The second module focuses on the manufacturing processes and the applications of composites. First, this module deals with typical issues such as joining and coating. Then, an overview follows on advanced manufacturing for aerospace applications, glasses, and composites for health care, energy production, and ICT. Recent advances in low-cost composites and composites from waste close this module.

The third module offers insights on design and optimization of composite structures. Lectures deal with some of the most important methods related to tailoring, tow placement, microstructural tailoring, suppression and mitigation of buckling, multistability, and morphing.

The fourth module deals with the multiscale analysis, failure, and delamination. After an introduction to the modeling of composite material and structures, the modelling damage and failure of laminates follow. Then, the core part is on details on multiscale approaches for the simulation of composite material and structure at the micro meso and macro scales.

The fifth module is on impact problems. First, contact laws and impact dynamics concepts open this module. Then, assessments on some of the most important impacts for composites follow; that is, low-velocity impact damage, ballistic impact, explosions. Experimental techniques, numerical models, and guidelines on the design for impact resistance close this module.

The sixth module of the course deals with the design of lightweight, composite shells. This module covers some of the most important issues related to composite shells; that is stability, nonlinearity, imperfections, and probabilistic optimization. Furthermore, an introduction to the material behavior at different scales, quasi-static and fatigue failure, and the design and analysis of structural joints follow.

The course is addressed to most of the European Ph.D. schools with curricula in structural mechanics, and material science. Also, researchers and professionals dealing with the design and analysis of advanced structures for aeronautics, space, naval, automotive, biomedical applications, and material science could be interested in the course as well as researchers and professionals dealing with the design and analysis of advanced structures for aeronautics, space, naval, automotive, and biomedical applications.

Invited Lecturers:
Serge Abrate (Southern Illinois University, Carbondale, IL, USA), Olivier Allix (Ecole Normale Supérieure de Cachan, France), Erasmo Carrera (Politecnico di Torino, Italy), Monica Ferraris (Politecnico di Torino, Italy), Raimund Rolfes (Leibniz Universität Hannover, Germany), Paul Weaver (University of Bristol, UK).

Coordinator: E. Carrera (Italy).

Dynamics Stability and Bifurcation in Nonconservative Mechanics
CISM-AIMETA Advanced School

April 10 - 14, 2017

Nonconservative mechanical systems have been examined since the end of the XIX-th century when Greenhill posed a problem on the buckling of a screw-shaft of a steamer subject to both an end thrust and a torsion with the torque vector being tangential to the deformed axis of the shaft (the follower torque). Such follower loads represent non-potential positional forces, also referred to as circulatory or curl forces, producing non-zero work on a closed contour (e.g. optical tweezers can generate a circulatory force field). At the same time Kelvin and Tait, studying problems of planet formation, discovered the destruction of gyroscopic stabilization in rotating ellipsoids filled with liquid by dissipation. This was the first example of dissipation-induced instabilities of negative energy modes. Nowadays dissipative and circulatory forces are recognized as the two fundamental nonconservative forces in the growing number of scientific and engineering disciplines including physics, fluid and solids mechanics, fluid-structure interactions, and modern multidisciplinary research areas such as biomechanics, micro- and nanomechanics, optomechanics, robotics, and material science.
From the very beginning, nonconservative systems demonstrated unusual and counter-intuitive dynamics and stability properties. Efficient prediction of flutter and divergence instabilities which, in non-conservative systems can be both desirable, as in energy harvesting and harmful as in aircraft structures, is mathematically challenging. This is due to the non-self-adjoint (non-Hermitian) character of the governing equations that, as a rule, depend on multiple parameters. However, traditional university curricula do not offer a coherent collection of modern mathematical tools for the analysis of multi-parameter families of non-self-adjoint differential equations combined with a first-hand demonstration of how they actually work in practical applications.
The present course fills this gap and offers a unified view on classical results and recent advances in the dynamics of nonconservative systems. The theoretical fundamentals are presented systematically and include: Lyapunov stability theory, Hamiltonian and reversible systems, negative energy modes, anomalous Doppler effect, non-holonomic mechanics, sensitivity analysis of non-self-adjoint operators, dissipation-induced instabilities, and absolute and convective instabilities. They are applied to engineering

