ThirdSperlonga Summer School onMechanics and Engineering Sciences

This is the third edition of the Sperlonga Summer School on Mechanics and Engineering Sciences, as part of the activities under the homonymous PRIN Project, run jointly by the International Research Centre on the Mathematics and Mechanics of Complex Systems (M&MoCS), the Foundation "Tullio Levi-Civita" and the Italian Association of Theoretical and Applied Mechanics (AIMETA), with the support of the town of Sperlonga—the permanent seat of the School.

The School will consist of three courses—ofheight hours each—and four seminars. The courses will be given by **Claude Lamarque** (EcoleNationale des Travaux Publics de l'Etat - ENTPE, France), **Angelo Luongo** (M&MoCS and University of L'Aquila), and **David Steigmann**(University of California, Berkeley). The seminars will be given by **Billie F. Spencer**(University of Illinois at Urbana-Champaign), **Stefano Lenci** (Marche Polytechnic University), and **Vincenzo Gattulli**(University of L'Aquila). Courses and seminars are organized with an interdisciplinary attitude, aiming to introduce young scientists to present-day developments in mechanics at the interface with mathematics, physics, materials science, and engineering applications.

Course programmes

Claude-Henri Lamarque (EcoleNationaledesTravauxPublics de l'Etat)

Nonlinear Dynamics of Smooth and Non-Smooth Systems with Application to Passive Control

Non smooth dynamical systems (friction, impact): simple introductory examples; models of some mechanical systems involving friction (differential inclusions); main mathematical results, a class of implicit Euler numerical scheme, non-event driven scheme, convergence order one for large class of mechanical systems; assembling simple friction elements in series or in parallel; stochastic frame; other cases (systems with delay, with non locallyLipschitz terms, cascade of elements, infinite number of internal variables, e.g. Persoz's case); identification and modeling from hysteretic cycles for systems including Saint-Venant elements; simple examples of mechanical systems with impacts and questions about numerical schemes. Passive control: basic scenario of localization via a two degree-of-freedom mechanical systems, involving two nonlinear modes; energy pumping and targeted energy transfer (smooth or non smooth systems, cases of two degrees of freedom mechanical systems); the «Master» system coupled to «Slave» system, involving an essential nonlinear term (Nonlinear Energy Sink- NES); smooth nonlinearities and different external solicitation (free oscillations of the system under initial conditions, oscillations under periodic forcing); analytical methods to understand the mechanism of localization and one-to-one resonances, and to design the NES for passive control; master systems with more than one degree-of-freedom; efficiency of the localization of energy designed analytically via a few degrees of freedom system; experimental devices and results; linear or nonlinear dynamical systems coupled to a smooth or a non smooth NES under periodic excitation; projection on main Fourier coefficients of the equations of the dynamical system and multiple scale approaches (reduced dynamical system); singularities and fixed points of reduced dynamical systems for passive control via 1:1 resonance scenario; miscellaneous points (robustness, experiments and quasi-periodicity, multiple nonlinear energy sinks, etc.).

Angelo Luongo (M&MoCS, University of L'Aquila)

Perturbation methods for Bifurcation Analysis

Elementary examples of perturbation analysis: quasi-linear algebraic problems, perturbation parameter, multi-parameter systems, linear and nonlinear algebraic eigenvalue problems, initial value problems (the straightforward expansion), the Multiple Scale Method. Stability and Bifurcation of Dynamical Systems: general definitions, fundaments of stability and bifurcation theory, multiple bifurcations from a known path, the Center Manifold Method, the Normal Form Theory. Static bifurcations of low-dimensional systems: codimension-1 static bifurcations, imperfection sensitivity, Multiple Scale analysis of sample systems. Dynamical bifurcations of low-dimensional systems: simple-Hopf bifurcation, non-resonant double-Hopf bifurcation, divergence-Hopf bifurcation,resonant double-Hopf bifurcations of 1:1 and 1:3 type, the 1:2 resonant double-Hopf bifurcation, defective bifurcations (the double-zero case and the double-Hopf case).

Francesco dell'Isola (Sapienza University of Rome)

Modelling the onset of shear boundary layers in fibrous composite reinforcements by second gradient theory

It has been known since the pioneering works by Piola, Cosserat, Mindlin, Toupin, Eringen, Green, Rivlin and Germain that many micro-structural effects in mechanical systems can be still modeled by means of continuum theories. When needed, the displacement field must be complemented by additional kinematical descriptors, called sometimes microstructural fields. In this paper, a technologically important class of fibrous composite reinforcements is considered and their mechanical behavior is described at finite strains by means of a second-gradient, hyperelastic, orthotropic continuum theory which is obtained as the limit case of a micromorphic theory. Following Mindlin and Eringen, we consider a micromorphic continuum theory based on an enriched kinematics constituted by the displacement field **u** and a second-order tensor field ψ describing microscopic deformations. The governing equations in weak form are used to perform numerical simulations in which a bias extension test is reproduced. We show that second-gradient energy terms allow for an effective prediction of the onset of internal shear boundary layers which are transition zones between two different shear deformation modes. The existence of these boundary layers cannot be described by a simple first-gradient model, and its features are related to second-gradient material coefficients. The obtained numerical results, together with the available experimental evidences, allow us to estimate the order of magnitude of the introduced second-gradient coefficients by inverse approach. This justifies the need of a novel measurement campaign aimed to estimate the value of the introduced second-gradient parameters for a wide class of fibrous materials.

