Centre International des Sciences Mécaniques
International Centre for Mechanical Sciences

Rectors:

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

PROGRAMME 2013

Udine, Italy

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The van Dike Session

Iso-Geometric Methods for Numerical Simulation

May 20 - 24, 2013

Since the first initiative by Prof. Hughes, followed by the publication of an excellent book by T.J.R. Hughes, J.A. Cottrell and Y. Bazilevs, isogeometric methods have become very popular. The main motivation for this method was to more closely tie Computer Aided Design (CAD) and finite element analysis. The method also addresses the need for a very accurate description of the geometry for example for thin shell problems, for describing the shapes of aircraft wings and ships, turbines etc. but it was found that the method also has advantages for other problems where the precision of the geometrical description is less important. For an accurate description of the geometry Non-uniform Rational B-splines (NURBS), that are also used by CAD programs, allow a much more accurate description of a complex surface geometry with reduced input data, than the Serendipity shape functions generally used by Finite Element (FEM) and Boundary Element (BEM) software. More recently T-Splines have been introduced, that allow the description of complex surfaces with an even reduced amount of data. The term "iso-" is used to indicate that the same functions, that are used to describe the geometry of the problem, are also used for describing the variation of the unknown. Recently the idea of a "super-geometric" approach was proposed, where different functions are used for the description of the unknown, as this may be advantageous in some applications. It has already been shown that iso-geometric methods have significant advantages over conventional methods. One main advantage is an improvement in the quality of the results with fewer unknowns. The other advantage is that it is possible to avoid the generation of surface meshes by using the geometrical information (for example from a CAD program) directly.

The aim of the school is to present the state of the art in iso-geometric modelling and to show that the method has advantages over existing methods. The unique feature of the proposed course is that the implementation in both the FEM and BEM will be discussed. First an (method agnostic) introduction to geometric modelling with NURBS and T-Splines will be presented. Next the implementation of this type of numerical modelling will be discussed.

Proposed lecture topics: • From B-splines to NURBS • T-Splines • Isogeometric Analysis basics • FEM, enriched iso-geometric analysis • Isogeometric CFD and FSI • Iso-geometric Boundary Element Method (BEM).

After the course participants will have a basic knowledge of iso geometric modelling and will understand the subtle differences with conventional methods. Participants will also have seen, on practical examples, the advantages of the method over conventional methods.

The intention is to concentrate on practical aspects and the implementation of iso- and supergeometric methods. Some numerical examples with the two open-source software (GeoPDEs and CMOS http://arxiv.org pdf/1205.2129) will be presented.

The course up-to-date is a must for all that want to be up to date with the latest trends in numerical simulation.

Invited Lecturers:
Yuri Bazilevs (University of California, San Diego, La Jolla, CA, USA), Gernot Beer (Graz University of Technology, Austria and University of Newcastle, Callaghan, Australia), Stéphane P.A. Bordas (Cardiff University, UK), Bert Jüttler (Johannes Kepler University, Linz, Austria), Alessandro Reali (Università di Pavia, Italy), Michael A. Scott (Brigham Young University, Provo, UT, USA).

Coordinators:
G. Beer (Austria and Australia), S.P.A. Bordas (UK).

Active and Passive Vibration Control of Structures

May 27 - 31, 2013

Active and Passive Vibration Control of Structures forms an issue of very actual interest in many different fields of engineering, for example in the automotive and aerospace industry, in precision engineering (e.g. in large telescopes), and also in civil engineering. The course intends to bring together engineers of different background, and it will try to fill gaps between structural mechanics, vibrations and modern control theory. It will also establish links between the different applications in structural control.
To a large extent, in vibration control it is still common practice to regard the design of mechanical structures and their damping and control as different issues. Thus they are often treated sequentially, with the design of the structure carried out first, followed later by designing the active and passive vibration control. Similarly, in the standard curricula at most universities, the mechanical modelling and the design of structures, as well as their control, are treated as separate subjects. The present course intends to fill some of the gaps between these different issues. The intention is to give a solid foundation of the mechanical modelling and the vibration control for discrete and continuous structures, with an emphasis on the interfaces of the different disciplines.
A thorough introduction into the relevant theory both of mechanical modelling and vibration control theory are presented and the most important design goals are discussed. Various strategies for modelling complex mechanical structures are given and an introduction to active, passive and semi-active strategies for vibration control are discussed.
In a number of examples from different areas it will be shown that a comprehensive approach, in which both the mechanical design problem and the development of suitable controls are considered simultaneously, can present considerable advantages. Even in research communities, the problem of integrating structure and control design is not always satisfactorily dealt with. As opposed to a control system pushing a structure away from its equilibrium, it can be far more promising to modify the equilibrium positions of the uncontrolled structure in such way as to achieve the desired shapes with moderate

control effort, possibly in such a way that no control power at all is required to hold the new shape. Tensegrity structures will be discussed in this context.
Summarizing, the course will offer a unified view on active and passive control, and the mechanical modelling of structures. The underlying theory is presented and applied to different challenging engineering examples. The course is directed to young researchers, to doctoral students and also to engineers working in fields related to structures, vibrations and control.

