



**Centre International des Sciences Mécaniques
International Centre for Mechanical Sciences**

Rectors:

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



PROGRAMME 2016

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 Horst H.E. Leipholz Session

Small Scale Modeling and Simulation of Turbulent Multi-phase Flows

May 16 - 20, 2016

The numerical simulation of multi-phase flows involving immiscible phases or solid particles generally considers the interaction between an ambient fluid and another phase (solid particles, droplets, bubbles, fms, sprays, jets). Either deformable grids, which are adapted to the interface, or fixed grids, with an independent representation of the interface, such as front-tracking, volume-of-fluid, level-set and phase-field, can be used to investigate these flows. The direct numerical simulation and large eddy simulation of multi-phase flows can be achieved with different mathematical models (Navier-Stokes, Boltzmann, Saint-Venant, Smooth-Particle Hydrodynamics) with emphasis on different physical aspects of the flow (representation of the capillary force with constant and variable surface tension, phase change, wettability and contact lines, and more complex phenomena involving electric and magnetic fields). Other topics of interest to the mechanical and CFD community are the multi-scale modeling of multi-phase flows. The present course aims at providing basis and recent research insights concerning the small scale modeling and simulation of turbulent multi-phase flows. By small scale, it has to be understood that the grid size for the simulation is smaller than most of the physical time and space scales of the problem. Small scale modeling of multi-phase flows is a very popular topic since the capabilities of massively parallel computers allows to go deeper into the comprehension and characterization of realistic flow configurations and at the same time, many environmental and industrial applications are concerned such as nuclear industry, material processing, chemical reactors, engine design, ocean dynamics, pollution and erosion in rivers or on beaches...

The main goal of this course is to propose a complete and exhaustive presentation of models and numerical methods devoted to small scale simulation of turbulent multi-phase flows from specialists of the research community. Attention has also been paid to promote illustrations and applications with senior researchers experts in CFD, multi-phase flows and collaborations with industry.

The idea is also to bring together developers and users of different numerical approaches and codes to share their experience in the development and validation of the algorithms and discuss the difficulties and limitations of the different methods and their pros and cons. The focus will be mainly on fixed-grid methods, however adaptive and unstructured grids will be also partly broached, with the aim to compare and validate the different approaches and models.

Invited Lecturers:

Sivaramakrishnan Balachandar (University of Florida, Gainesville, FL, USA), Jean-Luc Estivalèzes (ONERA, The French Aerospace lab, IMFT, Toulouse, France), Djamel Lakehal (Ascomp GmbH, Zurich, Switzerland), Ruben Scardovelli (Università di Bologna, Italy), Stéphane Vincent (Université Paris-Est, Marne-La-Vallée (UPEM), France).

Coordinators: J-L. Estivalèzes and S. Vincent (France)

Computational Acoustics

May 23 - 27, 2016

Noise levels have become an issue for urban communities for many years due to the rapid growth of air and ground traffic densities (e.g., airplanes, trains, cars, etc.). Additionally to these noise sources, many other machines (e.g., wind turbines, pumps, fans, etc.) producing significant noise levels surround our daily activities and contribute to deterioration of quality of life. A quite large part of this noise is generated by vibrating structures and by flows (flow induced sound), and manufactures have considered the noise level of their products as a relevant design parameter. Therefore, the demand towards reliable and computationally efficient numerical simulation programs is strongly growing, so that these tools can be used within a virtual prototyping development cycle. The aim of the course is to present the state-of-the-art overview of numerical schemes efficiently solving the acoustic conservation equations (unknowns are acoustic pressure and particle velocity) and the acoustic wave equation (pressure or acoustic potential formulation). Thereby, the different equations model both vibrational and flow induced sound generation and its propagation. In addition, state-of-the-art methods for the solution of so-called inverse problems, i.e., problems of identifying sources, scatterers, material properties, etc., will be presented. Main applications, which will be discussed within the course, will be towards aerospace, rail and automotive industry as well as medical engineering. Thereby, we have composed a team of lecturers who are able to address these topics from the engineering as well as numerical points of view.

The course will contain both the physical / mathematical modelling, latest numerical schemes to solve the underlying partial differential equations, and relevant practical applications. Thereby, we will derive the conservation equations of acoustics both for a stagnant as well as moving fluid. In addition, we will derive the couplings to structural mechanics and fluid flow.

This will allow us to describe vibrational as well as flow induced (aeroacoustics) sound. In a next part, we will present appropriate numerical schemes for the solution of the derived partial differential equations: finite difference, finite element, finite volume, and boundary element methods. We will discuss latest numerical schemes as higher order and spectral finite elements, mixed finite elements, nonconforming grid techniques as well as discontinuous Galerkin methods. For many practical applications, one needs to apply impedance boundary conditions and has to cope with free radiation. Here, we will discuss higher order absorbing boundary conditions and perfectly matched layer techniques to efficiently approximate free radiation conditions. Since numerical schemes lead to a system of algebraic equations, which have to be solved, we will also present algorithms for direct and iterative solvers as well as latest developments on multigrid methods.

