Centre International des Sciences Mécaniques
International Centre for Mechanical Sciences

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

PROGRAMME 2014

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 J. Carlos Simo Session

Complex Viscous Flows

May 19 - 23, 2014

Nowadays, many basic applications (separation techniques, biological flows, lab-on-a-chip, protein and DNA dynamics,...) concern micro-scale or nano-scale hydrodynamics. At these scales, the liquid flow is a viscous flow governed by the Stokes equations, since it is essentially driven by the viscous force while the inertial force becomes negligible. In practice, the viscous flow boundary may consist of surfaces of quite different (and even complex) nature such as no-slip or slipping solid or flexible surface of a micro-particle, liquid-gas interface (bubble or free surface), liquid-liquid interface (droplet), bio-membranes (vesicles, capsules).

The aim of this Course is to present examples of modern systems recently in focus of a research study, and the methods developed to efficiently (theoretically and numerically) determine the resulting viscous (Stokes) flow from the prescribed (and not necessarily linear) boundary conditions at the liquid domain boundary.

The Course, addressing doctoral students and young or senior researchers, summarizes the fundamentals of viscous flows and introduces and explains different methods used nowadays to study the challenging dynamics of various micro-objects.

As examples, behavior of the following systems will be discussed: -dynamics of sedimenting swarms of particles and the role of oscillations; -motion and shapes of particles in shear or Poiseuille flows (flexible fibers, capsules, vesicles); -rheology of dilute emulsions; -electro-hydrodynamics with particles in uniform electric field (electro-rheology and instability).

To describe such systems, the following material will be handled: -Stokes equations and fundamental singularity solutions; -3D viscous eddies in a bounded region; -Green tensors (both for a free-space and a few bounded liquid domains); -Related key integral velocity and pressure, representations for a Stokes flow; -Relevant properties of the resulting boundary-integral equations (both for direct and so-called indirect approaches); -Modern and efficient numerical methods for Stokes flow: boundary element method, multipole method, bead model, parallel programming, coupling of a boundary-element technique and a Finite Element Method for non-rigid bodies (capsules); -Different encountered boundary conditions and related current topics such as: linear (Navier) slip condition for slipping particles and/or walls, nonlinear slip condition including thermal creep and mechanical properties (model and characterization) of capsules.

Invited Lecturers:

Maria Ekiel-Jezewska (IPPT, Polish Academy of Sciences, Warsaw, Poland), Henry Power (University Park, Nottingham, UK), Anne-Virginie Salsac (Université de Technologie de Compiègne, France), Osamu Sano (Tokyo University of Agriculture and Technology, Japan), Antoine Sellier (LadHyX, Ecole Polytechnique, Palaiseau, France), Petia Vlahovska (Brown University, Providence, RI, USA).

Coordinators:

A. Sellier (France), O. Sano (Japan).

Collective Dynamics of Particles: from Viscous to Turbulent Flows
COST-ERCOFTAC Training School

May 26 - 30, 2014

Particulate flows are present in many natural and industrial processes. Transport of sediment in rivers and estuaries, convection of pollutants in the atmosphere, bioconvection of zooplankton, gravity and turbidity currents near coastal shore, pyroclastic flows from volcanic eruptions are a few examples that can be encountered in natural phenomena. In industry, processes involving flows of particles are numerous: among others, fluidized bed reactors, the treatment of waste materials in clarifiers, food processing, and ink technologies. In all the above-mentioned instances, proper understanding and accurate modelling of such complex flows are crucial aspects from scientific and engineering perspectives, as they directly impact the environment we live in.

The understanding of such flows is a daunting task for several reasons. The most straightforward is the very large number of particles one needs to account for. Another equally significant difficulty arises from the subtle coupling between particle-particle and particle-fluid interactions: particles have an effect on the fluid flow (and sometimes even drive it) by exerting stresses on the fluid around them, and in turn the fluid flow modifies the motion of the suspended particles. This two-way coupling often makes attempts at comprehending such flows highly difficult, other than in very simplified settings.

Particulate flows have been examined in the past in a wide variety of situations. A very large number of studies have focused on highly viscous flows in which inertial forces can be neglected. This low-Reynolds-number limit is a valid approximation in small-scale systems or very slow flows, and is often justified when the size of the particles involved in the process is small. In many practical applications, however, fluid inertia cannot be neglected owing the large system sizes, even when the suspended particles are small. In some cases, it is of fundamental importance such as in pyroclastic flows or in fluidized bed reactors where the flows are highly turbulent in spite of the microscopic size of the particles involved.

Several studies have focused on the Lagrangian properties of particles in turbulence (e.g. Lagrangian acceleration) to gain further insight on the relevant forces acting on isolated particles. Preferential concentration and clustering effect of inertial particles in a turbulent flow have been also examined in many recent works. However, collective effects in turbulent particle laden flows have been not thoroughly examined and there is a compelling need to provide a robust body of knowledge in this active field of research.

The scope of the course is therefore to provide a state-of-the-art and accessible survey of numerical and experimental approaches as well as modelling tools for the analysis of collective dynamics of particles in flows. The general approach will be made specific through the most tractable analytically case of low-Reynolds flows but will go beyond viscous flows and will tackle inertial and turbulent flows. The course will also cover the two basic avenues for addressing particulate flows, one being discrete particle simulations and the second being continuum two-phase modelling. In the later, the influence of particles is captured through constitutive relations often resulting from simulations or experiments. The most common discrete methods for the description of particle-laden flows, both in the Stokes regime and in the inertial and turbulent regimes, will be presented and discussed. Among the topics to be included are finite-size particles, deformable particles, and particles of different shapes, in particular rod-like particles or fibres whose interest lies in part in the availability of methods for slender bodies as well as in their importance in industrial applications, such as the fabrication of fibre-reinforced materials and of pulp and paper.

The course delivers a comprehensive overview of particulate flows, from low Reynolds numbers to full turbulent flows, and hence will be particularly attractive to graduate students, PhD candidates, young researchers and faculty members in applied physics and chemical-mechanical engineering. The advanced topics and the presentation of current progress in this very active field will also be of considerable interest to many senior researchers, as well as industrial practitioners having a strong interest in understanding the multi-scale complex behavior of such multiphase flows.

Workshop sessions on Tuesday will be chaired by C. Marchioli (University of Udine).

