Thursday 25 January 2018

18:00 - 19:15 Welcome and Introduction (Room R2)

19:30 - 21:30 Social dinner - Villa Madruzzo (Via Ponte alto, 26 - Trento)

Friday 26 January 2018

8:30 - 9:45 SESSION 1 (Room R2)

8:30 - 8:45 G. Piccardo
Vortex-induced vibrations in wind engineering

8:45 - 9:00 M. Lepidi
Scientific research in structural dynamics and stability at University of Genoa. Some recent development and future trends

9:00 - 9:15 F. Dal Corso
Stability and dynamics of structures subject to movable and configurational constraints

9:15 - 9:30 M. Pantano
Load sensor instability in microsystems for tensile testing of nanomaterials

9:30 - 9:45 D. Misseroni
Experimental and numerical proof of dissipative instabilities induced by dry friction

9:45 - 10:30 Coffee Break + Visit to Instabilities Lab

10:30 - 11:45 SESSION 2 (Room R2)

10:30 - 10:45 M. Serpilli, S. Lenci
Asymptotic modelling of the linear dynamics of laminated beams

10:45 - 11:00 F. Clementi, S. Lenci
Dynamic analysis of ancient masonry towers by the Non-Smooth Contact Dynamics method

11:00 - 11:15 M. Ferretti, A. Luongo, F. D'Annibale
Critical and postcritical behavior of the Nicolai column

11:15 - 11:30 F. D'Annibale, A. Luongo, M. Ferretti
Paradoxes in dynamic stability of beams: investigating the causes and detecting the nonlinear behaviors

11:30 - 11:45 A. Luongo
Perspectives and trends in stability analysis of nonconservative systems

Vortex-induced vibrations in wind engineering

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The analysis of the vortex-shedding phenomenon and its possible interactions with other aeroelastic behaviors is a formidable task that has attracted many researchers. Vortex-induced vibrations (VIV) occur in many engineering situations and are studied in a number of disciplines including fluid mechanics, structural mechanics, vibrations and acoustics. They arise from a combination of forces induced by pressure fluctuations, associated with the shedding of vortices, and additional motion-dependent forces, which may cause large across-wind oscillations when the shedding frequency is close to a natural frequency of the structure. A typical result of vortex resonance is the lock-in effect. It usually occurs in lightweight, low-damped structures when the vortex shedding becomes synchronized with the vibration frequency violating the Strouhal law over a specific range of wind velocity. It is an inherently nonlinear self-governed phenomenon, the knowledge of which needs to interlace physical and numerical experiments.

Calculation procedures commonly used in wind engineering evaluation are based on semi-empirical models such as the spectral and the harmonic model. The former, based on a fluid-elastic conception of the phenomenon, supplies an analytical expression for the equivalent aerodynamic damping derived from a modified van der Pol oscillator. The latter, deduced from a simple forced-system model, supplies an exciting force governed by the so-called 'effective correlation length' of vortex-induced forces. Other advanced models, such as wake oscillators, allow to better capture the essential features of VIV also in complex geometries but have, at the moment, few applications on real structures.

Some current challenging problems of scientific and technical interest are introduced, such as the limiting amplitude in fluid-elastic model, the influence of mechanical nonlinearities, two-dimensional VIV models and the technical importance of higher vibration modes.

Scientific research in structural dynamics and stability at University of Genoa. Some recent development and future trends

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Structural dynamics and stability are active and distinctive lines of scientific research at the Department of Civil, Chemical and Environmental Engineering (DICCA) of the University of Genova. Some recent developments are illustrated in the fields of (i) linear and nonlinear dynamics of multi-body systems, (ii) aeroelasticity and passive control of bluff bodies, (iii) wave propagation and band structure design in periodic beam lattices, (iv) dynamic performance of sailing boats in cruising conditions. The talk is focused on specific theoretical and methodological aspects, like the analytic formulation and low-order reduction of mechanical models, the application of perturbation techniques to the approximate solution of direct and inverse eigenproblems, the parametric description of stability charts describing the bifurcation scenario. Feasible future trends in the framework of smart structures, microstructured metamaterials and – in a more general perspective – advanced applications of high-performance engineering are outlined.