The course is addressed to doctoral students and postdoctoral fellows, as well as to academic and industrial researchers and practicing engineers, with a background in mechanics, acoustics, applied physics, aerospace engineering, civil engineering or applied mathematics.

Invited Lecturers:

Gary Cohen (EPI POEMS, INRIA and ENSTA ParisTech, France), Dan Givoli (Technion Israel Institute of Technology, Tel Aviv, Israel), Manfred Kaltenbacher (Vienna University of Technology, Austria), Ulrich Langer/Martin Neumüller (Johannes Kepler University Linz, Austria), Steffen Marburg (Technische Universität München, Germany), Claus Dieter Munz (Universität Stuttgart, Germany).

Coordinator: M. Kaltenbacher (Austria)

Visco-plastic Fluids: from Theory to Application

May 30 - June 3, 2016

In classical models of visco-plastic fluids, these materials do not deform when subjected to a shear stress smaller than a certain value, which is called the yield stress. In this range of applied shear stress, these materials behave as ideal rigid solids. If the shear stress in the fluid exceeds the yield stress then the fluid deforms as a (nonlinearly) viscous fluid and is typically shear thinning since the fluid structure breaks down progressively with shear. Therefore, from both a physical and mathematical perspective, the yield stress threshold effects a fundamental change to the fluid mechanics of the problem. The visco-plastic fluids play a prominent role in many industrial processes, as in the food industry (e.g., dairy products, chocolate confections, pulp suspension), the petroleum industry (drilling mud, cement, waxy crude oil), the biological industry (e.g., mucus and blood clot), the natural phenomena (e.g., flows of slurries, debris and lava), and in various complex printing and coating processes.

The proposed course is designed for advanced graduate students as well as postdoctoral researchers across several disciplines (e.g., Mathematics, Physics and Engineering), with the aim of providing them with tools and techniques that are essential in performing research on the flow problems of visco-plastic fluids. Notably, we envision a broad and lively discussion of all the theoretical developments, analytical and computational methodologies, recent experimental methods and existing applications.

The followings summarize the broad subtopic breakdown introduced by the course:

- Analysis of classical viscoplastic fluid models The history of classical models, the variational formulation, the general results on existence and uniqueness of weak solutions and the hydrodynamic stability.
- Mathematical modeling of flows of visco-plastic fluids Visco-plastic lubrication theory, free-surface flows, sheets and threads and visco-plastic convection.
- Computing flows of viscoplastic fluids. Finite element discretization scheme, the Augmented Lagrangian and the regularized methods in computing visco-plastic flow problems, adaptive mesh refinement techniques and the fictitious domain methods.
- Rheology of visco-plastic fluids and visco-plastic suspensions Introduction to the conventional Rheometry and recent measuring techniques such as Magnetic Resonance Imaging (MRI) and X-ray microtomography, sedimentation and migration of solid and bubble inclusions.

- Application of visco-plastic fluids in engineering sciences. Flow and shape generation (e.g. forming and extrusion, wall slip, etc.), flow and heat transfer (e.g. casting and fouling) and unsteady flows (e.g. injection moulding, start-up and shutdown, flushing and cleaning).
- Complex flows of visco-plastic fluids. Multi-layer flows of visco-plastic fluids, solid dispersion in flows of visco-plastic fluids, natural phenomena of visco-plastic fluids e.g., submarine avalanches and mudslides.

Invited Lecturers:

Neil Balmforth (The University of British Columbia, Vancouver, Canada), Ian Frigaard (The University of British Columbia, Vancouver, Canada), Sarah Hormozi (Ohio University, Athens, OH, USA), Guillaume Ovarlez (CNRS, Bordeaux University, LOF, France), Anthony Wachs (The University of British Columbia, Vancouver, Canada), Ian Wilson (University of Cambridge, Cambridge, UK).

Coordinators: S. Hormozi (USA), G. Ovarlez (France)

Fabric Tensors – Measures of Porous or Granular Material Anisotropy

June 6 - 10, 2016

Fabric tensors are tensors that characterize the anisotropic architecture of the microstructure in a porous material. Fabric tensors are considered to be higher order measures of porous media microstructure, after porosity or relative volume fraction. The fabric tensor concept arose in geomechanics and soil mechanics and is now widely applied in biomechanics.

This workshop will address the imaging of porous media or granular media, the quantification of porous media morphology or granular architecture (quantitative stereological measures) and the structure-function relationship in porous/granular anisotropic media from the theoretical, experimental and numerical viewpoints. Specifically, the role of fabric in the elastic and inelastic behavior of porous media will be discussed. An analysis of failure mechanisms in a porous/granular medium and its constituents will be presented, as well as the role of fabric on the strengths and on the toughness of porous/granular media.

The inclusion of the fabric tensor as a measure of the porous medium anisotropy in both quasi-static and dynamic poroelasticity will be presented. The relationship between fabric, porosity, tortuosity and permeability of the porous medium will be considered. Also, the influence of fabric on poroelastic wave propagation will be analyzed. Ultrasonic wave propagation is a noninvasive technology for the measurements of material properties of geomaterials and biomaterials. Fabric dependent poroelasticity will be presented as the basis for understanding elastic ultrasound in porous media. The presentation will include theory, experiment and technology. The determination of drained and undrained elastic properties from fabric measurements (imaging) and monotonic elastic test loadings will be discussed. Inverse models in porous elastic propagation will be reviewed, that is to say models that determine drained and undrained mechanical properties from ultrasound data.