situations that include the coupled mode flutter of wings, flags and pipes, flutter in granular materials, piezoelectric mechanical metamaterials, wave dynamics of infinitely long structures, stability of high-speed trains, experimental realization of follower forces, soft-robot locomotion, wave energy converters, friction-induced instabilities, brake squeal, non-holonomic sailing, and stability of bicycles.

The course is targeted at young researchers, doctoral students and engineers working in fields associated with the dynamics of structures and materials. The course will help to get a comprehensive and systematic knowledge on the stability, bifurcations and dynamics of nonconservative systems and establish links between approaches and methods developed in different areas of mechanics and physics and modern applied mathematics.

Invited Lecturers:

Davide Bigoni (Università di Trento, Italy), Olivier Doaré (ENSTA ParisTech, France), Oleg Kirillov (Russian Academy of Sciences, Steklov Mathematical Institute, Moscow, Russia), Andrei Metrikine (Delft University of Technology, The Netherlands), Oliver O'Reilly (University of California, Berkeley, USA), Andy Ruina (Cornell University, Ithaca, USA).

Coordinators: D. Bigoni (Italy), O. Kirillov (Russia).

Mesoscale Models: from Micro-Physics to Macro-Interpretation

May 22 - 26, 2017

In the past few decades, significant advances in computational modeling of materials on multiple length and time scales have brought about the realization that the critical questions are often encountered on the mesoscale: the length and time scales much larger than atomic, yet much smaller than macroscopic observables. This is the focus area of the course. We select four broad areas representative of the field in the sense that:

(a) significant progress has been made in the past two decades,

(b) some outstanding problems remain as a challenge for future researchers, and,

(c) the past efforts have been multidisciplinary, and future efforts are expected to remain such, involving researchers in engineering disciplines, physics and mathematics.

- Dislocation plasticity is an extremely challenging problem, owing to: geometrical and statistical complexity of dislocation assemblies, long-range interactions of dislocations, and, still poorly understood dislocation – interface interactions.,Several levels of mathematical analysis have emerged over the years involving different level of approximation and computational costs.
- Structure and motion of interfaces in solids and fluids, and their role in the deformation of polycrystalline assemblies remain active area of research. For problems with mobile interfaces and topological discontinuities, the phase field formulations have emerged as the most effective methods, but they require solid physical and mathematical foundations, which is typically accomplished with firm mathematical grounding in the corresponding sharp interface model.
- Foundations of continuum theories: Mixing, composites and generalized continua. Moving interfaces typically require mass transport, so that mass diffusion models naturally fall within the scope of phase field models. However, the presence of lattice

structure in crystalline solids implies fundamental differences between diffusion in fluids and diffusion in solids and thus, different continuum formulations. Higher order continua have been proposed in connection with most problems discussed in this course.

- Granular matter is the second most manipulated type of matter after water, with a range of applications, including soils, powders, colloids, amorphous metals and alloys. Depending on the state, they exhibit solid-like or liquid-like properties. Microscopically, granular materials are strongly disordered and require the identification of new variables and descriptors to relate rheological features such as dilatancy (volume change under shear) or strain localization to vortex flow patterns and force chains.

The course is addressed to young researchers including doctoral students, postdocs and early career faculty. Upon completion of the course, attendees will acquire deeper understanding of the following questions.

- How far have the understanding and mesoscale modeling advanced in recent decades?
- What are the key open questions that require further research?
- What are the mathematical and physical requirements for a mesoscale model intended to provide either insight or a predictive engineering tool?