The course will be organized under the auspices of ERCOFTAC and with the support of COST, through Action FP1005 "Fiber suspension flow modeling" and ANR CoDSPiT "Collective dynamics of settling particles in turbulence".

Invited Lecturers:

Gilles Bouchet (Aix-Marseille University, CNRS, France), Michael Bourgoin (University of Grenoble, CNRS, France), Jason Butler (University of Florida, Gainesville, FL, USA), John Hinch (University of Cambridge, UK), Holger Homann (Observatoire de la Côte d'Azur, Nice, France), Martin Maxey (Brown University, Providence, RI, USA).

Coordinators:

G. Bouchet (France), C. Marchioli (Italy).

Extremely Deformable Structures

June 2 - 6, 2014

Traditionally, structures have been designed to work below critical loads, while attainment of an instability was normally identified as connected to failure or, at least, to loss of functionality of the involved structural elements. Therefore, structural deformations under service loads were small, so that instability and bifurcation were viewed simply as potentially dangerous phenomena, a perspective that can be summarized in the word 'buckliphobia'.

Recently, a new research stimulus has derived from the observation that soft structures, such as for instance biological systems, but also rubber and gel, may work in a post-critical regime, where elastic elements are subject to extreme deformations, though still exhibiting excellent mechanical performances.

The possibility of exploiting highly deformable structures opens new and unexpected technological possibilities. In particular, the challenge is the design of deformable and bi-stable mechanisms which can reach superior mechanical performances and can have a strong impact on several high-tech applications, including stretchable electronics, nanotube serpentines, deployable structures for aerospace engineering, cable deployment in the ocean, but also sensors and flexible actuators and vibration absorbers.

The so-called 'extreme mechanics' is an emerging branch of instability of solids and structures aimed at the investigation of instabilities as related to pattern formation and the subsequent large deformation nonlinear behavior, a design approach that can be summarized with the sentence 'joy of buckling'.

We draw the attention on recent results on how to exploit the post-critical path of an

elastic structure to obtain flexible mechanisms with special behaviours: (i.) a spherical shell shrinking towards its center, a problem related to buckling of periodic structures; (ii.) a one-degree-of-freedom elastic structure buckling in tension and compression and providing a constant force ('neutral') post-critical behaviour; (iii.) dynamical instabilities explaining wrapping of a liquid drop by an elastic strip; (iv.) wrinkling of thin films attached to a soft substrate; (v.) folding and deployment of ultrathin shell structures.
Participants will be introduced to a variety of interrelated topics involving the mechanics of extremely deformable structures, with emphasis on bifurcation, instability and nonlinear behaviour, both in the quasi-static and dynamic regimes. Essential and up-to-date theoretical, numerical, and experimental methodologies will be covered, as a tool to progress towards a satisfactory modelling of the nonlinear behaviour of structures. In this way, the course will provide a unique opportunity to learn simultaneously a broad range of subjects and techniques that are a prerequisite to research in the fields of highly deformable structures and thin films, and to the design of deformable mechanisms, adaptive and periodic structures, and stretchable electronics. Finally, it will be shown how the mechanics of highly deformable structures is the key to understanding several phenomena in biomechanics, such as morphogenesis, growth and propulsion.

Invited Lecturers:
Davide Bigoni (Università di Trento, Italy), Basile Audoly (Université Pierre et Marie Curie and CNRS, Paris, France), Katia Bertoldi (University of Harvard, Cambridge, MA, USA), Alain Goriely (University of Oxford, UK), Sébastien Neukirch (Université Pierre et Marie Curie and CNRS, Paris, France), Sergio Pellegrino (California Institute of Technology, Pasadena, CA, USA).

Coordinator:
D. Bigoni (Italy).

Topology Optimization of Structures and Continua – Computational Aspects and Background

June 9 - 13, 2014

Structural Topology Optimization is a relatively new, but rapidly expanding and extremely popular field of structural mechanics. Various theoretical aspects, as well as a great variety of numerical methods and applications have been discussed extensively in international journals and at conferences. At the last three World Congresses of Structural and Multidisciplinary Optimization, the ratio of papers on topology optimization was about 40, 40 and 50 per cent. The ratio has been similarly high in the journal Structural and Multidisciplinary Optimization (Springer). Such a level of interest in this field is due to the substantial savings that can be achieved by topology optimization in industrial applications. Moreover, structural topology optimization has interesting theoretical implications in mathematics, mechanics, multi-physics and computer science.
The present proposal is for the fourth CISM Advanced Course on Structural Topology Optimization. The previous courses (1992, 1997 and 2012) were organized by the proponent of this one (Rozvany), the 2012 course jointly with T. Lewinski. Whilst the Advanced Course in 2012 mostly dealt with theoretical issues and exact analytical solutions, the present one is aimed at covering numerical (discretized) methods and computational aspects of structural topology optimization, including the mathematical

background of these methodologies. Consequently, there is no overlap between the two courses. Numerical methods are more directly applicable to practical problems in the industry. Each of the lecturers is a leading specialist in some aspects of numerical topology optimization, including the most eminent researcher in the field, Prof. Sigmund. All invited lecturers are full professors at prestigious universities in Europe or the USA.
In an introductory lecture, the organizer (Rozvany) will explain the connections between exact analytical methods (reviewed in the 2012 course) and discretized, numerical algorithms, discussing the relative importance of both. Analytical solutions are extremely useful as reliable benchmarks for checking on the validity, convergence and accuracy of numerical solutions. Moreover, many numerical algorithms are actually discretized versions of exact analytical methods.
The 2012 course was highly successful in terms of the number of participants, but the one proposed for 2014 should be of even greater interest to researchers and practitioners in the field. The main topic of the 2014 course is planned to be topology optimization of structures, i. e. stressed systems consisting of solids, but several lecturers (Profs. Sigmund, Maute and Paulino) intend to discuss problems concerning fluids, photonics, and also multi-physical applications.
It is proposed that the mathematical background of topology optimization methods will be explained by a top mathematician in the field, Prof. Svanberg, who has created the most efficient, and therefore most popular, non-linear programming method (MMA) of structural optimization (and of topology optimization in particular). Other aspects of the mathematical background will be reviewed by Prof. Duysinx, who will also look at particular classes of topology optimization problems (e. g. stress-based, eigenvalue type, multi-body and discrete material problems). Various techniques of numerical topology optimization, including density based (SIMP) and Level Set methods, as well as filtering, robust formulations and advanced discretization techniques will be reviewed in depth by Profs. Sigmund and Maute. Polygonal discretization and multi-resolution topology optimization, with applications in solid and fluid mechanics, will be discussed in detail by Prof. Paulino, who will also show applications in architecture and medicine.
The advanced school is addressed to Ph.D. students and post-doctoral scholars in engineering, mathematics, computer-science and multi-physics, their supervisors, as well as practicing engineers and senior researchers.