Invited Lecturers:
Peter Hagedorn (fnb, TU Darmstadt, Germany), Gottfried Spelsberg-Korspeter (fnb, TU Darmstadt, Germany), André Preumont (ULB, Brussels, Belgium), Robert Skelton (University of California, San Diego, La Jolla, CA, USA), Adnan Akay (Bilkent University, Turkey), Reiner Nordmann (Technical University of Darmstadt, Germany).

Coordinators:
P. Hagedorn (Germany), G. Spelsberg-Korspeter (Germany).

Identification Methods for Structural Health Monitoring and Residual Lifecycle Assessment

June 3 - 7, 2013

Structural Health Monitoring (SHM) is a term coined several years ago within the research community; however it has only recently received increased attention when it comes to practical implementation. Although certain pronounced failures in large civil structures could be the trigger for this turning point, it was more so the realization of dealing with an ageing infrastructure demographic that stressed the need for monitoring methods other than traditional visual inspection. Infrastructure operators in developed countries are currently more and more concerned with the number of structures approaching their design lifespan and are faced with decision making processes for the proper maintenance, repair and future use of structural systems.
For infrastructure systems, SHM aims at developing a long-term monitoring system able to provide information for evaluating structural integrity, durability and reliability throughout the structure life cycle and ensuring optimal maintenance planning and safe operation. This task poses challenges at different levels, from the selection of appropriate instrumentation to the actual design of a structural health evaluation system. More recently, the significant progress in sensor development and communication technologies required for handling the bulk of generated data, has allowed for the deployment of dense sensor arrays at a relatively low cost.
As a result, advanced computational methods are required in order to handle the large bulk of information as well as to achieve an accurate online system representation that can serve as input for extreme event detection and life cycle assessment.
The purpose of this course is firstly to provide an introduction to well known and established system identification methods on SHM and secondly to introduce more

advanced, state-of-the-art tools, able to tackle the challenges associated with actual implementation. In addition, focus will be given on full scale applications and field deployments that illustrate the workings and effectiveness of the introduced monitoring schemes. The deployments will involve monitoring of large scale landmark structures during regular operation as well as large scale systems that have undergone damage due to seismic events. As part of the more established methods, introductory concepts will be provided on the general framework of time and frequency domain, parametric and non-parametric methods, input-output or output only techniques.

The more innovative tools will include Bayesian methods and advanced modal identification techniques. Damage detection methods will be addressed as well, with a focus on inverse problem formulation within the SHM framework. The course syllabus will also involve advanced computational tools for uncertainty quantification and structural reliability in an effort to provide the link between monitoring and structural integrity assessment. Overall this is a joint effort from a diverse group of lecturers working on different aspects of SHM, to report the current state-of-the-art in the field and form collaboration network and shared knowledge platform in an area where there is still considerable room for research.

The course is addressed to doctoral and postdoctoral students, young and senior researchers, working in the fields of civil, mechanical engineering or other related disciplines.

Invited Lecturers:
Siu Kui Au (City University of Hong Kong), Eleni Chatzi (ETH, Zürich, Switzerland), Vincenzo Gattulli (Università dell'Aquila, Italy), Geert Lombaert (Katholieke Universiteit Leuven, Belgium), Costas Papadimitriou (University of Thessaly, Volos, Greece), Andrew Smyth (Columbia University, NY, USA).

Coordinators:
E. Chatzi (Switzerland), C. Papadimitriou (Greece).

Non-Spherical Particles and Aggregates in Fluid Flows

June 17 - 21, 2013

Dynamics of non-spherical particles and aggregates in fluid flow are encountered both in nature and in industrial applications. Examples for non-spherical particles include airborne solid particles or aerosols, carbon nanotubes, micro-organisms like phytoplankton, sediment-laden

lows and wood-fibre suspensions. Particle aggregates are found in chemical, industrial or material processes for colloids and in polymer manufacturing. In these processes, particle size ranges from several nanometers to several centimeters, with loadings that may substantially change the macroscopic (rheological) properties of the suspension flow. On the other hand, transport and interaction of particles/aggregates in complex (e.g. turbulent) flows is governed by a number of physical processes occurring at a wide range of different scales. The rapidly increasing computational power has recently made feasible three-dimensional, time-dependent simulations of non-ideal particles in fluid flows, producing an entire branch of flourishing literature which is fostering research in dispersed multiphase flow. Progress has been substantial also from an experimental viewpoint, with improved measurement techniques based on optics or magnetic resonance flow imaging. Due to the multiscale nature of the problem, investigation and modelling require synergetic use of such approaches.

