3rd International Conference on Structural Nonlinear Dynamics and Diagnosis

M. Belhaq, M. Houssni & I. Kirrou

Group of Energy and Nonlinear Dynamics
Department of Physics
Faculty of Sciences Aïn chock

University Hassan II – Casablanca

CSNDD 2016

Conference on Structural Nonlinear Dynamics and Diagnosis

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Booklet of Abstracts

Eds.: M. Belhaq, M. Houssni & I. Kirrou

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The abstracts of the paper in this Booklet were set individually by the authors. Only minor typographical changes have been made by the local organizing committee.

Booklet of Abstracts

Preface

The 1^{st} and 2^{nd} International Conference on Structural Nonlinear Dynamics and Diagnosis (CSNDD 2012 and CSNDD 2014) organized by the Group of Nonlinear Dynamics, Hassan II University-Casablanca were held, respectively, in Marrakech, April 30-May 2 and in Agadir, May 19-21. Both conferences have attracted a representative international scientific community in nonlinear dynamics, diagnosis and control. More than 300 scientists from 30 countries attended the meetings. Thirty mini-symposia were organized by leading experts in nonlinear dynamics, who contributed to attract top-quality scientists.

Following the success of the two last versions of the conference, the nonlinear dynamics group of Hassan II University-Casablanca is pleased to organize the 3^{rd} version of the conference in the charming city of Marrakech, May 23-25, 2016.

The 3^{rd} CSNDD 2016 provides a meeting place where scientists working in nonlinear dynamics and control in different branches of applied mathematics, advanced physics and mechanics can meet to discuss the latest achievements and to exchange ideas in theoretical, numerical and experimental techniques. Focuses are directed toward diverse topics, ranging from dynamical systems theory to different physical and engineering applications. The CSNDD 2016 topics cover a large field of complex dynamics, including:

Nonlinear dynamics in spatially extended systems
Deterministic and stochastic dynamics
Mechanical, aeronautic, aerospace and naval structures
Stability of rotating machines
Model reduction methods
Nonlinear PDEs and their dynamics
Structural health monitoring and damage detection
Multiple time scale dynamical systems
Optimization and reliability in structural vibrations
Nonlinear dynamics in MEMS/NEMS/AFM
Nonlinear dynamics of flexible structures
Dynamics of non-smooth systems
Rogue waves, solitons, and supercontinuum in nonlinear fiber optics

It is a great privilege for the nonlinear dynamics group in Casablanca to host the CSNDD 2016 and to sustain such a high-level meeting in a developing country.

I am happy to report that the 3^{rd} CSNDD 2016 has already accomplished its goal. The meeting has attracted more than 200 participants from more than 35 countries. Twelve keynote lectures are invited and 24 minisymposia are organized by leading experts in nonlinear dynamics. More than 120 oral presentations are scheduled and about 60 poster presentations are expected.

On the behalf of the organizing committee, I would like to thank the Keynote lecturers, the invited speakers, the minisymposia organizers as well as reviewers for their precious help in maintaining a high-quality scientific program of the conference.

At the same time, I would like to thank all participants, PhD students, colleagues and friends who meaningfully helped with the organization.

On behalf of the CSNDD 2016 committees, welcome to Marrakech. Enjoy a scientific stimulating and socially nice conference!

Mohamed Belhaq
CSNDD 2016 Chair

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The 3rd *International Conference on Structural Nonlinear Dynamics and Diagnosis* takes place in Marrakech, Morocco, **May 23 - 25, 2016**.

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M. Belhaq, M. Houssni & I. Kirrou, *3rdInternational Conference on Structural Nonlinear Dynamics and Diagnosis* (CSNDD 2016).

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Scientific Program

The scientific program includes:

- Plenary Lectures
- Minisymposia Sessions and Poster Sessions on pre-defined topics

The minisymposia are organized through parallel lecture sessions. As a rule, the available time slot per lecture presentation is 20 min, including discussion. For some specific lecture presentations, they can be longer (30 min).