Invited Lecturers:
Ole Sigmund (Technical University of Denmark, Lyngby), Kurt Maute (University of Colorado at Boulder, CO, USA), Krister Svanberg (Royal Institute of Technology, Stockholm, Sweden), Pierre Duysinx (University of Liege, Belgium), Glaucio H. Paulino (University of Illinois at Urbana-Champaign, Urbana, IL, USA), George I.N. Rozvany (Budapest University of Technolgy and Economics, Budapest, Hungary).

Coordinators:
G.I.N. Rozvany (Hungary), G.H. Paulino (USA).

Mechanobiology of Cells and Tissues: Motility and Morphogenesis

June 16 - 20, 2014

The role of Mechanics in governing key biological processes at the cell scale is becoming increasingly apparent. At the triple point between biology, biophysics, and mechanics, Mechanobiology is emerging as a new, thriving research field, that is attempting to understand Biology from the perspective of Mechanics. And while the key role played by bio-chemical regulation in molecular cell biology is undisputed, the importance of forces and stresses in determining how cells function is becoming more and more widely recognized. Forces control shape and motion of the cells. But also how cells decide when and how much to differentiate (e.g., depending on the stiffness of the substrate or of the surrounding extracellular matrix), and where cells migrate to (mechano-sensing). Unveiling the details of this mechano-transduction opens the way to understanding key biological process at the cell scale.

In addition, forces define much of the organization of the cells, hence they are important at the tissue and organ level, and are being used to drive artificially grown tissues in tissue engineering. Finally, many pathologies such as atherosclerosis, cancer, neurological and developmental deseases can be traced to abnormal mechanics.

Cell motility provides one concrete example where Mechanics is shaping our understanding of key biological processes. Depending on whether the surrounding medium is a fluid or a solid (a matrix or a substrate), cells move either by swimming or by crawling. Mechanics is the natural tool to estimate the forces cells need to exert and the power to spend in order to move as we see them moving. Quantitative analysis of swimming of unicellular organisms, in which experimental observations are compared with numerical simulations of fluid flows, is shedding light on the observable strokes, their efficiency, the underlying mechanisms, and metabolic requirements, with important consequences from the point of view of evolution.

More generally, Mechanics is providing us with a conceptual framework to go beyond the identification of the molecular components and their individual function, by integrating them into a comprehensive understanding of cell motion and migration, of cell and tissue morphogenesis. The course will survey recent advances in the fields of cell motility and mechanobiology of cells and tissues, emphasizing such an integrative approach.

Topics covered in the course will include the mechanics of cell motility by swimming and crawling, fluid-structure interaction problems in the modeling of individual and collective behavior of unicellular swimmers, synchronization effects, discrete and continuous models of the mechanics of the cytoskeleton, morphogenesis of cells and tissues and dynamics of their growth, mechanics of biological membranes and of active surfaces, design and engineering of bio-inspired motile artifacts. Both theoretical aspects (mathematical and computational modeling) and recent experimental findings will be surveyed.

The Course will consist of 12 introductory lectures by the organizers, and 24 lectures on more specialized topics given by four among the most eminent experts in the field.

The course is addressed to doctoral students, young researcher, senior researchers, practicing engineers and technologists.

Invited Lecturers:

Antonio De Simone (SISSA, Trieste, Italy), Marino Arroyo (Universitat Politecnica de Catalunya, Barcelona, Spain), Daniel Fletcher (University of California, Berkeley, CA, USA), Ray Goldstein (DAMTP, Cambridge, UK), Frank Jülicher (Max Planck Institute for the Physics of Complex Systems, Dresden, Germany), Ewa Paluch (MRC-LMCB, University College London, UK).

Coordinators:

A. De Simone (Italy), M. Arroyo (Spain).

Flowing Soft Matter: Bridging the Gap Between Statistical Physics and Fluid Mechanics

June 30 - July 4, 2014

Polymer solutions, colloidal suspensions, emulsions, gels, granular matter, biological materials such as the cytoskeleton, bacterial suspensions, and cellular tissues are all complex materials lying at the interface between fluids and soft solids. Their mechanical properties result from the subtle interplay between their microstructure at the mesoscales, and the forces driving the flows either at the macroscale (e.g. sheared, and advected fluids) or at the microscale (e.g. thermal fluctuations, or local self-propulsion).

Much research efforts have been devoted to understand the flow properties of these soft materials, in fields as diverse as soft-condensed matter physics, biophysics, materials science, chemical and mechanical engineering. Two main complementary descriptions have emerged in these different communities: on the one hand, these complex fluids can be described as continua using the equations of fluid mechanics with phenomenological constitutive laws; on the other hand, they can also be described using non-equilibrium statistical physics. In this context the constitutive laws and the mesoscale fluctuations are accurately described, but only yield minimalistic mechanical models. Both approaches have their merits, and their combination has proven to yield outstanding advances in the understanding of the large-scale mechanical properties of some complex systems such as polymeric fluids. However, over the last 20 years, interactions between the fluid-mechanics, soft-condensed-matter and statistical-physics communities have been scarce.

The objectives of this Summer School are twofold: first, present the participants with an overview of the exciting field of flowing soft matter, with focus on a few topics of active research interest; second, reconcile the statistical-physics and fluid-mechanics descriptions of these systems, by bringing together lecturers from both communities to discuss similar problems from the perspective of their own discipline.

The contents of the School will articulate around three main themes: (1) Fluctuations at all scales in Viscoelastic Fluids, (2) Mechanics and Structure of Active Fluids, (3) Flows and Arrest in Dense Suspensions and Granular Materials.

These themes have been selected to reflect current interests in soft-matter research, while being distinct enough from one another to provide a broad and general introduction of the field to the participants. Our purpose is to provide the Summer School participants with two complementary lectures on each theme: two researchers of different backgrounds will give 5 lectures each on a subject related to their research interests.