Invited Lecturers:
Samuel Forest (Centre des Materiaux Mines ParisTech, Evry, France), Istvan Groma (Eotvos University, Budapest, Hungary), David McDowell (Georgia Institute of Technology, Atlanta, USA), Sinisa Mesarovic (Washington State University, Pullman, USA), Jean-Noël Roux (Université Paris-Est, Champs-sur-Marne, France), Hussein Zbib (Washington State University, Pullman, USA).

Coordinators: S. Forest (France), S. Mesarovic (USA), H. Zbib (USA).

Towards a Seamless Integration of CAD and Simulation

June 5 - 9, 2017

Isogeometric analysis relies on the use of the same basis functions as employed in Computer Aided Design (CAD). This offers the possibility to facilitate design and optimisation. The previous course "Isogeometric methods for numerical simulation" held in 2013 had the aim to give an introduction to isogeometric analysis, its advantages, drawbacks and to the range of its applications.

The aim of the new course will be different. The focus will be more on the connection of simulation to CAD systems and how CAD data can be used directly for simulation, leading to a seamless integration. An overview of recent advances and applications will be also presented. The course will start with an introduction to NURBS and their use in describing geometry and in simulation. This will be followed by lectures from a CAD vendor describing the current state of development. Currently available connections to simulation software will also be discussed.

Next the use of NURBS for 3D structural analysis, structural optimisation and damage tolerance assessment will be presented, including such advanced topics as the treatment of discontinuities and real-time solvers. It will also be discussed when it might be advantageous to decouple the boundary discretisation from the field variable discretisation, in particular in shape optimisation. Isogeometric methods for the analysis of beam and shell structures, including shape optimisation and fluid structure

interaction, will be presented.
Lectures on the mathematical and algorithmic foundations of analysis-suitable geometry will follow. This includes an introduction to T-splines and multilevel spline schemes such as hierarchical B- splines. Common analysis-suitable spline algorithms will be presented in the context of Bézier extraction and projection as well as its application as a foundation for integrated engineering design and analysis. An important aspect of analysis-suitable geometry is the ability to locally adapt the smooth spline basis. Several common refinement algorithms will be reviewed as well as their application in several demanding areas of application. The emerging area of weak geometry will be introduced as well as its application to the rapid construction of complex structural assemblies.
With the rapid development of isogeometric analysis in recent years, there is an urgent need for volumetric parameterization such as volumetric T-spline model construction. Several volumetric T- spline modeling techniques, that were developed in recent years will be presented. They include converting any quad/ hex meshes to standard and rational T-splines, polycube-based parametric mapping, feature preservation using eigenfunctions, Boolean operations and skeletons, truncated hierarchical Catmull-Clark subdivision, weighted T-splines, conformal T-spline modeling, as well as incorporating T-splines into commercial CAD and FEA software, will be presented.
The target audience will be engineers, interested in simulation, software developers and researchers.

Invited Lecturers:
Gernot Beer (Graz University of Technology, Austria), Kai-Uwe Bletzinger (Technical University of Munich, Germany), Stéphane P.A. Bordas (University of Luxembourg and Cardiff University, LU and UK), Giuseppe Massoni (McNeel Corporation, Rome, Italy), Michael Scott (Brigham Young University, USA), Jessica Zhang (Carnegie Mellon University, Pittsburgh, PA, USA).

Coordinators: G. Beer (Austria) and Stéphane P.A. Bordas (Luxembourg and UK)

Growth and Remodeling in Soft Biological Tissue
23rd CISM-IUTAM International Summer School

June 12 - 16, 2017

One of the most remarkable differences between classical engineering materials and living cells or tissues is the ability of the latter to grow and remodel in response to diverse stimuli. The mechanical behavior of living tissues is thus governed not only by an elastic or viscoelastic response to loading on short time scales (up to several minutes), but additionally by often crucial growth and remodeling responses on time scales of hours to months. Such growth and remodeling play important roles, for example, during morphogenesis in early life as well as in homeostasis and pathogenesis in adult tissues, which often adapt continuously to changes in their chemo-mechanical environment resulting from, for example, aging, diseases, injuries, or surgical interventions. Mechano-regulated growth and remodeling are observed in various soft tissues, ranging from tendons and arteries to the eye and brain, as well as in lower organisms and plants. Therefore, understanding and predicting growth and remodeling of living tissues and organisms is one of the most important challenges in biomechanics.