Plenary Lectures

- Raouf Ibrahim, Wayne State University, USA
  Road tanker dynamics interacting with liquid sloshing dynamics
- Habil Michael Hanss, University of Stuttgart Germany
  Uncertainties in modeling and simulation-chance and challenge
- Ferdinand Verhulst, University of Utrecht, The Netherlands
  Inhomogeneous Fermi-Pasta-Ulam chains
- Christian Boller, University of Saarbrücken, Germany
  Damage tolerance in ageing steel infrastructure as a means for life cycle management
- Jinhao Qiu, Nanjing University of Aeronautics and Astronautics Nanjing, China
  Elastic constants identification and fatigue evaluation of composite materials based on elastic wave
- Edriss S. Titi, University of California-Irvine, USA
  Mathematics of turbulent flows: A million dollar problem!
- Nail Akhmediev, Australian National University, Australia
  Solitons, breathers and rogue waves basic theory and higher-order effects
- Walter Lacarbonara, Sapienza University of Rome, Italy
  Nonlinear dynamics for design: challenges and opportunities
- Marian Wiercigroch, University of Aberdeen, UK
  Grazing-induced bifurcations in impact oscillators
- Mario Di Paola, University of Palermo, Italy
  New trends for the probabilistic response of nonlinear system under stochastic agencies
- Peter Eberhard, University of Stuttgart, Germany
  Beauty of particle simulations

Minisymposia and chairs

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  D.B. Haviland (Sweden), S.M. Sah (Sweden), N. Kacem (France), F. Najar (Tunisia)

- **MS2. Monitoring and diagnosis of structures and assemblies**
  M. Ichchou (France), O. Bareille (France)
- **MS3. Nonlinear dynamics in spatially extended systems: theory and experiments/Rogue waves, solitons, and supervontinum in nonlinear fiber optics: Where are we now?**
  M. Tlidi (Belgium), A.G. Vladimirov (Germany), A. Taki (France), S. Grevich (Germany)
- **MS4. Nonlinear dynamics in spatially extended systems: theory and experiments/Rogue waves, solitons, and supervontinum in nonlinear fiber optics: Where are we now?**
  M. Tlidi (Belgium), A.G. Vladimirov (Germany), A. Taki (France), S. Grevich (Germany)
- **MS5. Analytical and semi-analytical methods in nonlinear dynamics**
  J. Awrejcewicz (Poland), R.H. Rand (USA), K.W. Chung (Hong Kong)
- **MS6. Deterministic and stochastic dynamics and control of nonlinear systems**
  J.M. Balthazar (Brazil), M.E.Semenov (Russia), P.B. Gonçalves (Brazil)
- **MS7. Mechanical, aeronautic, aerospace and naval structures: mathematical modeling, nonlinear and chaotic dynamical behaviors and control designs**
  J.M. Balthazar (Brazil), E.M. Jarzebowska (Poland)
- **MS8. Stability of rotating machines and energy harvesting**
  J. Mahfoud (France), N. Kacem (France)
- **MS9: Special Session**
  K. Allali (Morocco), M.E. Semenov (Russia)
- **MS10. Model reduction methods dedicated to low/high frequency system dynamics**
  N. Bouhaddi (France), M. Ichchou (France)
- **MS11. Nonlinear PDEs and their dynamics**
  E.S. Titi (USA)
- **MS12. Multiple time scale dynamical systems**
  J. Starke (Denmark)
- **MS13. SHM and damage detection**
  S. Masri (USA), G.R. Gillich (Romania)
- **MS14. Optimization and reliability in structural vibrations**
  A. El Hami (France), B. Radi (France)
- **MS15. Nonlinear dynamics of flexible structures: thermoelastic vibrations, rotating thin-walled beams, composite structures and delamination problems**
  J. Warminski (Poland), E. Manoach (Bulgaria)
- **MS16. Dynamics of non-smooth systems**
  M. Wiercigroch (UK), M. Jeffrey (UK)