Different boundary- and volumebased techniques for estimating orientation distribution functions (ODFs) will be presented. Also, different strategies will be described for analyzing and estimating fabric tensors from ODFs. The relationship between Cartesian tensors and spherical harmonics and their relevance in the analysis of anisotropic materials will be discussed. Higherorder descriptors of anisotropy and estimation of fabric tensors in gray-scale images will also be introduced.

The course is addressed to doctoral students, starting and senior researchers, in the fields of modeling the mechanical behavior of materials, particularly in geomechanics and biomechanics.

Invited Lecturers:

Luis Cardoso (The City College of New York, NY, USA), Stephen C. Cowin (The City University of New York, NY, USA), Massimiliano Fraldi (Università di Napoli "Federico II", Italy), Stefan Luding (Universiteit Twente, The Netherlands), Rodrigo Moreno (Linköping University, Sweden), Philippe Zysset (University of Bern, Switzerland).

Coordinators: L. Cardoso and S.C. Cowin (USA)

Global Nonlinear Dynamics for Engineering Design and System Safety

CISM-AIMETA Advanced School

Course sponsored by AIMETA

June 13 - 17, 2016

Global nonlinear dynamics in applied mechanics dates back to the Eighties, when the scientific community realized the importance of nonlinear phenomena in view of technical applications. Since then, the area has been evolving in a revolutionary way, with applications to a wide variety of systems made possible by sophisticated analytical, geometrical and computational techniques employing powerful concepts/tools of bifurcation and chaos theory, properly updated and complemented with a view to engineering aims and meaningful experimental verifications.

The achievements occurred over the last thirty years entail a substantial change of perspective when dealing with vibration problems, and are deemed ready to meaningfully affect the analysis, control and design of mechanical/structural systems. This course aims at highlighting the important, yet still generally overlooked, role that the relevant concepts/tools may play as regards the load carrying capacity and safety of engineering systems.

Attention is paid to the evolution and update of the old concept of stability, as ensuing from consideration of global dynamics. Upon dwelling on bifurcation and complexity, theoretical and practical stability, recent results obtained for a variety of systems in applied mechanics and structural dynamics are overviewed in terms of analysis and control of nonlinear phenomena.

Local and global stability of systems are discussed by also considering the effects of imperfections or small, but finite, dynamical perturbations, along with variations of control parameters. All of them may arise in technical applications and experiments, and are to be properly considered in design in order to secure the system capability to sustain changes

without modifying the desired outcome. Robustness of solutions against variations of initial conditions or control parameters, and system dynamical integrity, are fundamental concepts to be addressed in view of global phenomena, which may entail the existence of merely residual levels of robustness and integrity, unacceptable in technical applications. The overall transition from a local to global safety concept has also major implications as regards the feasibility and effectiveness of techniques aimed at controlling nonlinear dynamics, which may drastically change according to whether the control goal is local or overall. All these issues, which also permit to explain partial discrepancies between experimental and theoretical/ numerical results based on merely local analyses, are overviewed for systems from macro- to micro/nanomechanics. Archetypal discrete systems and reduced order models of continuous systems are addressed. Specific phenomenological aspects are discussed, paying attention to the common or distinguishing nonlinear dynamical features expected to play a meaningful role in analysis and design engineering.

The course is addressed to doctoral students and postdocs, but also to academics, industrial researchers and practicing engineers in mechanical, civil and aeronautical engineering, as well as in applied physics or applied mathematics.

Invited Lecturers:

Paulo Goncalves (PUC-Rio, Rio de Janeiro, Brazil), Stefano Lenci (Università Politecnica delle Marche, Ancona, Italy), Giuseppe Rega (Sapienza Università di Roma, Italy), Jian-Qiao Sun (University of California at Merced, CA, USA), Michael Thompson (University of Cambridge, UK), Mohammad Younis (KAUST, Thuwal, Saudi Arabia and Binghamton University, NY, USA).

Coordinators: S. Lenci and G. Rega (Italy)

Computational Fluid-Structure Interaction

CISM-ECCOMAS International Summer School

June 27 - July 1, 2016

Fluid-Structure Interaction (FSI) problems, as well as many other coupled multi-field problems, have received much attention in recent years and continue to attract more interest. The main reason is that they are of great relevance to many fields of engineering (civil, mechanical, aerospace, bio, etc.) and applied sciences. Similarly, the development and application of corresponding numerical simulation methodologies have received wide attention over the past decades.

Thanks to many advances in computational sciences and computing hardware, the numerical modeling and solution of a difficult subset of such problems that was thought to be unfeasible even five years ago, is either feasible today or will become feasible within the nearby future.

In recent years, research in computational FSI has witnessed great progress. However, the field remains an active topic of research with many remaining open problems. Current foci center on the better understanding of various numerical approaches via

more rigorous analysis, the generalization of special-purpose solution schemes to comprehensive methodologies, and the maturing of computational technologies that have demonstrated great potential a decade ago to transcend them into numerical assets for the solution of grand challenge FSI problems. Nevertheless, the bar for entering this exciting research field is considerably high.