Stability and dynamics of structures subject to movable and configurational constraints

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A summary of recent results obtained within the framework of structures subject to movable and configurational constraints is presented.

- A soft robot arm, loaded at one end with an hanging load, has the other end constrained by a slowly rotating clamp. Depending on the load amount, the behaviour of this system switches from an 'elastica compass' to an 'elastica catapult';
- A strip with controlled ends. Universal surfaces collecting the critical boundary conditions for which the structure display snap-back instability is disclosed;
- A rod constrained by a sliding sleeve ending with a linear spring may display self-restabilization. In this case, at increasing load, the deflection initially increases and then progressively decreases until the rod is totally inserted into the sliding sleeve;
- A rod subject to transversal forces (twist or bending) and frictionless constraints generates a longitudinal propulsive force realizing (torsional or flexural) locomotion. This motion occurs by tranforming elastic energy in kinetic energy.

The presented structural systems are modelled as nonlinear elastic structures and solved analytically. Physical models have been designed, realized and tested, confirming the theoretical predictions.

The results represent innovative concepts ready to be used in advanced applications, as for example in soft-robotics and locomotion.

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Load sensor instability in microsystems for tensile testing of nanomaterials

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MEMS-based tensile testing devices are very powerful tools for mechanical characterization of nanoscale materials, as they allow for testing of micro/nano-sized components in situ electron microscopes. In a typical configuration, they consist of an actuator, to deliver force/displacement, and a load sensor, which is connected to the sample like springs in series. Such configuration, while providing a high resolution force measurement, can cause the onset of instability phenomena, which can later compromise the test validity. Such phenomena can be quantitatively discussed through the development of an analytical model, which allows to find a relationship between the rise of instability and the sensor stiffness, which is the key parameter to be optimized. Finally, a new device configuration is proposed to overcome such instability issues.

Experimental and numerical proof of dissipative instabilities induced by dry friction

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A new experimental setup, nicknamed 'Flutter machine', is proposed for the investigation of flutter and divergence instabilities in Beck's and Pflüger's columns (two types of cantilever elastic rod with an additional concentrated mass in the latter case). Flutter instability is a dynamical instability which passes undetected using static methods and is a phenomenon that can affect structures loaded with follower forces. The attempt to provide follower forces on elastic structures were done first by Herrmann et al. (1966) [1] and then by Sugiyama et al. (1995) [2]. They tried to apply follower forces respectively through a fluid flowing from a nozzle, or through a solid motor rocket fixed at the end of the structure. In both cases were revealed remarkable problems due to the complexity of the experimental setup so that follower forces were even considered of impossible practical realization. These complications were circumvent by Bigoni and Noselli [3], who induced follower forces on a special version of the Ziegler pendulum by dry friction via lever principle. Although innovative, the Bigoni and Noselli experimental apparatus does not allow applying follower forces in the case of diffuse elasticity such as Pflüger's column.

For this reason, the experimental setup proposed by Bigoni and Noselli has been completely redesigned and realized. By the new 'Flutter machine' flutter, divergence, and dissipation-induced instabilities on very complicated structures, such as Beck's and Pflüger's columns, can be easily investigated. This new setup opens new and unexpected possibilities to test the dynamical behaviour of structures under nonconservative load.

References

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Asymptotic modelling of the linear dynamics of laminated beams

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The precise determination of the natural frequencies of an elastic thin structure has great importance in engineering applications. Especially in the case of structures subjected to dynamic loads, the knowledge of the natural frequencies can prevent resonance phenomena, and, hence, the amplification of the eigenmodes and, finally, the definitive collapse of the structure. This becomes crucial in the case of thin three-dimensional beams and plates, and in the case of thin layered assemblies. When we are dealing with layered thin structures with strong contrasts in the geometry (small thicknesses) or in the mechanical properties (presence of ‘‘soft’’ or ‘‘rigid’’ layers), numerical instabilities can occur due to those differences and to the complicated finite elements discretization. Therefore, much attention has been directed towards the formal derivation of simplified models.