This course is addressed to doctoral students and postdoctoral researchers in engineering and applied mathematics. It will start with a few introductory lectures that summarize the motivation for study and the current state of the art; subsequent lectures will focus on cutting edge research. This way, the course will be accessible for participants with a basic background in nonlinear continuum mechanics or soft tissue biomechanics, but without any specific prior knowledge about soft tissue growth and remodeling. The lectures will address in particular:

- important experimental and clinical observations, including tensional homeostasis, micromechanical and molecular foundations (mechanotransduction, signaling, etc.), pathologies (aneurysms, tortuosity, etc.), and observations from comparative biology and animal models;
- major mathematical approaches to model growth and remodeling in soft tissues, including the kinematic growth theory, constrained mixture models, hybrid approaches, open system thermodynamics, and computational implementations;
- archetypal biomechanical phenomena that arise from growth and remodeling and that are not observed in classical solid or structural mechanics, including growth-induced instabilities, growth-induced residual stresses, and mechanobiological instabilities;
- chemo-mechanical stimuli governing growth and remodeling and how they can be modeled appropriately in continuum mechanics using quantities such as Cauchy stress, Green-Lagrange strain, Eshelby stress, Mandel stress etc.
- mathematical modeling of the interplay between growth and remodeling and biochemistry, including concepts from poroelasticity, configurational forces, and mass transport;
- differences and similarities of growth and remodeling in different types of tissue, such as blood vessels, skin, tendons, ligaments, skeletal muscle, tumors, the heart, the brain, etc.

Invited Lecturers:
Davide Ambrosi (Politecnico di Milano, Italy), Martine Ben Amar (Ecole Normale Supérieure, Paris, France), Christian Cyron (Technical University of Munich, Munich, Germany), Alain Goriely (University of Oxford, Oxford, UK), Jay Humphrey (Yale University, New Haven, CT, USA), Ellen Kuhl (Stanford University, Stanford, CA, USA).

Coordinators: C. Cyron (Germany) and J. Humphrey (USA).

Continuum Mechanics and Physics of Liquid Crystals

June 26 - 30, 2017

Liquid crystals (LCs) are matter in a state that exhibits intermediate physical properties between those of conventional liquids and those of solid crystals: they may flow like a liquid, but their molecules may be oriented along a common direction like in a crystal. The particular shape of LCs renders the molecules very sensitive to the presence of physical boundaries and to the action of magnetic or electric fields. Depending on the magnetic properties of the LC, molecules may reorient along, or normally to, the direction of the field. In particular, the sudden application of a field switches on/off the transmission of polarized light. Thus, LCs may find wide applications in computer monitors, flat-panel televisions, cell phones, calculators and watches.

The classical mathematical theory of LCs (that concerns only statics) is a continuum theory based on the pioneer works by Oseen (1933), Zocher (1933) and Frank (1958). The continuum dynamical theory is instead due to the independent contributions by Ericksen (1962) and Leslie (1968). These theories use a single order parameter, called the director, a unit vector pointing along the average microscopic molecular orientation. Many phenomena in LCs fit well within the classical description. However, the transition from ordered to disordered states escapes the director theory. The classical microscopic description of defects and surface phenomena yields undesired results as well. The more recent order-tensor theory put forward by de Gennes (Nobel Prize laureate in physics in 1991) in two works (dated 1969 and 1971) focuses on the orientational probability distribution, and introduces the measures of the degree of orientation and biaxiality. This theory was reformulated rigorously by Ericksen (1991).
Recent studies have shown the inadequacy of classical continuum theories to study:
- the geometry and topology of active liquid crystals under confinement,
- the mechanics of ultra-thin nematics deposited on curved substrates (nematic shells),
- the anisotropic elasticity and dynamic relaxation of LCs.