It requires mastering a fair amount of computational fluids or fluid dynamics, linear and/ or nonlinear computational solid and/or structural dynamics, timeintegration, linear algebra, and parallel computing, among other topics. Textbooks in this general area are either specialized, or tend to cater to specific solution approaches rather than fundamental issues. This latter gap is what this CISM course modestly attempts to address. To this effect, the course brings together experts in the area of computational FSI who will cover complementary aspects of this topic from different perspectives. On the disciplinary side, incompressible and compressible flow regimes and linear and nonlinear structural behaviors will be covered. On the interaction side, all three classes of FSI problems will be discussed:

(1) those where the interaction is of short duration and the fluid subsystem is characterized by limited displacements, as in shock and impact problems;
(2) those problems where the fluid subsystem is also characterized by limited displacements but the interaction is of longer duration, as in elastoacoustic problems;
and (3) those problems where the fluid and structural subsystems have large relative motions and the interaction process is dominated by the flow, as in aeroelasticity problems. The formulations of these problems in the Arbitrary Lagrangian Eulerian (ALE) and purely Eulerian settings will be discussed and contrasted.

Various associated semidiscretization and discretization schemes will be covered, and their strengths and weaknesses will be explained. These will include ALE and embedded boundary methods for CFD in the first case, and monolithic and partitioned solution procedures in the second case. To address the issue of CPU intensive parametric problems, the course will also include a few lectures on model order reduction in the context of FSI problems.

Participants will be given the opportunity to present a poster covering their interest and contribution to this field. This will enable fostering a collegial discussion and provide the lecturers with an opportunity to tailor their material to address specific applications and concerns.

Invited Lecturers:

Santiago Badia (Universitat Politècnica de Catalunya (UPC) and CIMNE, Barcelona, Spain), Charbel Farhat (Stanford University, CA, USA), Jean-Frédéric Gerbeau (INRIA Paris and Sorbonne Universités UPMC, France), Roger Ohayon (Laboratoire de Mécanique des Structures et des Systèmes Couplés, CNAM, Paris, France), Wolfgang A. Wall (Technical University of Munich, Munich, Germany).

Coordinators: C. Farhat (USA), W.A. Wall (Germany)

Biological and Bio-inspired Fluid Mechanics

22th CISM-IUTAM International Summer School

July 4 - 8, 2016

At all scales of Nature, from bacterial flagella to tree branches, biological organisms interact with a surrounding fluid environment. These interactions are generally critical for their survival and are often fully coupled: the organisms modify or create flows around them, and these flows, through surface forces (pressure or viscous forces), exert loads on the organisms that can deform them and modify their behavior. One example is blood flow, where fluid stresses acting on red blood cells have well-studied impact both in normal physiology and disease. Another example is the fluid-based motility of organisms, at all scales, from cells to birds, or fish. Much research efforts have been devoted to understanding the adaptation of biological organisms to resist or exploit aero- or hydrodynamic constraints. One motivation for these studies, beyond the desire to gain a deeper understanding of the natural world, is to design efficient biomimetic artificial systems. This school will teach the fundamental modeling tools required to quantify and understand the fluid mechanics of biological and bio-inspired systems. The various branches of fluid mechanics can be divided according to the relevant Reynolds number involved. The same classification is applicable to biological fluid mechanics. Although there may be some apparent kinematic similarities between the swimming motion of an eel and a spermatozoon, the Reynolds numbers involved and thus the fluid dynamics are very different. Accordingly, the lectures of this school will be divided into two groups.

Three series of lectures will be concerned with the low-Reynolds number regime and the fluid mechanics around cells. At this scale, important problems include the physics of membranes, thermal fluctuations, elastic instabilities such as cell wrinkling and buckling, flagellar and ciliary locomotion, collective motion of bacteria, chemotaxis, and rheology of non-Newtonian flows.

The second series of three lectures will focus on the large Reynolds number limit and macroscopic locomotion. These courses will address the fluid mechanics and the fluid-structure interactions of flying, swimming, and human motion with emphasis on the importance of unsteady effects, vortex dynamics, boundary layers, efficiency, optimization, and athletic performance in sports.

The objective of this school is to provide an introduction to fluid mechanics for biological and bio-inspired systems with an emphasis on the role of fluidstructure interactions.

The lectures will address both the experimental and theoretical aspects of the field, and will cover the fundamentals as well as recent developments and open questions. This course is aimed at PhD students, postdoctoral fellow, and young researchers in the fields of Physics, Biophysics, Applied Mathematics, Robotics, and Engineering.

Invited Lecturers:

Christophe Clanet (Ecole Polytechnique, Palaiseau, France), Christophe Eloy (IRPHE, Centrale Marseille, France), Eric Lauga (University of Cambridge, UK), Geoff Spedding (University of Southern California, Los Angeles, CA, USA), Holger Stark (TU Berlin, Germany), Petia M. Vlahovska (Brown University, Providence, RI, USA).