The targeted audience for this Summer School will be advanced PhD students as well as postdoctoral researchers in departments of Physics, Biophysics, Engineering, and Materials Science. The participants are also invited to give a short oral presentation on their research.

Invited Lecturers:

Alexander Morozov (University of Edinburgh, UK), Todd Squires (University of California, Santa Barbara, CA, USA), Davide Marenduzzo (University of Edinburgh, UK), David Saintillan (University of California San Diego, La Jolla, CA, USA), Olivier Pouliquen (IUSTI, Polytech Marseille, France), Matthieu Wyart (New York University, NY, USA).

Coordinators:

D. Bartolo (France), D. Saintillan (USA).

Cavitation Instabilities and Rotordynamic Effects in Turbopumps and Hydroturbines

July 7 - 11, 2014

The attainment of higher power densities in modern hydraulic turbomachinery is invariably obtained by running the impeller at the maximum allowable speed and lower shaft torque. Therefore, operation under cavitating conditions with lighter – but also more flexible – shafts is often tolerated especially in space propulsion applications, exposing the machine to the onset of dangerous self-sustained, cavitation-induced fluid dynamic and rotordynamic instabilities. Since these phenomena actually represent the major source life and reliability degradation of the machine, fundamental information on their nature and behavior is of crucial importance for the effective design of today's high-performance hydraulic turbomachinery. However, the extreme complexity and imperfect understanding of the phenomena involved pose formidable obstacles to the modeling, prediction and control of cavitation-induced instabilities. For this reason, nowadays theoretical analyses and simulations alone are still of limited value for the solution of specific technical problems and progress in this field must rely on the support of dedicated experimentation.

The objective of the course consists in providing the participants with a detailed approach to the physics, fluid dynamics, modeling, experimentation and numerical simulation of cavitation phenomena, with special emphasis on cavitation-induced instabilities and their implications on the design and operation of high performance turbopumps and hydraulic turbines. To this purpose the first part of the lectures will cover the fundamentals (nucleation, dynamics, thermodynamic effects, erosion) and forms of cavitation (attached cavitation, cloud cavitation, supercavitation, vortex cavitation) relevant to hydraulic turbomachinery, discuss the physical mechanisms and occurrence of cavitation erosion phenomena, illustrate modern experimental techniques for the characterization, visualization and analysis of cavitating flows, and introduce the main aspects of the hydrodynamic design and performance of axial inducers, centrifugal turbopumps and hydo-turbines. The second part of the lectures will focus on the theoretical modeling, experimental analysis, and practical control of cavitation-induced fluid-dynamic and rotordynamic instabilities of hydraulic turbomachinery, with special emphasis on cavitating turbopumps (cavitation surge, rotating cavitation, higher order cavitation surge, rotordynamic whirl forces). Finally, the third part of the course will illustrate the alternative approaches for the simulation of cavitating flows, with emphasis on both modeling and numerical aspects. Examples of applications to the simulation of unsteady cavitation in internal flows through hydraulic machinery will be illustrated in detail.

The lecturers will use the background information to introduce the major topics currently open for cavitation research and stimulate the active participation of the audience by presenting and discussing original findings and results in their areas of expertise. The course is addressed to doctoral/postdoctoral students, researchers, scientists, scholars and professionals from universities, research institutions and industries active in aerospace, mechanical, hydraulic, naval and chemical engineering, applied mechanics, applied mathematics, industrial chemistry and applied physics, who are interested in perfecting their knowledge and understanding of cavitating flow phenomena and research in wide range of engineering applications.

The aim of the Workshop session is to provide an overview of state of the art models and numerical methods for the simulation of cavitating flows with a more fundamental ND broader perspective than the SPECIFIC application to turbopumps and hydroturbines.

Invited Lecturers:
François Avellan (EPFL, Lausanne, Switzerland), Steven Ceccio (University of Michigan, Ann Arbor, MI, USA), Jean-Pierre Franc (LEGI, Grenoble, France), Luca d'Agostino (Università di Pisa, Italy), Maria Vittoria Salvetti (Università di Pisa, Italy), Yoshinobu Tsujimoto (Osaka University, Japan), Eric Goncalvès (LEGI, Grenoble, France), Richard Saurel (Aix-Marseille Univ. and University Institute of France, France).

Coordinators:
L. d'Agostino (Italy), M.V. Salvetti (Italy).

Structure and Multiscale Mechanics of Carbon Nanomaterials

July 21 - 25, 2014

Carbon nanomaterials play a key role in modern energy storage devices such Lithium-ion batteries, super capacitors, or fuel cells; they are thought to have the potential to revolutionize electronics by at least partly replacing silicon technology by carbon technology; and most importantly in the present context, they have extraordinary mechanical properties. The strong covalent bonding between sp^2 hybridized carbon atoms leads to materials with unsurpassed stiffness and strength. Graphene is known to be the strongest material ever tested with a tensile strength 200 times greater than that of steel and a tensile modulus beyond 1000 GPa. Although the graphene hammock carrying a whole cat is still a rather theoretical concept, there are already many potential mechanical applications envisaged with this unique material. Similar prospects hold also true for its rolled-up versions in 1D (nanotubes) and 2D (fullerenes). Beside these "modern" highly ordered carbon nanomaterials, there exist a broad variety of more disordered carbons with properties which are also largely determined by their nanostructure. From crystalline graphite to fully amorphous (glassy) carbon, a whole continuum of partly disordered, defect rich materials such as carbon (nano) fibers, carbon black, activated carbons, etc. are widely used in diverse applications and they are continuously improved. Modern carbon fibers for instance almost reach the tensile modulus of graphene, and their tensile strength can be more than 6 GPa, which is yet an order of magnitude larger than that of a typical steel. These outstanding mechanical properties of carbon materials are not only useful for structural applications (e.g. in composites), they are also of critical importance for the mechanical integrity of essentially all functional devices based on them.