Conference Synthetic Timetable

Registration (Adam Park Hotel, Marrakech)

- Sunday, May 22, 16:00–22:00

Monday, May 23, 2016

08:00–09:00	***Registration***
09:00–09:15	Opening Ceremony
09:15–09:45	Opening Plenary Lecture 1: Raouf Ibrahim
09:45–10:15	Plenary Lecture 2: Machael Hanss
10:15–11:00	***Conference Photo and Welcome Reception***
11:00–11:30	Plenary Lecture 3: Ferdinant Verhulst
11:30–12:00	Plenary Lecture 4: Christian Boller
12:00–12:30	Plenary Lecture 5: Jinhao Qiu
12:30–14:00	***Lunch***
14:00–15:30	Minisymposia (Parallel Sessions: S1, S3, S5, S12)
15:30–16:00	***Coffee Break and Poster Session***
16:00–17:30	Minisymposia (Parallel Sessions: S1, S3, S5, S6)

Tuesday, May 24, 2016

08:30–09:00	Plenary Lecture 6: Idriss Titi
09:00–09:30	Plenary Lecture 7: Nail Akhmediev
09:30–10:00	Plenary Lecture 8: Walter Lacarbonara
10:00–10:30	***Coffee Break***
10:30–12:10	Minisymposia (Parallel Sessions: S2, S3, S6, S13)
12:10–14:30	***Lunch***
14:30–16:15	Minisymposia (Parallel Sessions: S3, S7, S11, S15)
16:15–16:50	***Coffee Break and Poster Session***
16:50–18:30	Minisymposia (Parallel Sessions: S3, S11, S14, S15)

Wednesday, May 25, 2016

08:30–09:00	Plenary Lecture 9: Marian Wiercigroch
09:00–09:30	Plenary Lecture 10: Mario Di Paola
09:30–10:00	Plenary Lecture 11: Peter Eberhard
10:00–10:30	***Coffee Break***
10:30–12:20	Minisymposia (Parallel Sessions: S8, S10, S16, S9)
12:30–12:45	***Closing***
12:45–14:00	***Lunch***
15:00	**City Tour**

Technical Program

	Monday, May 23, 2016		Tuesday, May 24, 2016		Wednesday, May 25, 2016
08:00	**Registration**	08:30	Plenary Lecture 6 **Edriss S. Titi**	08:30	Plenary Lecture 9 **Marian Wiercigroch**
09:00	Opening Ceremony	09:00	Plenary Lecture 7 **Nail Akhmediev**	09:00	Plenary Lecture 10 **Mario Di Paola**
09:15	Opening Plenary Lecture 1 **Raouf Ibrahim**	09:30	Plenary Lecture 8 **Walter Lacarbonara**	09:30	Plenary Lecture 11 **Peter Eberhard**
09:45	Opening Plenary Lecture 2 **Machael Hanss**				
10:15	**Conference Photo and Welcome Reception**	10:00	**Coffee Break**	10:00	**Coffee Break**
11:00	Plenary Lecture 3 **Ferdinant Verhulst**	10:30	S16 / S6 / S3 / S2	10:30	S8 / S16 / S10 / S9
11:30	Plenary Lecture 4 **Christian Boller**				
12:00	Plenary Lecture 5 **Jinhao Qiu**			12:20	**Closing**
12:30	**Lunch**	12:10	**Lunch**	12:35	**Lunch**
14:00	S1 / S5 / S3 / S12	14:30	S7 / S15 / S3 / S11	15:00	**City Tour**
15:30	**Coffee Break & Poster Session**	16:15	**Coffee Break & Poster Session**		
16:00	S1 / S5 / S3 / S6	16:50	S14 / S15 / S3 / S11		

Abstracts

Plenary Lectures Abstracts

Scheduled:

Monday *9:20–12:35* Adam Park Hotel **Room Louka**

Road tanker dynamics interacting with liquid sloshing dynamics

Mon. 09:15–09:45 R Louka

Raouf Ibrahim

Wayne State University, Department of Mechanical Engineering, Detroit, USA

The problems encountered with the design, dynamics and stability of road tankers and their interaction with liquid sloshing dynamics are identified. Generally, the research activities pertaining these problems may be classified into three groups. These are liquid sloshing dynamics in moving containers, trucks dynamics carrying solids, and dynamic coupling of liquid-vehicle systems. The most serious problems of road tankers is rollover accidents due to lateral acceleration during vehicle maneuvers. For this reason many countries have imposed regulations for the minimum threshold of vehicle lateral acceleration during its maneuvers. This threshold value is usually estimated on quasi-dynamic approach which assumes that the liquid the free surface takes a position orthogonal to the total body forces due to gravity and lateral acceleration. The modal analysis of liquid free surface on common tank cross-section geometries, such as horizontal circular, elliptic and generic cross section is presented together with the corresponding equivalent mechanical models. In particular, the trammel equivalent pendulum received extensive research activities and the main results are discussed. In order to minimize the problem of rollover, two approaches have received the attention of engineers. These are the design optimization of the liquid container cross section and the passive and active control of liquid sloshing. The most difficult problem of road tankers is the coupling dynamics of liquid and vehicle dynamics under different conditions such as braking and lateral acceleration. In view of its complex nature, computer numerical simulations have been developed.

Uncertainties in modeling and simulation-chance and challenge

Mon. 09:45–10:15 R Louka

Michael Hanss

Institute of Engineering and Computational Mechanics, University of Stuttgart, Germany

A common problem in the numerical simulation of complex real-world systems is the fact that the parameters of the models can exhibit a high level of uncertainty and exact values for their quantification can hardly be provided. This non-determinism in numerical models may arise as a consequence of different sources: natural variability or scatter, which is often referred to as aleatory uncertainties, as well as so-called epistemic uncertainties, which arise from an absence of information, vagueness in parameter definition, subjec-

tivity in numerical implementation, or simplification and idealization as it usually appears in every modeling procedure.

While aleatory uncertainties have successfully been taken into account by the use of probability theory, the additional modeling of epistemic uncertainties still remains a challenging topic. As a practical approach to solve this limitation, an interdisciplinary methodology to an advanced modeling and analysis of systems is presented, which allows for the inclusion of uncertainties from the very beginning of the modeling procedure. This approach is based on fuzzy arithmetic, a special field of fuzzy set theory, where the uncertain values of the model parameters are represented by so-called fuzzy numbers, which reflect in a rather intuitive and plausible way the blurred range of possible parameter values. As a result of this advanced modeling technique, more comprehensive system models can be derived which outperform the conventional, crisp-parameterized models by providing simulation results which reflect both the system dynamics and the effect of the uncertainties. Moreover, making use of measured data within a new approach based on inverse fuzzy arithmetic, the comprehensive system models can be used to effectively validate the models and to rate different models for the same physical system with respect to their appropriateness and quality.

The methodologies are illustrated by a number of exemplary applications from different fields of mechanical engineering which demonstrate that advanced modeling and simulation techniques using some well-thought-out inclusion of the presumably limiting uncertainties can provide significant additional benefit, revealing the uncertainties to be both challenge and chance.

Inhomogeneous Fermi-Pasta-Ulam chains

Mon.
11:00–11:30
R Louka

Ferdinand Verhulst

Mathematic Institute, University of Utrecht, The Netherlands

In contrast to the classical Fermi-Pasta-Ulam (FPU) chain, the inhomogeneous FPU chain shows nearly all the principal resonances. Using this fact, we can construct a periodic FPU chain of low dimension, for instance a FPU cell of four degrees-of-freedom that can be used as a building block for a chain of FPU cells.