On the contrary, these phenomena can be studied by means of suitable generalizations or adaptations of existing classical models or thanks to novel more complex theories. The course aims at providing carefully crafted overviews of classical and novel continuum theories for LCs to study topological defects, equilibrium textures, active flows and acoustic wave propagation. The lectures will include surveys of relevant differential geometry and analytical methods that are essential to a proper understanding, in addition to overviews on the mathematical modelling of the subject from various perspectives. Representing a “tour d’horizon” on the physics of LCs, the presentations will highlight the efficiency of continuum theories in modelling real world phenomena. The course is addressed to doctoral students, post-doctoral researchers and academics interested in the use of continuum mechanics to model, analyse and understand the physics and mechanics of liquid crystals.

Invited Lecturers:
Paolo Biscari (Politecnico di Milano, Italy), Samo Kralj (FNM, University of Maribor, Slovenia), Gaetano Napoli (Università del Salento, Lecce, Italy), Tim Sluckin (University of Southampton, UK), Luigi Vergori (University of Glasgow, UK), Vincenzo Vitelli (Institut-Lorentz for Theoretical Physics, Leiden University, The Netherlands).

Coordinators: G. Napoli (Italy) and L. Vergori (UK).

Mechanics of Liquid and Solid Foams

July 3 - 7, 2017

This course will focus on the relationships between the cellular microstructure and the nonlinear mechanical behavior of liquid and solid foams, as well as 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 space-filling polyhedra, forming regular or random networks of surfaces and edges. 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, as well as 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 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 of 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 on 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 includes 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 (Johns Hopkins University, Baltimore, MD, USA), Sascha Hilgenfeldt (University of Illinois, Urbana-Champaign, IL, USA), Reinhard Höhler (Université Pierre & Marie Curie, Paris, France), Andrew Kraynik (Sandia National Laboratories - retired, Albuquerque, NM, USA), Stelios Kyriakides (University of Texas, Austin, TX, USA), Patrick Onck (University of Groningen, The Netherlands).

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

Bone Cell and Tissue Mechanics

July 10 - 14, 2017

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 remarkable 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 are 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 (MOVE Research Institute 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).

The Franz Ziegler Session

Novel Finite Element Technologies for Solids and Structures
CISM-ECCOMAS International Summer School

September 18 - 22, 2017

A majority of today's engineering applications can be solved by finite element technologies. Nevertheless, for several important problems, the application of standard numerical simulation techniques, as for example the Galerkin method, is limited due to drawbacks like numerical stability issues, locking phenomena and non-smoothness of the solution. In order to improve capabilities and the reliability of numerical simulations, advanced finite element methods are a major part of today's research in the field of mechanics and mathematics.

Due to the progress in this emerging field the objective of this course is to present new ideas in the framework of novel finite element discretization schemes. Thereby the lectures are focused as well on the mechanical as also on the mathematical background. Here, recent developments in mixed finite element formulations in solid mechanics and on novel techniques for flexible structures at finite deformations will be emphasized. A special focus will aim on the implementation and automation aspects of these technologies. The presented automation processes will pay attention to the application of automatic differentiation technique, combined with the symbolic problem description, automatic code generation and code optimization. The combination of these approaches leads to highly efficient numerical codes, which are fundamental for reliable simulations of complicated engineering problems.