Coordinators: E. Lauga (UK), C. Eloy (France)

The Role of Mechanics in the Study of Lipid Bilayers

July 11 - 15, 2016

Lipid bilayers constitute the membrane that encloses every animal cell and many of its interior structures, including the nuclear envelope, the organelles and the endoplasmic reticulum. They possess some of the features of conventional engineering shell structures such as flexural resistance, but they are unusual in that they also possess the properties of two-dimensional curved fluid sheets. This combination is responsible for a myriad of remarkable mechanical and physical responses that make lipid bilayers a unique and fascinating topic of study. The basic molecular mechanism responsible for this range of behavior is the lipid molecule. It is polar, with one end – the molecular tail - being hydrophobic, and the other –the head group - hydrophilic. The lipids constitute the two leaves of the bilayer, with the hydrophobic tails juxtaposed in such a way as to exclude the surrounding aqueous solution. Thus the bilayer is the product of a self-assembly process driven by a clear physical mechanism.

In recent years the study of this subject has been undertaken by experts in physics and mechanics. The perspective brought to bear by the mechanics community has facilitated a large number of significant advances, not only with respect to an improved understanding of the foundations of the subject, but also with respect to the modeling of phenomena that had heretofore been treated on an ad hoc basis without the benefit of the overall intellectual viewpoint that modern mechanics brings to bear. Thus the broad framework afforded by mechanics has led to important conceptual advances in such topics as phase equilibria in lipid bilayers, diffusion and transport phenomena, cell adhesion and motility, tubule formation, coupled electromechanical response, edge and pore effects, intra- and extramembrane viscous flow, inter-leaf friction, the role of tilt (known to the shell theorist as transverse shear deformation), bifurcation and instability, membrane rheology, models based on molecular considerations, and so on. Indeed the field is nowadays extremely active, and has grown into a major discipline lying at the intersections of mechanics, bio-physics and applied mathematics.

One of the most important conceptual aspects of the subject is the profound interplay it exhibits between mechanics and geometry. Thus the field makes essential use of advanced topics in the differential geometry of surfaces. Indeed it requires considerable facility with the latter subject, and provides an opportunity to exercise our knowledge of virtually that entire branch of applied mathematics. For this reason much modern work on bilayers is primarily geometric in nature.

The presentations will be carefully crafted overviews of the basic theory and its various enhancements and extensions from several points of view. They will also include surveys of relevant differential geometry and variational methods that are essential to a proper understanding, overviews on the foundations of the subject from various perspectives, applications of modern bifurcation theory to the analysis of membrane equilibria, and further developments encompassing a range of coupled-field phenomena.

The course is addressed to doctoral students, post-doctoral researchers and academics interested in the use of mechanics to model, analyze and understand the physics of lipid bilayers. Lipid bilayers are ubiquitous in biology, and related structures occur in fluid interfaces and experimental vesicles. While the course is largely self-contained, students would benefit from prior exposure to courses on continuum mechanics, tensor analysis and elementary electromagnetism.

Invited Lecturers:

Marino Arroyo (Universitat Politècnica de Catalunya, Barcelona, Spain), Luca Deseri (Università di Trento, Italy), Markus Deserno (Carnegie Mellon University, Pittsburgh, PA, USA), Jemal Guven (University of Mexico, Mexico City, Mexico), Timothy J. Healey (Cornell University, Ithaca, NY, USA), David Steigmann (University of California at Berkeley, CA, USA).

Coordinator: D. Steigmann (USA)

Wall-Bounded Turbulence

July 18 - 22, 2016

Despite significant progress achieved in recent years, fluid turbulence is still escaping our complete understanding, mainly because of its complex nonlinear behavior. Within the broad subject of turbulent flow, turbulence over solid walls is of special conceptual and practical importance, and its prediction is crucial for the accurate design of aircraft, turbomachines and ships. Understanding the physics of wall turbulence may lead to effective techniques for the reduction of wall friction, with incurred benefits in terms of reduced power expenditure.

The present course is aimed at presenting the state-of-the-art of wall turbulence and highlighting avenues for future research.

The emphasis will be mainly on canonical flows over flat surfaces including boundary layers, pipes, and channels, in the case of both smooth and rough walls.

Wall-bounded turbulence has been tackled over the years along different fronts, which include theoretical analysis and experimental and numerical investigations. Regarding theory, it appears that the best established features of wall turbulence, including the presence of a logarithmic layer in the mean velocity profile and in the wallparallel velocity variances can be explained within relatively well-established conceptual models. Important recent theoretical findings include the discovery that linear processes of transient growth may be responsible for the onset of self-sustained global modes in the wall layer.

Experimental techniques have also undergone major development in recent years, mainly with the introduction of high-resolution anemometry probes down to the nano-scale. This has allowed to shed light on such long-debated subjects as the presence of an outer peak in the streamwise velocity variance.

Computational experiments based on Direct Numerical Simulations (DNS) have lately become of widespread use to get insight into the physics of wall turbulence, because of the potential to access any flow property of interest. Also given the exponential growth of available computer power, DNS has reached Reynolds numbers comparable to those attained in experiments.