The objective of the present work is to derive a mathematical model of the linear dynamical behavior of a laminated beam and to characterize its natural frequencies by means of an asymptotic analysis. Although the results of this paper can be applied to different mechanical problems, the authors have been inspired by laminated glass beams that have been studied from a practical, experimental and theoretical point of view in [1]. In this work, we want to lay down a rational background to classical linear dynamical models of multilayer beam usually used in literature.

We consider a two-dimensional beam consisting of three thin layers made of linear elastic isotropic materials: the upper and lower layers are called adherents, the middle layer is called adhesive. In order to perform an asymptotic analysis (see [2]) of the dynamical problem, we choose a small real parameter ε which is used to scale respectively the thicknesses and the elastic moduli of the three layers. The thicknesses of the adherents are of order ε, while the thickness of the adhesive, being thinner than the upper and lower layers, is scaled with ε^2. The elastic moduli of the upper and lower layers remain unscaled, while the Lamé’s constants of the middle layer are scaled with ε^2 since the adhesive is considered to be softer than the adherents. We characterize the limit kinematics, the limit eigenvalue problems and the associated limit natural frequencies corresponding to three different models of free vibrations for the laminated beam: the low, mean and high frequencies. This work can be extended to other layered beam and plate models with soft adhesive derived in [3].

References

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Dynamic analysis of ancient masonry towers by the Non-Smooth Contact Dynamics method

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The dynamics of historical masonry buildings is one of the most difficult task to be investigated in structural dynamics, since this kind of structures are commonly heterogeneous, with complex geometry, and with unknown quality of the connections between different structural parts, in particular walls and floors, that often play a crucial role. However, understanding the dynamical behavior is crucial for a reliable assessment, which became more and more important due to recent catastrophic earthquakes (Umbria-Marche 1997–1998, Abruzzo 2009, Emilia-Romagna 2012, Marche-Lazio-Umbria-Abruzzo 2016).

In this work the nonlinear dynamics of a medieval tower belonging to the Metropolitan Cathedral-Basilica of Saint Cyriacus in Ancona (Italy) is investigated. The building is an example of mixed Romanesque-Byzantine and Gothic elements, and stands on the site of the former acropolis of the Greek city, the Guasco hill which overlooks Ancona and its gulf.

To investigate the mechanical behavior of masonry towers, commonly finite element methods are utilized [1], often including very sophisticated constitutive laws taking into account post-elastic behaviors and damage. These methods, while being very appealing, do not focus on the possible non-smooth nature of the dynamic response, which can come sliding and impacting between different blocks, and situation that is common just before and during the collapse. For this reason, in the present paper, the dynamics of the Saint Cyriacus tower is investigated by means of a distinct element code that implements the Non-Smooth Contact Dynamics method (NSCD) [2].

The main goal is to determine the weakness zones of the structure during a dynamic action, and the possible collapse mechanisms. Harmonic oscillations applied to the basement of the tower is considered first, and a systematic parametric study is done, aimed at correlating the tower vulnerability to the amplitude and frequency of the excitation. In addition, numerical analyses are performed to see the effects of the friction coefficient and of the blocks geometry on the dynamics, and on the collapse modes. Then, the study of the tower stability against recorded seismic excitations is addressed.