Differences between chains in nearest-neighbour interaction and those in overall interaction are caused by symmetry. We will also show some results on the dynamics of a particular chain of FPU cells where different kinds of chaos play a part. This causes various recurrence phenomena.

Damage tolerance in ageing steel infrastructure as a means for life cycle management

Mon.
11:30–12:00
R Louka

Christian Boller

Universitat des Saarlandes, Saarbrücken, Germany

Steel is a structural material that has now been around in civil engineering for more than two centuries. An increasing number of those steel structures being one hundred years or more in age and listed in many of the cases is one class of structures to be considered. Another is the group of structures that have been established during a period of specific economic growth would it have been the establishment of road or railway traffic in general or after detrimental events such as wars or revolutions. All of those structures have been designed in accordance to the scientific and technological knowledge and the economic needs at the time of their design and establishment. Around a century or more ago not much was known with regard to fatigue, fracture or corrosion and even when this was known the resulting implications on the infrastructure have been mainly covered by respective safety factors. In our current terms those structures have therefore been designed ’safe life’. Another important implication on many of those structures is the loads being applied. No designer has ever been able to predict the traffic or environmental loads our civil infrastructure had been finally have to withstand today. This all has resulted in an increased inspection effort required for this infrastructure, with the effort being near to fully manpower driven. However, this inspection effort could be automated to a large extent would much of today’s technology be better integrated into this infrastructure’s life assessment. The paper to be presented will look into the breadth of structural mechanics on the one side, such as structural loads (static and dynamic), design principles, fatigue and fracture, and on the other side to a large amount of analytic and simulation technology ranging from materials and structural characterisation over a variety of inspection technologies based on non-destructive testing to sensing systems and strategies in the sense of structural health monitoring (SHM). This will allow an advanced structural assessment based on damage tolerance principles to be performed that will most likely lead to an extension of an infrastructure’s operational life and a better management of infrastructure in general, would it be its maintenance or structural integrity.

Elastic constants identification and fatigue evaluation of composite materials based on elastic wave

Mon.
12:00–12:30
R Louka

Jinhao Qiu

Nanjing University of Aeronautics and Astronautics, Nanjing, China

Nine elastic constants are necessary to describe the elastic properties of composite materials of unidirectional laminae. If they are assumed to be transversely isotropic, five independent elastic constants are still necessary. Usually the measurement of these constants is tedious and some of them are even difficult to measure precisely. Hence it is desirable to establish a method that can reconstruct these constants at the same time. On the other hand, fatigue of composite materials has become an important issue as the percentage of composite materials in aircraft structures increases continuously. However the in-situ fatigue evaluation of composite structure is still a difficult problem.
In this talk the application of laser ultrasonic method in visualization of wave field and damage, identification of elastic constants and fatigue evaluation of composite materials are introduced. First, a laser ultrasonic scanning system was established and applied to visualization of wave propagation in anisotropic composite materials. A third -order plate theory was also proposed for computation of phase velocity and dispersion curves of elastic wave in composite materials. Then the anomalous incident wave (AIW) energy was obtained from the wave-field data to image the damages, including artificial damage and impact damage in the composite materials. The laser ultrasonic method was also used to measure the phase velocity of Lamb wave in the composite material, which in

turn was used for reconstruct the parameters of the composite material by minimizing the difference between the theoretical and experimental phase velocities.
Since the phase velocity of composite materials mainly depends on the elastic constants, it can be used to evaluate the fatigue state of the materials. The relationship between the phase velocity and loading cycle was established through fatigue test of composite materials. The conversion ratio of different modes of elastic wave was also found to be an important fatigue index of composite materials due to the increase of nonlinearity during fatigue process.

Scheduled:

Tuesday *9:00–10:30* Adam Park Hotel **Room Louka**

Mathematics of turbulent flows: A million dollar problem!