The course is mainly addressed to doctoral students in mechanical and aerospace engineering and related subjects, but post- Doc fellows and young researchers are also warmly encouraged to attend. The course is intended to provide the audience with all fundamental notions about the structure of wall-bounded turbulent flows, but most classes will be devoted to advanced topics covering the freshest developments in

the discipline, and to highlight paths for future investigation. Theoretical, experimental, and numerical issues will be covered. The course will be complemented by a short tutorial on DNS of turbulent flows. Attendants will be introduced to modern techniques of parallel computing, and will be made to exercise on sample channel and pipe codes to get familiar with important practical issues as mesh generation and data analysis.

Invited Lecturers:

Javier Jimenez (Universidad Politecnica de Madrid, Spain), Ivan Marusic (Melbourne School of Engineering, Australia), Beverley McKeon (California Institute of Technology, Pasadena, CA, USA), Paolo Orlandi (Sapienza Università di Roma, Italy), Sergio Pirozzoli (Sapienza Università di Roma, Italy), Alexander J. Smits (Princeton University, NJ, USA).

Coordinator: S. Pirozzoli (Italy)

Multiscale Modeling of Flowing Soft Matter and Polymer Systems

July 25 - 29, 2016

Soft materials such as polymer melts or solutions, colloidal suspensions, emulsions, foams and gels are materials lying at the interface between fluids and solids requiring, for their simulation, highly innovative computational methods. In a similar way, simulation of fluid flows in nanoscale geometries also needs to account for the molecular nature of the fluid while at the same time retrieving hydrodynamic properties.

This advanced school aims at covering the theory and practice of multiscale modeling of these materials (and the corresponding chemical processes involved) and is specifically addressed to graduate students in physics, chemistry and engineering (chemical, mechanical, environmental, computational) and to scientists and engineers already working in the field. Particular attention will be paid to full-atom and coarse-grained molecular dynamics, dissipative particle dynamics, hybrid molecular/continuum methods, and computational fluid dynamics.

Some lectures will focus on molecular dynamics, which is currently used for the estimation of equilibrium (thermodynamic) and non-equilibrium (transport) properties of complex systems. These simulations can employ models with all the structural details of the chemical system (called full-atom) or with only few of them (known as coarsegrained models). Molecular Dynamics treats the atoms as classical objects following Newtonian dynamics, but relies on information obtained from quantum chemistry, which will be also covered in this advanced school. Force fields (employed in molecular dynamics) and many other important properties (such as partial/net atomic charges) are often derived from quantum chemistry calculations, which are also useful for the estimation of chemical reaction rates. As the chemical complexity of the new materials increases it becomes necessary to develop rapid methods to parametrize reasonably accurate atomistic force fields. In selected applications, e.g. soft materials for electronics, the microstructure and dynamics of the material influences its electronic structure, i.e. one needs larger scale simulations to understand smaller scale properties. With these modeling techniques, the size of the simulated systems is very limited; the simulation of larger systems requires the use of further coarse-graining, or hybrid methods, that link molecular to hydrodynamic models. Among the different techniques

available at these larger time- and length-scales, dissipative particle dynamics, certain hybrid methods, and computational fluid dynamics will be covered. Some lectures will describe the extension of these methods to the simulation of multiphase systems and will discuss some of the numerical issues related to the solution of the governing equations with the finite volume method. Finally, some applications related to the simulation of polymer selfassembly in solution and polymer foam expansion and evolution will be described.

Invited Lecturers:

Michael Allen (University of Bristol, UK), Paola Carbone (University of Manchester, UK), Daniele Marchisio (Politecnico di Torino, Italy), Ignacio Pagonabarraga (Universitat de Barcelona, Spain), Jason Reese (University of Edinburgh, UK), Alessandro Troisi (University of Warwick, Coventry, UK).

Coordinators: P. Carbone (UK), D. Marchisio (Italy)

The Alexandre Favre Session

Mechanics and Physics of Fracture: Multi-scale Modeling of the Failure Behaviour of Solids

September 26 - 30, 2016

Fracture of materials is a multi-scale process that couples the continuum scale from which elastic energy is released to the microstructure scale where this energy is dissipated through damage mechanisms at the crack tip vicinity. For that reason, the microstructural features of materials greatly influences their failure behavior. Powerful approaches have been recently developed to bridge length scales in fracture phenomena and this school will provide a pedagogical overview of the concepts and tools that allow to go from the small to the large scale and, vice & versa, the basic rules for the design of tough solids.

Three fundamental questions will be addressed during the school:

- (i) The relation between the microstructural features of materials and their effective fracture properties,
- (ii) the role of damage mechanisms and non-linear deformations near the crack tip on the failure behavior of solids and
- iii) the role of dynamic inertial effects during fast fracture.

Invited Lecturers:

François Barthelat (Mc Gill University, Montreal, Quebec, Canada), Jay Fineberg (Jerusalem University, Israël), Jean-Baptiste Leblond (UPMC, Paris, France), Alan Needleman (Texas A&M, College Station, Denton, TX, USA), Laurent Ponson (UPMC, Paris, France), Krishnaswamy Ravi-Chandar (Austin University, TX, USA).