The presented modeling techniques cover a huge range of advanced finite element techniques. The special topics of this course are: The isogeometric concept applied to solid and shell structures, novel C1-continuous finite element technologies for Kirchhoff-Love shell models, robust mixed and discontinuous Galerkin methods for solids, plates and shells including strong material anisotropies, flexible body systems considering holonomic and non-holonomic constrains, the Virtual Finite Element Method and concepts of robust preconditioning techniques for large scale problems. Furthermore, the course introduces the theory and application of AceGen: a multi-language and multi-environment tool for highly efficient numerical code generation. These techniques encounter a wide range of applications from elasticity, viscoelasticity, plasticity, and viscoplasticity in classical engineering disciplines, as for instance, civil and mechanical engineering, as well as in modern branches as biomechanics and multiphysics.

The course is intended for doctoral and postdoctoral researchers in civil and mechanical engineering, applied mathematics and physics as well as industrial researchers, which are interested in conducting research in the topics of advanced mixed Galerkin FEM, structural finite element methods, mathematical analysis as well as formulations and applications of these methods to finite strain or coupled problems. Through this course, the students can gain a deep insight into interesting discussions, based on the different backgrounds of the lecturers and it is a must for all that are interested and/or involved in advanced finite element technologies.

The course is closely related to the Priority Program 1748 "Reliable Simulation Techniques in Solid Mechanics. Development of Non-standard Discretization Methods, Mechanical and Mathematical Analysis" funded by the German Research Foundation.

Invited Lecturers:
Sven Klinkel (RWTH Aachen University, Germany), Jože Korelc (University of Ljubljana, Slovenia), Paulo de Mattos Pimenta (Polytechnic School at University of Sao Paulo, Brasil), Joachim Schöberl (Vienna University of Technology, Austria), Jörg Schröder (University Duisburg-Essen, Germany), Peter Wriggers (University of Hanover, Germany).

Coordinators: P. de Mattos Pimenta (Brasil) and J. Schröder (Germany).

Flowing Matter

September 25 - 29, 2017

Flowing matter occurs everywhere around us. There are many examples that illustrate the richness and complexity of flowing matter: from dilute suspensions of active and inactive matter (swimming micro-organisms or inorganic matter transported through the ocean) to dense complex fluids that are suspensions of many interacting parts (glasses, foams). Flowing matter is now an important research topic with many different facettes. Some have only recently appeared (active matter), while others have recently gained new momentum, due to new experimental techniques such as particle tracking, by recent advances in methods for first-principle computer simulations, and guided by new theoretical insights.

These recent developments have brought the fundamental questions of flowing matter into focus. What are appropriate microscopic models? How do microscopic dynamics and interactions give rise to large-scale macroscopic patterns and dynamics? Which aspects of the dynamics of flowing matter are universal? What role does turbulence play in flowing matter?

In the last few years there has been substantial progress in answering these questions, but there are still fundamental difficulties and many open questions. The aim of this CISM course is to give PhD students, postdocs and young researchers an overview of current analytical and computational techniques that are used in different fields to describe flowing matter.

The following topics are covered: low-Reynolds-number hydrodynamics; rheology of glasses, foams, and colloidal suspensions; active matter; particles in turbulence. We intend to highlight universal aspects, and the lectures will assess successes and shortcomings of the state-of the art theory. The goal is to identify key open problems that provide interesting research questions for PhD students, postdocs, and you researchers.

This school is organized in collaboration with the European Cost action MP1305 Flowing matter. In addition to the planned lectures the COST action will arrange a number of shorter research seminars that complement the topics covered in the regular lectures.

Invited Lecturers:
Benjamin Dollet (Institut de Physique de Rennes, CNRS and University Rennes 1, France), Ramin Golestanian (Department of Physics, Oxford University, UK), Elisabeth Guazzelli (Aix-Marseille University, CNRS, IUSTI, France), Kirsten Martens (Laboratoire Interdisciplinaire de Physique, CNRS and Grenoble Alpes University, France), Bernhard Mehlig (Department of Physics, University of Gothenburg, Sweden).

Coordinators: B. Dollet (France) and B. Mehlig (Sweden).