Objective of the course is to provide a general and unified frame of the current research on the dynamical behaviour of non-spherical particles and particle aggregates in complex flows and put future research paths in perspective. The focus will be on generic aspects and physics of non-ideal particle suspensions (e.g. rheological properties in suspensions of anisotropic deformable particles, and modulation of turbulence induced by particles/aggregates). Issues related to modelling and physical understanding at all various length scales will be covered: from the scale resolving the complex flow around individual non-spherical particles, to large eddy simulation models for flows with particles, to large-scale Eulerian-Eulerian models. Among the topics to be included are particle dynamics in free and wall-bounded turbulence, fluid-particle interactions, collision modelling, break-up and agglomeration, advances in measurement and simulation techniques, and rheological modelling.

The lectures will also provide a wide overview of cutting-edge work in this very active area of multiphase flow research and focus in more detail on a few advanced topics of significant practical and theoretical value in several areas of engineering and applied physics. This will reinforce understanding of the fundamental phenomena and their importance, providing participants with varied conceptual and methodological tools applicable to problems at hand. After the lectures, students should possess the necessary knowledge of the basic capabilities, potentials and limitations of the various numerical and experimental methods taught and, hence, should be able to critically evaluate the reliability and accuracy of the information these methods can provide when applied to practical situations.

The course delivers a comprehensive overview of non-ideal particle/aggregate dynamics in complex fluids, 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 research interest in understanding the multi-scale complex behavior of such multiphase flows, with particular emphasis on turbulent flows.

Workshop session on Thursday will be led by Marco Vanni (Politecnico di Torino, Italy) and by Bernhard Mehlig (Goteborg University, Sweden) on “Numerical simulation of agglomeration and aggregate dynamics: modelling of particle collision and agglomeration in turbulent flows” and on “Tumbling of non-spherical particles in random flows”.

The course will be organized under the auspices of ERCOFTAC’s SIG12 “Dispersed

Turbulent Two-Phase Flows" and SIG43 "Fiber suspension flow modelling" and with the support of two COST Actions: Action FP1005 "Fiber suspension flow modelling: a key for innovation and competitiveness in pulp & paper industry" and Action MP0806 "Particles in Turbulence".

In cooperation with COST and ERCOFTAC.

Invited Lecturers:

Cristian Marchioli (Università di Udine, Italy), Federico Toschi (Eindhoven University of Technology, The Netherlands), Fredrik Lundell (Royal Institute of Technology, Stockholm, Sweden), Eric Shaqfeh (Stanford University, CA, USA), Eric Climent (Institut de Mécanique des Fluides, Toulouse, France), Berend Van Wachem (Imperial College London, UK), Martin Sommerfeld (Martin Luther University, Wittenberg, Germany).

Coordinators:

C. Marchioli (Italy), F. Toschi (The Netherlands).

Bone Cell and Tissue Mechanics

June 24 - 28, 2013

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

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

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

At the level of the cell, promising candidates for the mechanosensory system will be discussed, as well as possible signaling pathways for the communication between bone cells. At this level, the porosity of the bone tissue itself also becomes an important factor since it is assumed that fluid flow plays an important role in the mechanosensory system. The visualization and modeling at this level still is a challenging field of research. Besides being informative, it is hoped that the course will function as a forum for the exchange of data, philosophy, and ideas across disciplinary divides and so provide further stimulus for a comprehensive approach to the problems of bone mechanics. The target audience are graduate students, PhD candidates and young faculty members. We expect an audience as diverse in background as the lecturers, that is to say spanning across the professional spectrum from biomedical and structural engineers, to biologists, veterinarians and orthopaedic and dental surgeons.

Invited Lecturers:
Bert van Rietbergen (Eindhoven University of Technology, The Netherlands), Jenneke Klein-Nulend (ACTA-VU University Amsterdam, The Netherlands), Nick Fazzalari (University of Adelaide, Australia), Ralph Müller (ETH, Zürich, Switzerland), Patrick Prendergast (Trinity College Dublin, Ireland), Tim Skerry (The University of Sheffield, UK).

Coordinator:
B. van Rietbergen (The Netherlands).

Nonlinear Mechanics of Soft Fibrous Materials

July 1 - 5, 2013

Soft fibrous materials are composites with highly flexible filaments embedded in a soft base matrix. They are found in many biological tissues and high performance elastomeric polymers. The fibers attribute the material with preferred directions thereby optimizing a set of mechanical properties.

There are many applications where natural or synthetic fibers are used to modify the mechanical response of the base material. Most broadly, biological materials are reinforced with some kind of proteins, such as collagen, silk, fibronectin, titin, and many others. Synthetic fibers are most often long chemically cross-linked elastomeric filaments, which in the unstretched state occupy a random coiled configuration. When stretched, the filaments extend and orient along the loading directions resulting in a decrease of entropy. Depending on processing, the macromolecular orientation can be altered resulting in high stiffness and high strength fibers. These are used as reinforcements for tires, ropes, cables, ballistic protections used by law enforcement agencies. Biological and engineered reinforced materials are therefore characterized by one or two families of fibers creating preferred directions in the mechanical response. Mathematical models and numerical simulations are a prerequisite in the development, testing and evaluation of the mechanical properties and play a fundamental role in the analysis of problems that arise in such materials.