This CISM course aims at providing a broad overview on the relationship between structure and mechanical properties of carbon nanomaterials from world-leading scientists in the field. The main goal is to get an in-depth understanding of the exceptional broad range of mechanical properties of carbon materials based on their unique nanostructure and on defects of several types and at different length scales. For instance, in basically sp^2 bonded carbons the role of curvature as well as in plane defects (e.g. 5-ring structures in fullerenes, 5-7-ring structures known as Stone-Wale defects, etc.), and out-of-plane "covalent" cross-links between graphene planes are known to strongly influence their mechanical behavior. In larger structures such as carbon fibers, not only such atomic defects, but also the preferred orientation and the cross-sectional texture of multilayer-graphene crystallites, as well as their size and anisotropy are responsible for a wide range in stiffness and strength under tensile and compressive loads. The main goal of the present CISM course is to provide a comprehensive and modern view on how targeted design of carbon based materials with specific mechanical properties can be reached by controlling nanostructure and defects at several scales of hierarchy.

The course will cover a broad range of nanomaterials such as graphene, single-wall- and multi-wall carbon nanotubes, fullerenes, carbon onions, nanodiamonds, carbon fibers, mesoporous carbons etc... One particular focus will be on the multiscale modeling of mechanical properties of such materials using ab-initio DFT calculations (including van der Waals interactions), atomistic simulations with Molecular Dynamics (MD) and Monte Carlo (MC) methods, as well as continuum mechanical approaches. Experimental lectures will cover many aspects of carbon nanostructures, such as their synthesis, their structure at several length scales, their mechanical properties, and their application potential in diverse fields. Special emphasis will be put on sophisticated experimental methods to assess the relationships between structure and mechanical properties at different scales. Micro- and nanomechanical testing, advanced Raman scattering, and X-ray scattering using microbeam synchrotron radiation are among the techniques that will be covered in the course. Moreover, in-situ mechanical testing in combination with the above and other techniques will be considered. Besides the many carbon nanomaterials themselves, the course will also include composites with these materials as reinforcing fibers or nanoparticles.

The course should be of particular interest for PhD students and Postdocs working in a specific field of carbon nanomaterials and/or –nanocomposites to widen their horizon beyond their specific topic. Materials scientists, physicists and chemists are the attendees particularly expected, but the course might also be of interest for mechanical and electrical engineers, and for researchers working in the fields of nanotechnology and biomedical engineering. Although the basic concepts will be covered by introductory lectures, it is expected that the attendees have at least some basic knowledge on mechanical concepts and on the physics of nanomaterials.

Invited Lecturers:
Oskar Paris (Montanuniversität Leoben, Austria), Claudia Draxl (Humboldt Universität Berlin, Germany), David Dunstan (Queen Mary, University of London, UK), Siddhartha Pathak (Los Alamos National Laboratory, NM, USA), Markus Hartmann (Montanuniversität Leoben, Austria), Bob Young (University of Manchester, UK).

Coordinator:
O. Paris (Austria).

The D. Howell Peregrine Session

Electrospinning: Exploiting Electrohydrodynamics and Rheology for the Control of Nanofiber Structural and Physical Properties

September 1 - 5, 2014

Preparation of quasi-one dimensional organic and inorganic structures, which are functionalized via a structuring process presenting itself on the submicrometer scale, is currently the focus of intense research activities both in fundamental and applied science. Depending on the application of interest, three-dimensional systems (photonic band gap, or scaffold for tissue engineering), two-dimensional systems (quantum well structures), or one-dimensional systems (quantum wires), reduction of the typical structure scale into the nm-range gives rise to a set of favorable properties including increased surface-to-volume ratio, variations in wetting behavior, modifications of thermodynamic properties, or significantly decreased concentrations of structural defects (which could enhance the strength) on the structure surface.

Electrospinning poses a unique means of producing quasi-one-dimensional structures such as fibers with a diameter in the range of 100 nm or even smaller. To this end, polymer solutions, liquid crystals, suspensions of solid particles and emulsions, are electrospun in an electric field of about 1 kV/cm. The electric force results in an electrically charged jet of polymer solution flowing out from a pendant or sessile droplet. After the jet flows away from the droplet in a nearly straight line, it bends into a complex path, whereupon other changes in shape occur, during which electrical forces stretch and thin it by very large ratios. After the solvent evaporates, birefringent nanofibers are obtained.

The aim of this lecture series is to present the state of the art in electrospinning modeling and the related process of electrospraying. The critical parameters affecting fiber structures and the relation between electrohydrodynamics, polymer rheology and microstructure formation will be addressed. The lectures will also discuss the morphology and molecular/supermolecular structure of the electrospun polymer nanofibers, and the experimental methods of molecular/ supermolecular structure analysis. This will be followed by the exploration of a number of typical properties of polymer nanofibers such as: elastic modulus and strength enhancement, melting temperature, and glass transition temperature shift, and crystallization on nanoscales. Special electrospinning processing techniques to achieve medically applicable materials will be presented, with focus on biodegradable-electrospun matrices, and encapsulation for the release of drugs.

The target audience is graduate students, PhD candidates and young faculty members. We expect an audience as diverse in background as the lecturers, that is to say spanning across the professional spectrum from mechanical, materials and biomedical engineers, to physicists.

Invited Lecturers:
Alexander L. Yarin (University of Illinois at Chicago, IL, USA), Ignacio G. Loscertales (The University of Malaga, Spain), Eyal Zussman (Technion, Haifa, Israel), Asa H. Barber (University of London, UK), Pawel Sajkiewicz (Institute of Fundamental Technological Research, Polish Academy of Sciences, Warsaw, Poland), Erhan Piskin (Hacettepe University, Ankara, Turkey).

Coordinators:
P. Sajkiewicz (Poland), E. Zussman (Israel).

Ferroic Functional Materials: Experiment, Modeling and Simulation

September 8 - 12, 2014

Functional materials play a key role in many modern technical devices ranging from consumer market items to applications in high-end equipment for automobile, aircraft and spacecraft, military, and information technology. Among functional materials, smart materials represent a class that transforms one basic physical property into another. The development of devices utilizing smart materials, as well as their testing, are generally very expensive. Therefore, considerable effort has been made to develop modeling tools that allow bypassing many of the experimental steps previously required in design.

The most important smart materials are certainly ferroelectrics (coupling between polarization and strain), ferromagnets (coupling between magnetization and strain), shape- memory alloys (coupling between temperature and strain), and the recently discovered magneto-electric multiferroics (coupling magnetization and polarization).