Tue.
08:30–09:00
R Louka

Edriss S. Titi

Texas A&M University

Turbulence is a classical physical phenomenon that has been a great challenge to mathematicians, physicists, engineers and computational scientists. Chaos theory has been developed in the end of the last century to address similar phenomena that occur in a wide range of applied sciences, but the eyes have always been on the big ball - Turbulence. Controlling the identifying the onset of turbulence has a great economic and industrial impact ranging from reducing the drag on cars and commercial airplanes to better design of fuel engins, weather and climate predictions.
It is widely accepted by the scientific community that turbulent flows are governed by the Navier-Stokes equations, for large Reynolds numbers, i.e. when the nonlinear advective effects dominate the linear viscous effects (internal friction within the fluids) in the Navier-Stokes equations. As such, the Navier-Stokes equations form the main building block in any fluid model, in particular in global climate models. Whether the solutions to the three-dimensional Navier-Stokes equations remain smooth, indefinitely in time, is one of the most challenging mathematical problems. Therefore, it was identified by the Clay Institute of Mathematics as one of the seven most outstanding Millennium Problems in mathematics, and it has set one million US dollars prize for solving it. Notably, reliable computer simulations of turbulent flows is way out of reach even for the most powerful state-of-the art supercomputers. In this talk I will describe, using layman language, the main challenges that the different scientific communities facing while attempting to attack this problem. In particular, I will emphasize the mathematical point of view of turbulence.

Solitons, breathers and rogue waves basic theory and higher-order effects

Tue.
09:00–09:30
R Louka

Nail Akhmediev

Research School of Physics and Engineering, Australian National University, Australia

Breathers introduce a new dimension into the seemingly well-known world of solutions of integrable evolution equations such as the well-known nonlinear Schrödinger equation.

They have drawn much attention recently because of their interactions and energy exchange with a constant background. Such interactions produce unique behaviors that are different from the usual soliton dynamics. Breathers are solutions that are periodic in space or in time. They are classified as either Kuznetsov-Ma solitons or Akhmediev breathers. The large-period limiting case of each is a Peregrine solution, which is localized both in space and time and which has been considered as a prototype of a rogue wave. As such, it is known as a wave that "appears from nowhere and disappears without a trace". The Peregrine solution has been observed both in water waves and in optics.

The nonlinear Schrödinger equation is a key example of a model for nonlinear wave evolution, describing a multiplicity of phenomena that arise in oceans, optical fibres, and many other physical disciplines. Being general, it captures the basic features of nonlinear propagation but leaves aside certain finer details of interest. More accurate models do allow higher-order effects to be considered, but often at the expense of losing integrability, a characteristic that is convenient for generating exact solutions. In fact, only a few evolution equations improving the accuracy of the NLSE are known to be integrable. Expanding this family is an important task that may provide qualitative steps forward in the study of nonlinear wave propagation.

Recent publications have revealed the intricate relation between the soliton and breather solutions of a certain class of evolution equations. Breathers can be converted into solitons with special perturbations. Solitons themselves can evolve into the form of breathers. Even the Peregrine solution can be converted into an infinitely elongated structure at certain conditions. There are special cases where breather oscillations can be suppressed, and, in those cases, breathers may be transformed into solitons. Mutual conversions between the two become possible when the evolution equation contains a sufficient number of free parameters that can be used to control their solutions.

Nonlinear dynamics for design: challenges and opportunities

Tue.
09:30–10:00
R Louka

Walter Lacarbonara

Department of Structural and Geotechnical Engineering, Sapienza University of Rome, Italy

Nonlinear dynamics is a mature field of research that has been traditionally focused on investigation and prediction of dynamical phenomena ensuing from system nonlinearities and/or interaction force fields. There is an on-going paradigm shift in the design of high performance structures and devices by which new ways are sought to exploit advantageously different kinds of nonlinearities at different scales rather than constraining operations to overcome the onset of nonlinear phenomena. Advanced tools of robust nonlinear modelling, analysis, and optimization can be turned into powerful design tools tailored for achieving high levels of vibration control authority and synthesis of engineered systems and materials.