References

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Critical and postcritical behavior of the Nicolai column

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The Nicolai paradox, concerning the loss of stability of a column subjected to an evanescent follower torque, is here analyzed in the linear and nonlinear regimes. A paradigmatic, discrete, minimal mechanical system is introduced, roughly describing the column. First, the linear stability problem is addressed by performing a perturbation of a double semi-simple eigenvalue, thus highlighting the beneficial effect of damping and imperfections on the symmetry, and giving an explanation of the paradox. Then the bifurcation equations, ruling the dynamics around a semisimple Hopf bifurcation, are derived via the Multiple Scale Method and the postcritical behavior of the system is investigated. It is shown that, while the trivial equilibrium configuration of the system is rendered unstable by vanishingly small circulatory forces, nonlinearities can, under certain conditions, limit the amplitude of the oscillations. The existence of unsafe initial conditions is discussed, and the dangerous effects of the follower torque, also in nonlinear regime, are highlighted. Finally, the linear and nonlinear analyses, developed on the discrete paradigmatic system, are generalized to the continuous Nicolai beam.

Paradoxes in dynamic stability of beams: investigating the causes and detecting the nonlinear behaviors

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There exist several paradoxes in mechanics; the most amazing, may be occur in stability analysis. A celebrated problem is the 'Ziegler Paradox', also known as the 'destabilizing effect of damping', according to which small damping has a detrimental effect on the stability of a circulatory system. The Beck's beam, i.e. a cantilever beam loaded at the tip by a follower force, is the prototype of such a paradox. A second paradox, recently discovered by the authors, concerns the stability of piezo-electro-mechanical systems, where the control strategy based on the 'similarity principle', usually working in controlling vibrations, has instead detrimental effects on the occurrence of dynamic bifurcations.

These phenomena are studied in this work and the reasons of the paradoxes are explained, by performing asymptotic expansions of the eigenvalues of the tangent operator. In some cases, the problems are discussed in new perspectives, with respect to the techniques commonly used in literature, and new mechanical interpretations are provided.

These problems, however, concern linear stability of beams. No papers known to the authors have been devoted to investigate the post-critical behavior of such paradoxical systems. Here, the problem is addressed in the framework of the asymptotic analysis, carried out via the Multiple Scale Method. The algorithms have been developed by the senior author and his coworkers in the last decade, and are believed to represent a valid alternative to the more popular Center Manifold and Normal Form Theories. The limit cycle, which arises after the occurrence of simple Hopf bifurcations, is determined, and the influence of the parameters is studied. It is found that a careful modelling of nonlinear damping is needed, since the linear laws usually adopted leads, in some cases, to very large (and may be unrealistic) amplitude of vibrations.

It is wished that the studies presented here will stimulate also experimental activity, necessary to validate the theoretical predictions.

Perspectives and trends in stability analysis of nonconservative systems

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Nonconservative autonomous systems suffer dynamic instability, manifesting via Hopf bifurcations. These entail the occurrence of oscillations of large amplitude, possibly stabilizing on limit cycles, when a critical value of a bifurcation parameter is exceeded. The l'Aquila school has developed in the last two decades several perturbation algorithms, able to deal with a large class of bifurcations, namely simple and multiple Hopf, resonant and nonresonant, defective and non-defective, for both discrete and continuous systems. Such algorithms, based on the Multiple Scale Method, represent a valid, and more efficient, alternative to the more known Center Manifold Method and Normal Form theory.

The attention is nowadays focused on a variety of physical systems prone to dynamic instability, aimed at: (a) correctly modelling their mechanical behavior, mainly concerning the internal damping, (b) modelling the velocity-dependent aerodynamic forces (via steady, quasi-steady and unsteady theories), (c) introducing passive control devices.

Differently from the current literature, in which aeroelastic phenomena are studied via discrete models, continuous models are proposed, aimed at understanding: (a) if the wind forces are or not able to modify the critical mode, and in which circumstances; (b) if the critical mode can be changed from real to complex. It is argued that such modifications could be induced by a more refined modelling of internal damping and/or of the aerodynamic action.

Some possible applications will be discussed, concerning: (1) flexural-torsional flutter of thin-walled beams under follower forces; (2) galloping of inclined iced cables under wind forces, possibly accounting for wind velocities variable with the quota; (3) dry galloping of cables; (4) multimodal galloping of high-modal density structures, as multispan electrical conductor lines, possibly exhibiting localization phenomena.