In particular, magnetoelectric multiferroics, that combine the mutual controllability of magnetic and electric state variables in one single material, are of the greatest interest in the development of multifunctional devices devoted to new advanced applications. In single-phase multiferroics, on the other hand, the interaction between the magnetic and electric fields is generally weak and, consequently, composite materials consisting of ferroelectric and ferromagnetic phases become relevant. The experimental preparation and characterization of composite materials, as well as their constitutive description based on homogenization strategies, are key challenges for the optimization of such magneto-electric composites. Furthermore, the coupled and non-linear behavior of the individual phases, as well as their interactions, have a significant impact on the overall performance of the composite material.

The development of new multifunctional devices made from ferroics is based on a comprehensive understanding of both the experimental and theoretical details of these materials. Thus, the lectures will cover experiments and theory in the fields of ferroelectrics, ferromagnets, ferroelastics, and multiferroics. The range of topics covered will include experimental preparation and characterization of magneto-electric multiferroics, the modeling of ferroelectric and ferromagnetic materials as well as of shape-memory alloys, the formation of ferroic microstructures and their continuum-mechanical modeling, computational homogenization, and the algorithmic treatment in the framework of numerical solution strategies.

The course is addressed to doctoral students and postdoctoral researchers in civil and mechanical engineering, materials science, physics and applied mathematics as well as industrial researchers. After the course participants will have a basic knowledge in experiments and theory in the framework of ferroic materials. A main focus will be on state-of-the-art experimental methods and advanced modeling techniques. These notions are essential to qualify young scientists for high-quality research and the development of innovative products and applications. Up to now, there are neither adequate textbooks nor advanced courses at research- or university-level available in this field. Thus, the aim of this CISM course is to fill such a gap and we are convinced that it will be successful in doing this.

Invited Lecturers:

Kaushik Bhattacharya (California Institute of Technology, Pasadena, CA, USA), Manfred Fiebig (ETH Zurich, Switzerland), John Huber (University of Oxford, UK), Doru C. Lupascu (University of Duisburg-Essen, Germany), Christopher Lynch (University of California, Los Angeles, CA, USA), Jörg Schröder (University of Duisburg-Essen, Germany).

Coordinators:

J. Schröder (Germany), D.C. Lupascu (Germany).

Shell-like Structures: Advanced Theories and Applications

September 15 - 19, 2014

Shell-like structures are widely used in engineering as basic structural elements. Such structures are also used in other branches of science as a model of analysis, e.g., in medicine, biology, nanotechnology, etc. New applications are primarily related to new materials - for example instead of steel or reinforced-concrete shells, now one has to analyze laminates, foams, functionally graded materials, shape-memory thin films, fullerenes, nanofilms, biological membranes, soft tissues, etc. The new trends in applications demand for improvements in the theoretical foundations of shell theory, since new effects must be taken into account. For example, surface effects play an important role in the mechanical analysis of small-size shell-like structures (thin films, multi-walled nanotubes, …). Furthermore, all theoretical achievements must be supplemented by the development of consistent numerical tools.

The aim of this course is to present not only the mathematical aspects of the theory of plates and shells but also their applications in civil, aero-space and mechanical engineering, as well as in other emerging research areas. The focus of the course relates to the following problems: -comprehensive review of the most popular theories of plates and shells; -relations between three-dimensional theories and two-dimensional ones; -presentation of recently developed refined plate and shell theories such as for example, micropolar theory or gradient-type theories; -applications in modeling of complex structures (multi-folded, branching and/or self-intersecting shells, plates and shells made of foams, functionally graded materials, etc.); -modeling of coupled effects in shells and plates related to electromagnetic and temperature fields, phase transitions, diffusion, etc.; -applications in modeling of non-classical objects, such as thin and nanofilms, nanotubes, and nanoparticles and biological membranes; -presentations of effective numerical tools based on finite elements approach.

The course is addressed to doctoral students, young researcher, senior researchers and practicing engineers in mechanical engineering, civil engineering, aerospace engineering and mathematicians.

Invited Lecturers:

Holm Altenbach (Otto-von-Guericke-University Magdeburg, Germany), Victor A. Eremeyev (Otto-von-Guericke-Universität Magdeburg, Germany and South Federal University and South Scientific Center of RASci, Rostov-on-Don, Russia), Gennady Mikhasev (Belarusian State University, Minsk, Belarus), Paolo Podio-Guidugli (DICII, Università di Roma Tor Vergata, Italy), Karam Sab (IFSTTAR, Marne-la-Vallée, France), Krzysztof Wisniewski (IPPT Polish Academy of Sciences, Poland).

Coordinators:

H. Altenbach (Germany), V.A. Eremeyev (Russia).

Singular Configurations of Mechanisms and Manipulators

September 22 - 26, 2014

Motivation and Aims

In singular configurations, the kinetostatic properties of mechanisms undergo sudden and dramatic changes. Hence the enormous practical value of singularity analysis for manipulator design and use. Its theoretical importance stems from the critical role singularity plays in algebraic geometry and in the theory of differentiable mappings. Attendees will be introduced to milestone results, key methods, and main problems in singularity analysis. The lectures provide an overview of cutting-edge work and focus on a few advanced topics.

Main Themes

Definition. Given the importance of kinematic singularity and the vast literature on the subject, it may be surprising that one rarely encounters a clear general definition of the phenomenon. To provide one is the course's first objective: singularity is defined rigorously and in simple terms.

Classification. Numerous singularity classifications exist. Since singularity is defined via instantaneous kinematics, the most fundamental taxonomy describes the types of degeneracy of the forward and inverse velocity problems. Finer distinctions exist for specific mechanism types, e.g., the important constraint singularities of parallel manipulators. When non-instantaneous properties are considered, other distinctions arise, such as between cusp-like and fold-like singularities, or the existence of self-motions.

Identification. One of the most practically-important problems of kinematic analysis is the explicit calculation of the singularity set. Two general methods using numerical partitioning of the ambient parameter space are outlined. A powerful approach for formulating and solving symbolically the algebraic equations of the end-effector's motion-pattern and singular-poses set is studied in detail.

Avoidance. The course explores the possibility of a singularity-free workspace and the ability to escape from singularity, issues of major practical importance for the design of path planning algorithms and singularity consistent control schemes.

Singularity-set and configuration-space topology. The singularity-free-connectivity properties of the configuration space are discussed, including the fascinating cuspidal manipulators, able to change posture while avoiding singularities. Related fundamental problems of genericity and configuration-space and singularity-set topology are explored. We examine the possibility of multiple operation modes, sometimes with strikingly different platform motion patterns, connected by constraint singularities.