The purpose of the course is to present a state-of-the-art overview of the fundamental theories, established models and ongoing research related to the modeling of these materials. Two approaches are conventionally used to develop constitutive relations for highly deformable fibrous materials. According to the phenomenological approach, a strain energy density function can be defined in terms of strain invariants. The other approach is based on kinetic theories, which treats a fibrous material as a randomly oriented inter-tangled network of long molecular chains bridged by permanent and temporary junctions. At the micro-level, these are associated with chemical crosslinks and active entanglements, respectively.

The presentations will include carefully crafted overviews of the fundamental formulation of the three-dimensional theory from several points of view, and will address their equivalences and differences. We will also include solutions to boundary-value problems which are amenable to experimental verification. A further aspect of the course will be the elasticity of filaments, stability of equilibrium and thermodynamics of the molecular network theory.

The course is addressed to doctoral students and postdoctoral researchers in mechanical, civil and electrical engineering, materials science, applied physics and applied mathematics, academic and industrial researchers and practicing engineers.

Invited Lecturers:

Michel Destrade (National University of Ireland, Galway, Ireland), Luis Dorfmann (Tufts University, Medford, MA, USA), Salvatore Federico (University of Calgary, Canada), Ray W. Ogden (University of Glasgow, UK), Giuseppe Saccomandi (Università di Perugia, Italy), David Steigmann (University of California at Berkeley, CA, USA).

Coordinators:

L. Dorfmann (USA), R.W. Ogden (UK).

Separated Representations & PGD Based Model Reduction: Fundamentals and Applications

July 8 - 12, 2013

Today many problems in science and engineering remain intractable, in spite of the impressive progresses attained in modelling, numerical analysis, discretization techniques and computer science during the last decade. In fact their numerical complexity, or the restrictions imposed by different requirements (real-time on deployed platforms, for instance) make them unaffordable for today's technologies. We can enumerate different challenging scenarios for efficient numerical simulations: (i) models defined in high-dimensional spaces suffering the so-called curse of dimensionality, usually encountered in quantum chemistry, kinetic theory descriptions, chemical master equation, …; (ii) simulation based real time control; (iii) multi-scale and multi-physics non-linear problems involving strong couplings; (iv) models defined in degenerated domains; (v) problems needing too many direct solutions (optimization, inverse analysis, …); (vi) DDDAS (dynamic data driven application systems); (vii) augmented reality needing fast simulation in deployed computing platforms and finally

(viii) models involving uncertainty.
While the previous list is by no means exhaustive, it includes a set of problems with no apparent relationship between them that can, however, be treated in a unified manner as will show this course. Their common ingredient is our lack of capabilities (or knowledge) to solve them numerically in a direct, traditional way. In order to obtain a solution, some kind of model order reduction is thus compulsory.
In this course we first describe the construction of reduced models by revisiting POD (Proper Orthogonal Decomposition) and reduced bases models, from the point of view of their mathematical foundations and some challenging applications. Then, we will move to a new generation of simulation strategies based on the use of separated representations (space -including physical and conformational coordinates-, space-time or space-time-parameters) at the origin of the so-called Proper Generalized Decomposition -PGD- techniques.
Because such representation allows circumventing the course of dimensionality, models can be enriched by considering parameters as extra-coordinates, making possible fast and cheap online calculations from off-line richer parametric solutions.
Separated representations will be analyzed in detail, from their mathematical foundations to their most spectacular applications. We will illustrate how this approximation could constitute a new paradigm in computational sciences allowing to circumvent the above computational issues in a panoply of applications in engineering sciences, as the ones just referred.
The course is addressed to doctoral students, young and senior researchers, practicing engineers working in the area of simulation software, who are faced by the strong limitations of standard simulation techniques for solving complex models, and require new approaches for ensuring efficient simulations of such challenging models.

Invited Lecturers:
Francisco Chinesta (Ecole Centrale de Nantes, France), Elias Cueto (Universidad de Zaragoza, Spain), Antonio Huerta (LaCàN, UPC Barcelona, Spain), Boris N. Khoromskij (Max-Planck Institute, Leipzig, Germany), Pierre Ladeveze (LMT/ENS Cachan/CNRS/UPMC/PRES, UniverSud Paris, France), Gianluigi Rozza (SISSA MathLab, Trieste, Italy and EPFL MATHICSE CMCS, Lausanne, Switzerland).

Coordinators:
F. Chinesta (France), P. Ladeveze (France).

The Fluid Dynamics of Climate

August 26 - 30, 2013

Climate dynamics offers some of the most intriguing scientific problems in science, as well as a set of applied issues of central importance, such as the definition of mitigation and adaptation strategies, the assessment of the potential risks associated with climate change (droughts, floods, extreme events, sea level rise) and the social, economic and geopolitical implications of global warming.