David Steigmann (University of California at Berkeley)

Fundamentals of Elastic Stability, including Application to Structures

Basic definitions: stability and instability. Lyapunov's method based on Lagrange's equations of motion. Lyapunov functions for discrete (finite-dimensional) systems. Tests for instability: Chetaev's method. Applications to discrete models of structures. Extensions of Lyapunov's method to continuous systems. Norms and Fréchet differentiability. Elasticity, structural mechanics, relationship between bifurcation of equilibria and instability, buckling of rods and plates.

Seminars

Billie F. Spencer, Jr. (University of Illinois at Urbana-Champaign)

The design, fabrication, and construction of smart structures is one of the ultimate challenges to engineering researchers today. Smart structures technology, a natural application of the information revolution to civil engineering, provides a deep understanding of the state and performance of a structure. Such information can be used to control a damping system during earthquake or wind loading, assess the health of the structure after a critical earthquake or wind loads, and track the degradation of the structure for maintenance purposes. In this regard, smart structures technology facilitates sustainable infrastructure.

Current Practice and Future Trends in Structural Control

In recent years, considerable attention has been paid to research and development of passive and structural control devices, with particular emphasis on alleviation of wind and seismic response of buildings and bridges. In both areas, serious efforts have been undertaken to develop the structural control concept into a workable technology, and today we have many such devices installed in a wide variety of structures. The focus of this lecture is on active, semi-active and hybrid structural control with seismic applications. These systems employ controllable force devices integrated with sensors, controllers and real-time information processing. This paper includes a brief historical outline of their development and an assessment of the state-of-the-art and state-of-the-practice of this exciting, and still evolving, technology. Also included in the discussion are their advantages and limitations in the context of seismic design and retrofit of civil engineering structures.

Health Monitoring of Civil Infrastructure

The ability to continuously monitor the integrity of civil infrastructure in real-time offers the opportunity to reduce maintenance and inspection costs, while providing for increased safety to the public. Furthermore, after natural disasters, it is imperative that emergency facilities and evacuation routes, including bridges and highways, be assessed for safety. Addressing all of these issues is the objective of structural health monitoring (SHM). This second lecture first provides an overview of structural health monitoring of civil infrastructure. Subsequently, the potential of smart sensors to provide rich information for structural health monitoring using their sensing, computational, and wireless communication capabilities. Several examples are given, including the Jindo Bridge, a cable-stayed bridge in South Korea with a 344m main span. This project constitutes the world's largest deployment of wireless sensors to monitor civil infrastructure and signifies a new paradigm for structural health monitoring that is leading to dramatic improvements over existing capabilities.

Stefano Lenci(Marche Polytechnic University)

Dynamical Integrity in Structural and Nonlinear Dynamics

Since the 90's it has been understood that classical stability (in the Lyapunov sense) is not sufficient for practical purposes, especially close to bifurcation points. In fact, while in the mathematical definition of stability the perturbations are infinitesimal, in real word the perturbations are always finite, even though they are small. To properly take into account this fact one must necessarily consider basins of attraction. This introduces a cornucopia of difficulties, the main being (i) that a global analysis is necessary, and (ii) that the basins of attraction often have a complex topology (e.g. fractal basin boundaries) and so are not so easy to be detected. The scope of the Dynamical Integrity is to address this topic, with the final goal of providing tools permitting safe design of structures. Applications in the field of structural dynamics, and in particular in the load carrying capacity of structures will be discussed in depth.

Vincenzo Gattulli (University of L'Aquila)

Advanced applications in the field of Structural Control and Health Monitoring after the 2009 L'Aquila Earthquake

Structural control and health monitoring are related research fields, which have found several applications in earthquake engineering. The technological development is still in progress and new enhancement may come out from the design of smart control devices and innovative sensor networks in a large number of different studied cases. In this respect, the lecture will summarize the main features of numerous activities, which have been performed after the 2009 L'Aquila earthquake, regarding the use of the base-isolation and passive energy dissipation technologies and the observations made available through different monitoring system already on-site or immediately installed for the after-shock swarm and during the reconstruction phase.

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