Mathematical tools and formalisms. The course is a hands-on introduction to the various analytical and computational tools for dealing with singularities. We explore screw-geometrical techniques and Lie-group-based local-analysis methods. Algebraic-geometry formulations combined with either symbolic computation or numerical methods (linear relaxations and interval analysis) are used. Topology and differential geometry provide the basis for the definitions and formulations throughout the course.

Invited Lecturers:

Dimiter Zlatanov (Università di Genova, Italy), Manfred Husty (University of Innsbruck, Austria), Jean-Pierre Merlet (INRIA, Sophia Antipolis, France), Philippe Wenger (IRCCyN, CNRS and École Cent, de Nantes, France), Andreas Müller (Shanghai Jiao Tong University, China).

Coordinators:

D. Zlatanov (Italy), A. Müller (China).

Advanced Finite Element Technologies

October 6 - 10, 2014

Advanced finite element technologies are essential for the solution of almost all problems in computational mechanics. Many engineering and mathematical approaches of novel finite element methods were developed in recent years in order to improve the capabilities and the reliability of numerical simulations.

One of the great attractions of the finite element method is its enormous range of applicability. Beside the classical application areas like mechanical, aerospace or civil engineering, also fields like e.g. physics, biology and medicine use the manifold possibilities of this method. New materials, technologies or production methods and the optimization of products and components make great demands on the quality and performance of numerical methods for the solution of the arising, mainly nonlinear, problems. These demands led to many interesting developments in a wide field of finite element methods, e.g. (adaptive) mixed and enhanced finite element methods as well as stabilized or discontinuous Galerkin schemes. Their application often aims at improved or robust discretizations that are superior to standard finite element methods, which often do not provide reliable solutions for nonlinear problems, and, sometimes, collapse completely.

The objective of the course is to present an overview of the state of research of advanced finite element technologies. The course will cover some of the most important application areas in modern element technologies ranging from element development in engineering to mathematical analysis. The audience is introduced into new methods and technologies under consideration of efficiency, robustness and performance.

Therefore, the challenging discretization methods will be developed and fundamental mathematical analysis for reliable simulations will be discussed. The special topics of the course are mathematical foundations for variational formulations, a deep mathematical understanding of the analytical requirements of modern FEM approaches for finite deformations and related adaptive strategies, incompressible, isotropic or anisotropic material behavior, the mathematical and numerical treatment of the well-known locking phenomenon and domains with oscillating coefficients. Furthermore, new results within the finite element development and discretization schemes for the adequate approximation of all process variables in nonlinear engineering applications under consideration of extreme cases will be discussed.

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 the topic. After the course participants will have a basic knowledge of advanced mixed Galerkin FEM, least-squares FEM, discontinuous Galerkin methods, mathematical analysis (e.g. convergence, ellipticity and coercivity, algebraic interpretation and modern adaptive strategies) as well as formulations and applications of these methods to finite (in-)elastic problems. The course is a must for all that are interested and/or involved in advanced finite element technologies.

Invited Lecturers:

Ferdinando Auricchio (Università di Pavia, Italy), Antonio Huerta (Universitat Politècnica de Catalunya, Spain), Daya Reddy (University of Cape Town, South Africa), Jörg

Schröder (Universität Duisburg-Essen, Germany), Gerhard Starke (Universität Duisburg-Essen, Germany), Peter Wriggers (Leibniz Universität Hannover, Germany).

Coordinators:
J. Schröder (Germany), P. Wriggers (Germany).

International Advanced Professional Training

Advances in Medium and High Temperature Solid Oxide Fuel Cells Technology

July 14 - 18, 2014

The course will cover the fundamentals of solid oxide fuel cells exposing students to relevant topics in materials science, thermodynamics, and fluid mechanics. The final aim is that of highlighting cutting-edge research priorities and discussing the state of the art developments in this field. Contents will be divided into two main sections:
1. Fuel cell fundamentals and materials; 2. Cell systems design and applications.
Fundamentals of medium and high temperature fuel cells (Solid oxide fuel cell, SOFCs) will be discussed with emphasis placed on different aspects of solid-state electrochemistry and on physical and physicochemical properties of electrode and electrolyte materials.
Principle and advances of main diagnostic techniques will also be briefly presented. The second part of the course will present the various types of stack design that have been developed and tested in recent years. In class, students will also learn the principle of mathematical modeling addressed to FC systems and processes optimization.
To conclude, potential and current application areas of SOFC systems will be explored.
Lecture topics include: -Introduction to fuel cell technology; -Current R&D issues on medium/high temperature Solid Oxide Fuel Cells (SOFCS); -Electrochemistry of medium/high temperature fuel cells and electrolysers; -Transport phenomena in fuel cells; -Fuels for medium/high temperature fuel cells and catalysis issues; -Direct conversion of fuels; -Cell components: materials, properties and challenges; -Diagnostic methods and performance evaluation; -Advances in electrocatalysis, diagnostics and durability; -Introduction to fuel cell modeling; -Cell and stack design; -System concepts and balance of plant components.
The school will draw on the knowledge and expertise of a group of internationally renowned scientists currently working at the cutting edge of fuel cell R&D with University or with FC enterprises operating on the market.
The course is designed for MSc-students, PhD-students, and Post-Doctorate researchers with a background in chemistry, physics and chemical engineering etc.
The classes are also aimed at experienced researchers and professionals whose expertise lie in other fields and are looking to enter the field of fuel cells and expand their knowledge on medium and high temperature fuel cell.
Participants to the course may also be interested in attending the workshop on “Fundamentals and Applications of Cerium Dioxide in Catalysis”, to be held in the same location the weekend before (Udine, Palazzo del Torso, July 11th-14th).

Please, refer to http://ceria.cism.it/ and http://www.cism.it/courses/E1402/ for the program and further information.
The school will take place under the auspices of University of Udine and with the endorsement of GRICU (Chemical Engineering University Group).

Invited Lecturers:
Raymond Gorte (University of Pennsylvania, Philadelphia, PA, USA), Massimo Santarelli (Politecnico di Torino, Italy), Panagiotis Tsiakaras (University of Thessaly, Volos, Greece), Robert Steinberger-Wilckens (University of Birmingham, UK), Mogens Mogensen (Technical University of Denmark, Roskilde), Subhash C. Singhal (Pacific Northwest National Laboratory, Richland, WA, USA).