Many of the components of the climate system are in fluid state, such as the atmosphere, the hydrosphere and the cryosphere. As an evolution of the well-established discipline of geophysical fluid dynamics, founded more than fifty years ago, the emerging theme of “climatic fluid dynamics” is now at the heart of the efforts devoted to understanding and modeling the climate system.

The objective of this course is to make students and researchers with a general background in fluid dynamics familiar with the fluid aspects of the climate system. The course will bring together contributions from diverse fields of the physical, mathematical and engineering sciences. The addressed audience is composed of doctorate students, postdocs and researchers working on different aspects of atmospheric, oceanic and environmental fluid dynamics. It will also be useful for researchers interested in quantitatively understanding how fluid dynamics can be applied to the climate system, and for climate scientists willing to gain a deeper insight into the fluid mechanics underlying climate processes.

The course outline includes: • A general introduction to the fluid dynamics of climate, including the role of stratification, rotation, and the issues related to the many interacting spatial and temporal scales in the climate system • The dynamical systems approach to ocean and climate dynamics. Specific topics will include the North Atlantic Oscillation, El Niño, the Atlantic Multidecadal Oscillation, the Dansgaard-Oeschger events and the Pleistocene Ice Ages • The physics of radiative and convective heat transfer and radiative convective equilibrium, including a discussion of the character of convection and tropical cyclones in changing climates and how they may serve to regulate climate. • A description of the climate system in terms of data and model hierarches and the problem of climate predictability. Discussion of an equation of state for the Earth’s continental climates to describe vegetation, rivers, lakes and glaciers, their means, sensitivities and variability • The working of coupled general circulation models, with a general overview of their strength and weakness and including the role of parameterizations. Quantification of model uncertainty, especially considering that state-of-the-art climate models contain many sources of uncertainty. • The dynamics of the global hydrological cycle in the climate system and its representation in global climate models. Regional scale climate dynamics, with examples from the Mediterranean, the Arctic and the Himalayas, and climatic downscaling.

Invited Lecturers:

Annalisa Bracco (Georgia Institute of Technology Atlanta, GA, USA), Henk Dijkstra (Utrecht University, The Netherlands), Kerry A. Emanuel (Massachusetts Institute of Technology, Cambridge, MA, USA), Klaus Fraedrich (University of Hamburg, Germany), Michael Ghil (Ecole Normale Superieure, Paris, France and University of California, Los Angeles, CA, USA), Antonello Provenzale (National Research Council, Torino, Italy).

Coordinators:

A. Provenzale (Italy), K. Fraedrich (Germany).

The Troger Session

Fractal Flow Design: how to Design Bespoke Turbulence and why

September 9 - 13, 2013

After more than a century of exhaustive research on the aerodynamics and hydrodynamics of geometrically simple shapes, whether streamlined as in wings or bluff as in spheres and cylinders, it is blindingly natural to expect much of the future in fluid mechanics to lie in the aerodynamics and hydrodynamics of geometrically complex, and thereby multiscale, shapes. There has of course been work over the past decades on how to model and simulate complex turbulent flows, but the emphasis here is on working out the rules for the design of multiscale objects so as to obtain, by passive flow manipulation, desired effects for particular applications and for fundamental research into turbulent flows.

The simplest cases of multiscale shapes are fractal and fractal-like shapes, which is why they have been a good start in this new research area. These are multiscale shapes with a complex appearance which can nevertheless be defined with only a small number of scaling parameters.

The study of turbulent flows generated in multiscale/fractal ways includes multiscale/broadband forcings as well as multiscale/fractal boundary and/or inlet conditions. One of the ideas is to interfere with the multiscale dynamics and inner multiscale geometry and topography of the turbulence itself or engineer a multiscale arrangement of wakes and/or jets for mixing and heat transfer enhancement. In particular, fractal grids led to the discovery of a hitherto unknown non-equilibrium turbulence regime with very unusual but well-defined dissipation properties. These new dissipation properties have led to current studies of interscale transfers and vorticity-strain dynamics in spatially developing turbulent flows and a re-examination of the classical Kolmogorov (1941) equilibrium theory of turbulence. There are also reasons to expect new turbulent diffusion laws in turbulent flows generated by multiscale/fractal grids. They are therefore opening a vast scope for fruitful research.

Apart from fundamental studies there are many potential applications, including use of multiscale/fractal grids in combustion, mixing and heat transfer, fractal mixers having been refered to as super-mixers by some workers in the field. There are also flow meter applications, aerodynamic and aeroacoustic applications (fractal spoilers and wings), applications to fences and flow profilers and even fractal sunshade roofs.

The aim of this course is to present the state-of-the-art in most current aspects of this new multifaceted area of research, including experiments, theory and computer simulations. The course will include accounts of the various scientific and engineering experiments carried out in this emerging field over the past few years as well as direct numerical simulations and other computer simulation techniques which have been applied to such problems, including aeroacoustic simulations.