Coordinator: L. Ponson (France)

Computational Contact and Interface Mechanics

October 3 - 7, 2016

The main objective of this course is to convey modern techniques and the latest state-of-the-art with regard to the most fundamental aspects of computational contact mechanics. However, since contact can readily be interpreted as a special type of interface problem, it seems advisable not to isolate contact mechanics, but rather to address it in the context of a broader class of problems denoted as computational interface mechanics. Apart from the computational treatment of contact interaction and friction, computational interface mechanics also comprises other related physical phenomena such as wear, fracture and phase boundaries.

Put in short terms, computational contact and interface mechanics are concerned with the treatment of complex interface effects at different length scales ranging from atomistic models to microand meso-scale models and further to classical continuum models at the macro-scale. The nature of many interface phenomena even requires a multi-scale perspective and associated models to bridge the spectrum of relevant length scales.

Therefore, the aforementioned aim of the course has been expanded towards firstly conveying a clear understanding of the underlying physics of interfaces, and secondly giving a comprehensive insight into the current state-of-the-art and selected cutting-edge research directions in the computational treatment of interface effects.

With regard to the first aim, the course will focus on the modeling of friction, wear, lubrication, cohesive interfaces, grain boundaries, phase boundaries, fracture, thermo-mechanics and particulate contact (e.g. granular media). In view of the second objective, the most important computational aspects will be addressed, including discretization techniques for finite deformations, solution algorithms for single- and multi-processor computing environments, multiscale approaches, discrete element models and multi-physics problems including contact and interface constraints. Among the computational techniques covered in this course are finite element (FEM) and boundary element (BEM) methods, atomistic models, molecular dynamics (MD), discrete element methods (DEM), coupling approaches for multi-scale simulations, and tools for an efficient automated FEM code generation.

Each set of lectures will start from the respective basics of physical modeling and computational techniques, but will then quickly move on to an in-depth treatment of cutting-edge research topics. While some attention to practical applications will of course be given, the main focus of all lectures is to convey sound theoretical formulations with regard to the underlying mathematics and mechanics.

The lectures are primarily designed for doctoral students of applied mathematics, mechanics, engineering and physics with a strong interest in the modeling and simulation of complex interface phenomena using high-performance computing environments. However, they are equally suited for young and senior researchers in the above-mentioned and neighboring fields, who have only little experience with regard to the computational treatment of interface effects and who would like to gain a compact yet comprehensive overview of the field. Last but not least, the course might also be interesting for practicing computational engineers working on high-level industrial applications of contact and interface mechanics.

Invited Lecturers:

Marc Geers (Eindhoven University of Technology, The Netherlands), Jean-François Molinari (École Polytechnique Fédérale de Lausanne, Switzerland), Alexander Popp (Technische Universität München, Germany), Stanisław Stupkiewicz (IPPT PAN, Warsaw, Poland), Peter Wriggers (Leibniz Universität Hannover, Germany), Tarek Zohdi (University of California, Berkeley, CA, USA).

Coordinators: A. Popp and P. Wrigger (Germany)

International Advanced Professional Training

Vehicle Dynamics of Modern Passenger Cars

Aug 29 - Sept 2, 2016

Driving an up-to-date passenger car you demand and expect – besides riding comfort – fine handling properties including electronic support in the background e.g. by dynamic stability control(DSC), torque vectoring, active stabilizer, active suspensions. What is behind these features and how are they applied and working?

In former times the development of a new car or better essential components and improvements was based mainly on tests and experiments and hardware adaptations; this is a time and material consuming process. The possibility to apply the mathematics of multibody system models via simulation programs for the prediction of the dynamics of a vehicle accelerates and shortens the development process. For this process it was necessary to develop mechanical models of the car and its components but also to find an appropriate mathematical/mechanical description of the tire behavior and also of other special car components. To improve handling behavior and driving security control schemes were integrated leading to such properties as generally avoiding wheel locking and today this is a common everyday feature of passenger cars. Future developments of control systems aim at automatic driving to relieve the stress of the driver and finally to replace part of his activities.

Moreover the control of the suspension system will provide best ride comfort. Today the application of vehicle and tire modeling, the application of control strategies and the simulation of the complex combined system open the door to investigate a large variety of configurations and select the desired one for the next passenger car generation.

Only final tests are necessary to verify the simulation quality and to get the confirmation for a proper introduction to the market.

As a consequence of these developments this course aims to provide the essential features necessary to understand and apply the mathematic-mechanical characteristics and tools for the vehicle dynamics including control mechanism. An introduction to passenger car modeling of different complexities provides the basics for the dynamical behavior and presents vehicle models later used for the application of control strategies. The presented modeling of the tire behavior, also for transient changes of

the contact patch properties, shows the necessary mathematical descriptions used for the simulation of the vehicle dynamics. The introduction to the control for cars and its extension to complex applications using e.g. observers and state estimators is a main part of the course. Finally the formulation of proper multibody codes for the simulation leads to the integration of all parts. Examples of simulations and corresponding test verifications will show the profit of such a theoretical support for the investigation of the dynamics of passenger cars.