Coordinators:
M. Boaro (Italy), A. Aricò (Italy).

Seismic Safety Assessment and Design of Industrial Plants Under Accident Conditions

October 13 - 17, 2014

The current worldwide situation of industry concerning natural events, e.g. earthquakes, is particularly critical. This is clearly demonstrated by the consequences of serious accidents caused by natural events to industrial plants (Na-Tech events), particularly in the chemical and oil processing industries. Consequences include the release of the hazardous materials (fires, explosions), human injuries and the increasing of overall damage to nearby areas, proving this to be a key emerging risk issue. In fact, industrial accidents triggered by natural events, like earthquakes, have been recognized to be the cause of about 5% of accidents with the release of hazardous substances. Earthquakes can cause severe damages to industrial plants and more in particular in process industry, initiating major accidents, as clearly shown in several events. The main reason is that process plants are complex systems, and this complexity, owing to numerous connections and components renders them particularly vulnerable to earthquakes.
Among process industry, chemical oil and gas plants, installed in several European countries, even in significantly earthquake-prone areas, are particularly vulnerable to seismic action. Risk associated with earthquakes has been either considered by some countries similar to the special risk of nuclear power plants - with the need of a probabilistic risk analysis for seismic hazard and plant components/systems and justifications by owners about the maintenance of safety functions in the case of operating basis earthquakes - or considered as normal risk, for which standard spectra and plastic analysis - compatible with the safety function of plant components/ systems - can be used.
The principal aim of these lectures is twofold: 1) to quantify the actual risk of potentially dangerous petrochemical and process plants in order to ensure a uniform level of earthquake protection of structures/plant components; 2) to train groups of PhD students, post docs and experienced researchers to provide them with a considerably wider understanding of a framework for probabilistic earthquake loss estimation. In order to do this, we will have to integrate cutting-edge research from the fields of non-linear dynamics, stochastic analysis, dynamic substructuring and advanced dynamic testing. The course will provide different techniques and tools in order to analyse,

design and assess chemical and process plants.

The course intends to train PhD students, post docs and experienced researchers, to provide them with a considerably wider understanding of a framework for probabilistic earthquake loss estimation.

Invited Lecturers:
Oreste S. Bursi (Università di Trento, Italy), Spyros A. Karamanos (University of Thessaly, Volos, Greece), Benno Hoffmeister (University of Technology, Aachen, Germany), Fabrizio Paolacci (Università di Roma3, Roma, Italy), Ioannis Politopoulos (Commissariat a l'Energie Atomique et aux Energies Alternatives, Saclay, France), Tomoyo Taniguchi (Tottori University, Japan).

Coordinators:
O.S. Bursi (Italy), S.A. Karamanos (Greece).

20th CISM-IUTAM International Summer School

Multiscale Mechanobiology of Bone Remodeling and Adaptation

June 23 - 27, 2014

Bone is a dynamic living tissue that has the ability to change its mass and structure in response to changes of the biomechanical and biochemical environment in which it operates. In the adult skeleton, bone is continuously being resorbed and reformed, both to maintain mineral homeostasis and to repair microcracks that occur in the bone as a consequence of cyclic loading incurred during daily activities like walking, cycling and running. The fundamental unit process that regulates bone mass and structure occurs within the Bone Multicellular Unit (BMU) which is a highly coordinated system of several cell types actively "turning over" or remodeling the bone matrix. Unbalanced regulation of bone resorption and bone formation during BMU operation lies at the root of many bone diseases, including osteoporosis, so an understanding of the interactions of bone cells and structural components in bone is central to understanding the cause of bone diseases and their effective treatments. The majority of bone diseases, including osteoporosis, Paget's disease, and cancer related bone diseases, are characterized by an increase in osteoclast formation due to activation of bone resorptive pathways, leading to bone loss and ultimately to bone fractures.

Bone is a hierarchical material comprised of macroscale units such as trabecular struts and plates and osteons, which are a microscale composite of hydroxyapatite-like crystals and collagen. The integrity of bone is maintained at each scale by homeostatic feedback processes regulated by bone cells. These processes act across large length and time scales, so interpretation of experimental data can be complex. Furthermore, latest bone biology research has shown that bone interacts with a variety of other tissues including muscles, cartilage and the central nervous system. Developing multiscale computational approaches together with experimental data obtained from latest imaging technologies makes it feasible to integrate and then interrogate these feedback processes. A major aim of this workshop is to present state-of-the-art developments in multiscale modeling and latest experimental data on multiscale mechanobiology of

bone remodeling and adaptation including fracture healing applications. The multiscale models will include musculoskeletal models describing bone-muscle interactions during daily activities such as walking or running, micromechanical models for estimation of bone mechanical properties, bone remodeling and adaptation models, cellular models describing the complex bone-cell interactions taking into account biochemical and biomechanical regulatory factors.
Also subcellular processes will be covered including arrangement of actin filaments due to mechanical loading and change of receptor configurations.
The course will gather experts from the fields of applied mechanics, bone biology, and material science, in order to give, in an unprecedented interdisciplinary fashion, the cutting-edge view on bone mechanobiology.
The course is addressed to graduate students, PhD candidates and early career researchers in the field of applied mathematics, biomedical engineering, physics, bone biology, bone tissue engineering and orthopaedics interested in a novel multidisciplinary approach to the mechanobiology of bone remodeling and adaptation with special emphasis on multiscale aspects.

Invited Lecturers:
Peter Pivonka (The University of Melbourne, Australia), Tim Skerry (University of Sheffield, UK), David Findlay (University of Adelaide, Australia), Taiji Adachi (Kyoto University, Japan), Justin Fernandez (Auckland Bioengineering Institute, New Zealand), Christian Hellmich (Vienna University of Technology, Austria).

Coordinator:
P. Pivonka (Australia).

Other Events

ROMANSY 2014, 20th CISM-IFToMM Symposium on Theory and Practice of Robots and Manipulators

Moscow, June 23 - 26, 2014

Chairmen:
Marco Ceccarelli (Cassino, Italy), Victor Glazunov (Moscow, Russia).

Fundamentals and Applications of Cerium Dioxide in Catalysis

July 11 - 14, 2014

Coordinators:
A. Trovarelli (Udine, Italy), P. Fornasiero (Trieste, Italy).

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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