The target audience are graduate students, PhD candidates, Post Doctoral Researchers

in Aeronautical, Chemical, Mechanical, Environmental and Civil Engineering, Applied Mathematics and Physics as well as Research Engineers working in industry. The participants are expected to have a background in some area of or involving fluid mechanics. It is hoped that everybody will be willing to participate in open debate and discussion.
In cooperation with ERCOFTAC.

Invited Lecturers:
Peter Lindstedt (Imperial College London, UK), Franck Nicolleau (University of Sheffield, UK), Joachim Peinke (Carl-von-Ossietzky University, Oldenburg, Germany), Satoshi Sakai (Kyoto University, Japan), Yasuhiko Sakai (Nagoya University, Japan), J. Christos Vassilicos (Imperial College London, UK).

Coordinator:
J.C. Vassilicos (UK).

Differential-Geometric Methods in Computational Multibody System Dynamics

September 16 - 20, 2013

Introduction:
Multibody system (MBS) dynamics, a branch of computational mechanics dealing with modeling principles and computational methods for dynamic analysis, simulation and control of mechanical systems, requires efficient and reliable formulations and computational methods.
Within research of novel computational concepts, geometric aspects of kinematical and dynamical modeling of MBS are increasingly recognized to play a significant role. By operating on manifolds, and Lie-groups in particular, instead of linear vector spaces, geometric algorithms respect the geometric structure underlying many technical systems and hence offer attractive features such as numerical robustness and efficiency as well as avoidance of the kinematical singularities. Also, it is well-known that differential-geometric methods are the key concepts in contemporary mechanism design, and control theory. As such, geometric methods can provide the unifying mathematical framework that allows for successful studying of multidisciplinary interactions within complex environments.
Objective and Audience:
The aim of the School is to deliver a panoramic overview of the mathematical concepts underlying modern geometric approaches to modeling, time integration, and control of MBS, followed by an in-depth introduction to the relevant computational algorithms and numerical methods. By merging geometric methods in MBS dynamics, non-linear control and mechanism theory, the School provides unique educational platform that will deliver novel modeling concepts as well as theoretical and computational insights into dynamics and control of mechanical systems. The lectures take an application-driven approach, and numerous case-studies from many fields of engineering are

presented and documented.

The School is primarily aimed for the audience of doctoral students and young researchers (post-docs) in engineering, mathematics and applied physics, but will be valuable also for senior researchers and practicing engineers who are interested in the field.

Lectures Outline:

The lectures provide a hands-on introduction to differential-geometric foundations and the audience will make acquaintance with these topics in a natural and application-driven way. A central topic of the school is efficient formulations using Lie-group concepts and screw theory, giving rise to numerically efficient and stable algorithms for MBS comprising rigid and flexible members. Special focus is given to energy and structure preserving numerical integration methods on manifolds for discrete and continuous systems. Natural coupling between mathematical modeling, numerical integration and control issues are covered by the lectures on variational integrators and optimal control with structure preserving integrators.

• Specifically, lectures will include: • introduction to mathematical concepts and differential-geometric modeling (manifolds, Lie-groups, Lie-algebras, exponential maps, screw theory etc.); • modeling of complex MBS using compact Lie- group formalisms; • time integration on Lie-groups; • geometrically exact formulations for beams and shells; • energy-consistent time integration procedures for MBS with flexible components; • numerical treatment of holonomic and non-holonomic constraints, constraint stabilization; • variational integrators, discrete mechanics and optimal control using structure-preserving integration schemes applied to high degree-of-freedom systems; • Lie-group/screw theoretic framework for design of MBS and articulated mechanisms; • multi-physics coupling procedures: aero-servo-elastic multidisciplinary models and applications.

A treatment of many numerical case-studies in the domain of robotics, wind energy systems, rotorcraft dynamics, aeronautical and mechatronical systems will highlight compact formulations, relevance and computational advantages of the geometric approach in the modern computational mechanics.

The unifying lecturing approach that combines computational procedures, control algorithms and design aspects, and provides new insights into the coupled modeling procedures, makes this School unique.

Invited Lecturers:

Zdravko Terze (University of Zagreb, Croatia), Andreas Mueller (Technical University of Chemnitz, Germany), Xilun Ding (Beijing University of Aero. & Astro, China), Olivier Bruels (University of Liège, Belgium), Carlo Bottasso (Politecnico di Milano, Italy), Todd Murphey (Northwestern University, Evanston, IL, USA).