Invited Lecturers:

Igo Besselink (Eindhoven University of Technology, The Netherlands), Timothy Gordon (University of Lincoln, Brayford Pool, UK), Davor Hrovat (Ford Motor Company, Dearborn, MI, USA), Peter Lugner (University of Technology Vienna, Austria), Masao Nagai (Japan Automobile Research Institute, Tokyo, Japan), Georg Rill (OTH Regensburg, Regensburg, Germany).

Coordinator: P. Lugner (Austria)

Time-periodic Systems: Theory and Application

September 5 - 9, 2016

This course provides a thorough introduction into basic and advanced concepts in applied mathematics, mechanics and engineering (civil, mechanical and electrical) on the analysis and design of time-periodic systems. A balance is provided between classic procedures, recent trends in the analysis and experimental observations of resonant and nonresonant behavior. A wide range of problems and their dynamic aspects are covered starting from simple linear differential equations, over small (perturbative) nonlinearities to strongly nonlinear systems including friction and contact, up to partial differential equations, delayed differential equations and large systems of differential equations. Special topics like high-frequency parametric excitation, quasi-periodic excitation, parametric excitation in gyroscopic systems and efficient analysis of complex structures are discussed.

All main dynamic effects are substantiated by experimental observations at lab scale as well as in real applications. Standard techniques in the context of parametric excitation are outlined like the Floquet theory, the method of averaging, the method of multiple scales and the complexification method which enable the (semi-) analytical description of stability boundaries in the system parameter space. Armed with these tools, analytical and numerical investigations of both multibody and continuous mechanical/mechatronic systems under parametric and external periodic excitations are discussed. Analytical studies are employed to detect and analyze stationary and non-stationary resonances. Numerical and experimental investigations are carried out for analyzing regular, chaotic, bifurcation and synchronization phenomena. The not well-known coexistence phenomenon and disappearance of resonance tongues is discussed in detail (Ince's generalization of Mathieu's equation) and the effects of quasi-periodic forcing and of time delay on the system dynamics are outlined.

One major point for real applications is the ability of a specific procedure to analyze (non-)linear, time-periodic systems consisting of large number of degrees of freedom. The classic Floquet method cannot be applied to this kind of system due to the high sensitivity of the results on numerical round-off errors. The symbolic calculation of the Lyapunov transformation matrix based on the Chebyshev polynomials is introduced which enables a transformation of the original time-periodic problem to a time-invariant problem and downscale the system to the relevant variables. A symbolic control technique for Floquet multiplier placement for linear time-periodic systems and bifurcation control and feedback linearization techniques for nonlinear time-periodic systems are presented. Reduction procedures of PDEs to ODEs are discussed with an emphasis on the reliability and validity of the obtained results. Advantages of construction of charts of vibration types and application of the Morlet wavelets and Lyapunov exponents are illustrated.

Another branch of this course covers linear and nonlinear effects of high-frequency (HF) timeperiodic excitation which lead to the main non-trivial effects like stiffening, biasing and smoothening and highlights their practical importance. Generalized results for nonlinear systems with rapid time-harmonic excitation are derived and extended to nonlinear discrete mechanical systems and linear continuous systems. The connection to practical examples is given by using HF excitation to quench friction-induced vibrations and resolving the famous Chelomei's pendulum.

The dynamic behaviour of discontinuous time-periodic systems covering different types of discontinuities like mechanical slip, stop and friction is discussed.

Asymptotic methods are generalized for non-smooth and discontinuous systems. Friction can be the energy source for exciting vibrations but can also be used for quenching vibrations excited by periodic forces. Methods for analysis of oscillations in strongly damped systems are derived and these tools are then exploited to design a sequential frictionspring for quenching resonance or understand the resonance in systems with inelastic collisions. The positive effect of a parametric combination resonance, the so-called parametric anti-resonance is discussed analytically and numerically for simple 2DOF systems as well as MDOF systems.

The conditions under which a parametric excitation becomes a parametric anti resonance are derived in detail. These conditions allow interpreting the attenuation effect as a modal interaction due to time-periodicity. The major findings are verified experimentally and future application fields are outlined.

This course offers a condensed view on time-periodic systems, their analytical and numerical analysis and avoidance or exploitation of parametric resonances. The underlying theory is explained and applied to simple and real-life engineering examples.

Invited Lecturers:

Jan Awrejcewicz (Lodz University of Technology, Poland), Fadi Dohnal (Ansaldo Energia, Baden, Switzerland), Alexander Fidlin (Karlsruher Institut für Technologie, Germany), Richard Rand (Cornell University, Ithaca, NY, USA), Subhash Sinha (Auburn University, AL, USA), Jon Juel Thomsen (University of Denmark, Bygning, Denmark).

Coordinators: F. Dohnal (Germany), R. Rand (USA)

Meetings and Events

CISM – Marie Curie Graduate School on Smart Structure for Vibro – Acoustic Control

April 18 - 21, 2016

Co-Chairs:

Wim Desmet, (Belgium), Paolo Gardonio (Italy) and Bert Pluymers (Belgium).

ROMANSY 2016, 21st CISM-IFTtoMM Symposium on Theory and Practice of Robots and Manipulators

Udine, June 20 - 23, 2016

Co-Chairs: V. Parenti Castelli (Italy), W. Schiehlen (Germany).

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