Material Parameter Identification and Inverse Problems in Soft Tissue Biomechanics

October 16 - 20, 2017

This advanced school follows the very successful and popular school CISM C1511 that took place at Udine from 2015, Oct 12 to Oct 16. It gathered six of the best worldwide specialists in hybrid experimental - computational methods applied to soft tissues, to teach focused and highly original courses in this area. Forty delegates registered to this course. They all appreciated learning skills in this multidisciplinary environment. Repeating this summer school will continue addressing this clear need within the biomedical engineering research community.

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 will be taught from scratch.
In addition to the theoretical background taught at the C1511 CISM school in 2015, it is planned for this new course to have hands-on sessions for a better practice of material parameter identification and inverse problems in soft tissue biomechanics.

Invited Lecturers:
Stéphane Avril (Université de Lyon, France), Sam Evans (Cardiff University, The Parade, UK), Christian Gasser (KTH, Stockholm, Sweden), Amit Gefen (Tel Aviv University, Israel), Cees W.J. Oomens (Eindhoven University of Technology, The Netherlands), Hazel Screen (Queen Mary University of London, UK).

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

International Advanced Professional Training

Pressure Control with Energy Production by PAT (Pump as Turbine) in Water Supply Networks

September 11 - 15, 2017

Pressure reduction in water supply networks is one of the key topics in hydraulic engineering. The benefits of pressure control are the containment of water leakages, reduced stress for pipelines and waterworks, and a better energy efficiency in water transportation. Pressure Reducing Valves (PRVs) are used to dissipate hydraulic energy and reduce pressure to the required value. The installation of micro and pico hydro power plants in substitution of PRVs could recover part of this energy.
PATs are commercial pumps used in reverse mode to generate energy. These devices are very reliable and inexpensive. The coordinator and the lecturers have performed extensive research activities on reverse pumps, covering the mechanical conditions, the design criteria for water supply networks, the mechanical reliability of the equipment, and the system life cycle.
The course is designed for advanced graduate students and for postdoctoral researchers across several engineering disciplines (e.g., Civil, Mechanical, Electrical), to provide participants with the tools and techniques to identify potential sites for PATs, to select the most reliable pump to be used at each site, to determine the best regulation mode for the power plant, and to address the life cycle performance of the system.
The followings paragraphs summarize the broad subtopic breakdown introduced by the course:

PAT Theory

The complete theory of pump working in reverse mode will be developed. A summary of the existing methodologies for pump selection to be used as turbines will be given. Lectures on PAT theory will be focused both on the PAT operating conditions, and on the industrial aspects for PAT design improvement.

Power plant location in water networks

The potentiality of small hydro power plant for pressure control in water supply networks will be fully analyzed. All aspects involved in power plant locations and the optimization of water network management will be considered, including energy production, reduction of water leakage through improved network control, and water network protection in case of power plant failure.

Power plant regulation modes

In water supply networks, PATs work under variable operating conditions for the daily and space variability of flow rate and available pressure head drop. The existing methods for PAT regulation will be explained and the objective functions in power plant design will be described.

Economic and environmental evaluation, resource assessment

The reduction of energy consumption for a sustainable use of natural resources is a real global challenge. The income from energy production is only one of the benefits of PAT diffusion. A methodology for the economic and environmental evaluation, and the resources assessment of the proposed technology will be provided.

Reliability and life cycle

As an effect of the variability of working conditions, the PAT could operate far from the machine's best efficiency point, and many components could work with larger stress than in pump mode. The presence of suspended sediments could further affect the PAT life cycle. PAT reliability and its effect on power plant design will be fully analyzed.

Invited Lecturers:

Armando Carravetta (University Federico II, Naples, Italy), Shahram Derakhshan (University of Science & Technology, Iran), John Gallagher (Bangor University, Bangor, United Kingdom), Stefano Malavasi (Politecnico di Milano, Milan, Italy), Aonghus McNabola (Trinity College, Dublin, Ireland), Helena M. Ramos (Instituto Superior Técnico, UL, Lisbon, Portugal).