Coordinators:

Z. Terze (Croatia), A. Mueller (Germany).

KMM-VIN - Skeletal Tissue Engineering Mechanics, with Links to Biology, Chemistry and Medicine

September 23 - 27, 2013

Tissue engineering is the use of cells and bio-chemical substances, in combination with engineering and materials methods, in order to restore, maintain, or improve the functioning of biological tissue. The material sciences and cell biological technologies used in contemporary tissue engineering have reached breathtaking sophistication. On the contrary, the current design process of tissue engineering (TE) scaffolds is still a pure trial and error approach. We propose that this conceptual weakness explains why reliable, safe TE solutions for the daily clinical use are the exception, rather than the rule. In fact, it is very complicated (if not impossible), even with tremendous input gained from sophisticated experimental work, to guess suitable combinations of the key design parameters (chemical composition, porosity, microstructural geometry, distribution of signalling factors and biological cells), which reflect a highly complex system of mutually coupled phenomena.

This is where the field of applied mechanics is expected to be of enormous help – and recent developments are planned to be disseminated to an interdisciplinary audience from civil and mechanical engineering, material science, biology, and biomedicine. In more detail, the lectures of the proposed course will cover topics concerning the key challenges of contemporary tissue engineering strategies, which result from (at least) two competing requirements: (i) the tissue engineering scaffolds must exhibit a sufficient mechanical competence, i.e. stiffness and strength comparable to natural bone. (This relates to structural soundness); and (ii) within the living organism, it should be continuously resorbed and replaced by natural bone. (This relates to the topic of bioresorbable scaffolds enabling internal growth of new tissue).

Thereby, bone tissue will be the key focus, since in this field, great progress has been made, not only in materials science and biology, but also in applied and computational mechanics.

The course will gather experts from the fields of applied mechanics, biology, and chemistry, in order to give, in an unprecedented transdisciplinary fashion the cutting-edge view on up-to-date ingredients of tissue engineering for load-carrying organs.

The course is addressed to all doctoral students, researchers, engineers, physicists, chemists, biologists, and medical doctors interested in a novel, comprehensive approach to the understanding and improvement of the tissue engineering field, with special emphasis on mechanics of tissue engineering scaffolds and on the mechanical aspects of biological systems.

Invited Lecturers:

Aldo R. Boccaccini (University of Erlangen-Nuremberg, Germany), Christian Hellmich (Vienna University of Technology, Austria), Kalpana Katti (North Dakota State University Fargo, ND, USA), Vladimir Komlev (Russian Academy of Sciences, Moscow, Russia), Damien Lacroix (University of Sheffield, UK), Laurence Vico (Université St. Etienne, France).

Coordinators:
Ch. Hellmich (Austria), A.R. Boccaccini (Germany).

Failure and Damage Analysis of Advanced Materials

September 30 - October 4, 2013

Failure as a limit state of the material behavior is well known from engineering practice. Different types of failure can be identified: • transition from the elastic to plastic state; • loss of stiffness; • loss of fracture resistance at different scale levels; • ultimate strength; • fatigue.

In addition, failure can be accompanied by various types of damage. The CISM course will discuss basic concepts and new developments in failure and damage analysis with focus on advanced materials such as composites, laminates, sandwiches and foams, and also new metallic materials. Starting from some mathematical foundations (limit surfaces, symmetry considerations, invariants) new experimental results and their analysis will be presented. Finally, new concepts for failure prediction and analysis will be introduced and discussed.

The classical strength criteria developed intensively in the 19th and 20th century are mostly based on the comparison of the stress state (usually three-dimensional) with some scalar-valued properties estimated in tests. Such a phenomenological approach can be easily extended to other types of limit states of a material (for example, plastic behavior, and damage or fracture toughness). But even in the case of classical, but anisotropic structural materials, predictions are not always satisfactory and the effort required for their experimental confirmation can increase dramatically. Furthermore, in the case of advanced materials additional effects such as load dependent material response should be taken into account. These effects can induce mechanisms leading to different behavior in tension and compression.

Considering advanced metallic and non-metallic materials new methods of failure and damage prediction will be discussed. Based on experimental results the traditional methods will be revised. In some cases it is enough to extend the classical approaches (for example, for metallic sheet material). In other situations (foams, composites) this is not satisfying since the different mechanisms cannot be adequately presented.

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

Invited Lecturers:
Holm Altenbach (Otto-von-Guericke-Universität Magdeburg, Germany), Frederic Barlat (GIFT-POSTECH, Pohang, South Korea), Liviu Marsavina (Politehnica University of Timisoara, Romania), Neil McCartney (National Physical Laboratory, Teddington, UK), Tomasz Sadowski (Lublin University of Technology, Poland), Ramesh Talreja (Texas A&M University, College Station, TX, USA).

Coordinators:
H. Altenbach (Germany), T. Sadowski (Poland).

Structure-Preserving Integrators in Nonlinear Structural Dynamics and Flexible Multibody Dynamics

October 7 - 11, 2013

The course focuses on structure-preserving numerical methods for flexible multibody dynamics, including nonlinear elastodynamics and geometrically exact models for beams and shells. Starting with early developments in the eighties, structure-preserving time-stepping schemes are nowadays well-known to possess superior numerical stability and robustness properties.

Originally, energy-momentum conserving schemes have been mainly developed in the framework of nonlinear elastodynamics and structural dynamics. In this connection, nonlinear finite elements are typically used for the discretization in space. Moreover, the parametrization of finite rotations and their impact on the discretization in space and time plays a crucial role.

Due to their success in the field of nonlinear structural dynamics, the energy-momentum method, as well as energy-decaying variants thereof, have been extended to the framework of flexible multibody dynamics. In fact, the nonlinear finite element approach to flexible multibody dynamics has been strongly supported by the availability of structure-preserving discretization methods.

Concerning the discretization in space of nonlinear beams and shells, the course will address two alternative approaches. Firstly, geometrically exact formulations which are typically used in the finite element community and, secondly, the absolute nodal coordinate formulation which is quite popular in the multibody dynamics community.

The semi-discrete equations of motion resulting from the discretization in space of flexible multibody systems in general assume the form of differential-algebraic equations.

Concerning the discretization in time, the energy-momentum method and energy-decaying variants thereof will be treated. In addition to that, the newly emerging class of variational integrators as well as Lie-group integrators will be dealt with.

In the wake of the structure-preserving discretization in space and time a number of issues arise that will be addressed as well. Among them are the parametrization of finite rotations, the incorporation of algebraic constraints and the computer implementation of the various numerical methods. The practical application of structure-preserving methods will be illustrated by a number of examples dealing with, among others, nonlinear beams and shells, large deformation problems, long term simulations and coupled thermo-mechanical multibody systems. In addition to that the novel time integration methods are linked to frequently used methods in industrial multibody system simulation.

The target audience of this summer school are research scientists, postgraduate and graduate students from universities, research institutes and industry, who are interested in the theoretical background and the practical application of computer methods in nonlinear structural dynamics and flexible multibody dynamics.

Invited Lecturers:
Martin Arnold (Martin Luther University of Halle-Wittenberg, Germany), Peter Betsch (University of Siegen, Germany), Alberto Cardona (Universidad Nacional del Litoral-Conicet, Santa Fe, Argentina), Johannes Gerstmayr (Austrian Center of Competence in Mechatronics, Linz, Austria), Adrian Lew (Stanford University, CA, USA), Ignacio Romero (Universidad Politecnica de Madrid, Spain).

Coordinator:
P. Betsch (Germany).

19th CISM-IUTAM International Summer School

Variational Approaches to Damage in Continua and Interfaces

June 10 - 14, 2013

The goal of this course is to give a modern presentation of the mathematical theory of damage completed by various applications. Specifically, the course can be divided into three main parts: Part I: General framework for developing damage models. This part will begin by a presentation of the physical aspects of damage in order to establish the basic ingredients required to model them at a macroscopic level. We do not intend to develop a full micromechanical approach. However, the main microstructural mechanisms of damage will be highlighted and a multi-scale approach will be used to make a link between damage and fracture. Then models of different types will be elaborated, each one being related to a particular class of materials or mechanisms: interfacial and cohesive zone models, local versus non local models, discrete versus continuous damage models, concrete and geomaterial damage models with chemo-mechanical coupling, isotropic versus anisotropic damage models, modelling of the asymmetric behaviour in tension and compression, modelling of Mullins effect in elastomers, damage models in biological systems...). Part II: Qualitative analysis of the evolution problem of damage. This part will be devoted to the mathematical study of the governing equations for the evolution of damage. In particular, we will emphasize the theoretical merits of the variational approach which allows to introduce in a natural and rational way the fundamental concepts of bifurcation and stability. We will show in particular that, in presence of softening, the classical approaches based on the equilibrium equations and the constitutive evolution laws are not sufficient to lead to well-posed problems while the introduction of stability conditions allows to rule out unphysical solutions. These concepts and their consequences will be illustrated by means of key examples.
Part III: Numerical implementation and various. Applications. In this last part various numerical methods will be presented and compared. Moreover, we will focus on the link between damage models and fracture mechanics. We will show how damage evolution can be used as a pre-cursor to crack propagation. Various numerical tests will illustrate the power of such an approach.

The course is addressed to a broad public: graduate students, doctoral students, young researchers and practicing engineers. Since a major part of the course will be devoted to theoretical and numerical modelling, a sound mathematical basis is expected. No specific prerequisite relative to damage mechanics is required, but basic knowledge of continuum mechanics and of elasticity theory is recommended.

Invited Lecturers:
Jean-Jacques Marigo (Ecole Polytechnique, Palaiseau, France), Claudia Comi (Politecnico di Milano, Italy), Blaise Bourdin (Louisiana State University, Baton Rouge, LA, USA), Antonio De Simone (SISSA, Trieste, Italy), Marc Geers (Eindhoven University of Technology, The Netherlands), Corrado Maurini (Université Paris 6, France).

Coordinators:
J.-J. Marigo (France), C. Comi (Italy).

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CISM, Chap. 1, Art. 1.

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