Coordinator: A. Carravetta (Italy).

Highlights and Challenges in Diagnosis of Structural Integrity and Failures

October 2 - 6, 2017

The objective of this course is to prepare future experts to configure diagnosis systems for civil, offshore, aerospace and mechanical structures.

To achieve this, so that the structures become lighter, damage is allowed to exist during operation as long as it is within safe, predetermined specifications. Course participants shall have the opportunity to learn about emerging technologies, dealing with the development and implementation of techniques and systems where automated monitoring, inspection and damage detection becomes an integral part of the structures.

A major part of the lectures will be dedicated to composite materials increasingly used for 'modern' structures.

Composite components are lightweight and have excellent fatigue and corrosion resistance.

Failure of these structures is still less understood when compared to metals, and therefore it is still a matter of concern and specific attention. To cope with damage in those comparatively new materials, monitoring technologies and strategies are required in order to allow for the advantage of their light weight potential to be used on one hand, and not to compromise safety on the other.

The aim of the course is therefore to describe and explain current research in areas of application and tendencies for the future of this technology including the various design issues.

The theory and techniques that are important for understanding the topics covered will be addressed.

Composite structures may be designed according to a damage tolerant philosophy, once the relevant technologies are available.

Defects in those composite materials may arise during manufacture due to voids/porosity, ply misalignment or inclusion of foreign microscopic particles that show no evidence to the naked eye. There is a list of examples of such defects: composite elements delaminated and/or contaminated by moisture (water, skydrol, etc.) or chemicals (silicon, etc.), thermal degradation and defects in composite bonds. Also surface contaminants of composite elements that appear during the manufacturing process are included in those examples.

Damage mechanisms for such materials shall be thus covered, along with the latest developments in monitoring technologies.

The objective of this lecture series is therefore also to get the basic knowledge from the field of smart structures that laterally encompasses disciplines such as structural dynamics, materials and structures, fatigue and fracture, non-destructive testing and evaluation, sensors and actuators, microelectronics, signal processing and many more.

This also includes monitoring of external and internal loads with the goal of obtaining information about impacts or excessive fatigue loads in view of damage prognosis.

A multidisciplinary approach among these disciplines is therefore required to holistically manage the operation of an engineering structure through its life cycle.

The most commonly used methods are: active thermography, ultrasound including electro-mechanical impedance techniques, eddy current, terahertz technology (THz), and others including variations and combinations.

The course is addressed to: students in post-graduate school (M.Sc. level); Ph.D. students; researchers interested in diagnosis of structural integrity and failures; practicing engineers interested in the field of health monitoring, maintenance, repair and overhaul.

Invited Lecturers:

Christian Boller (Universität des Saarlandes, Saarbrucken, Germany), Spilios D. Fassois (University of Patras, Greece), Claus-Peter Fritzen (University of Siegen, Germany), Alfredo Gúemes (Universidad Politecnica de Madrid, Spain), Malcolm McGugan (Technical University of Denmark, Roskilde, Denmark), Wiesław Ostachowicz (Polish Academy of Sciences, IMP, Gdansk, Poland), Afzal Suleman (University of Victoria, Victoria, BC, Canada).

Coordinators: C. Boller (Germany), W. Ostachowicz (Poland).

Joint Advanced School

CISM-JMBC Course on Complex Flows and Complex Fluids

Udine, May 8 - 12, 2017

Coordinator: Federico Toschi (TU Eindhoven, NL)

JMBC Representative: Gert-Jan van Heijst (TU Delft, NL)

CISM Representative: Alfredo Soldati (TU Wien, A)

CISM-EMS School on Rationality, Stable Rationality and Birationally Rigidity of Complex Algebraic Varieties

Udine, September 3 - 9, 2017

Coordinators:

Francesco Zucconi (University of Udine, I), Pietro De Poi (University of Udine, I)

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.

Admission to Courses

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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