First, the general principles of active resonance cancellation based on perturbation techniques are illustrated in the context of magnetically levitated bodies, cranes, and beams. The active control inputs delivered by the different actuators can be shaped to suppress resonances possessing an activation threshold as is the case for parametric resonances or subharmonic/superharmonic resonances.

Nonlinear passive absorbers based on hysteretic constitutive nonlinearities can also be designed to outperform linear viscoelastic absorbers in predefined ranges of operation.

This is achieved by using wire ropes made of shape memory material and steel for which the interwire friction and the SMA phase transformations are the primary mechanisms of energy dissipation. In this context, perturbation methods are also employed to drive the optimization process triggered by the approximate nonlinear solutions afforded by asymptotics. Examples are shown dealing with sway control of a five-story building and flutter control of a long-span bridge.
In conclusion, recent advances on high-damping nanomaterials made of a hosting matrix with dispersed carbon nanotubes are discussed. The microhysteresis exhibited as stickslip between carbon nanotubes and the matrix can be tuned within the developed computational framework to optimize vibration absorption up to unprecedented levels.

Scheduled:

Wednesday *08:30-10:00* Adam Park Hotel **Room Louka**

Grazing-induced bifurcations in impact oscillators

Wed.
08:30–09:00
R Louka

Marian Wiercigroch

School of Engineering, University of Aberdeen, Aberdeen, UK

Forced oscillators with impacts have been widely studied since they have many engineering applications such as rotating machinery, car suspension systems, cutting processes, and others. There are two different methods of impact modelling, namely rigid and elastic impacts. The rigid impacts usually can be modelled by using the coefficient of restitution rule, which assumes an instantaneous reversal of velocity. The elastic impact modelling assumes finite stiffness during impacts. There is no previous study which looks in detail at the differences between these two approaches, however, Blazejczyk-Okolewska et al. preliminary compared rigid and elastic models.

Grazing bifurcations have been intensively studied since they may cause complex dynamics. Foale classified the types of grazing bifurcation in a class of rigid impact oscillators and presented analytical results to show how the type of grazing bifurcation changes with a control parameter. Later on, Foale and Bishop classified and compared the first grazing bifurcation of two different models of impact oscillators, i.e. impact oscillators with the instantaneous coefficient of restitution impact law and the Hertz contact law. Recently, much attention has been paid to the interplay between smooth and non-smooth bifurcations since it plays an important role of the system dynamics near grazing. Ing et al. carried out experimental and numerical studies of an impact oscillator with one-sided elastic constraint near grazing to show the complex dynamics, which is induced by a transition between smooth and non-smooth bifurcations.

This paper compares the grazing-induced bifurcations in impact oscillators with one-sided soft and rigid constraints by the path-following (continuation) method. The grazing bifurcations are computed and classified for both oscillators. Two-parameter smooth (period-doubling, saddle-node) and non-smooth (grazing) bifurcations are analyzed. Frequency response curves including bifurcation points are determined for different values of stiffness ratios and restitution coefficients. As the stiffness ratio increases, the constraint changes from soft to rigid and the bifurcation structure varies correspondingly. Numerical results show that for the impact oscillators with one-sided soft constraint, the smooth (period-doubling, saddle-node) bifurcations approach the non-smooth (grazing) bifurcations as the stiffness ratio increases while for the impact oscillators with one-sided rigid constraint, none smooth bifurcation exists near the non-smooth (grazing) bifurcation points.

New trends for the probabilistic response of nonlinear system under stochastic agencies

Wed.
09:00–09:30
R Louka

Mario Di Paola

Università degli Studi di Palermo, Viale delle Scienze, Palermo, Italy

The probabilistic response of nonlinear systems under white noise processes is a subject of relevant interest in many research fields, including physics, chemistry and engineering. In the last decades, solution of Fokker-Planck equations (normal white noise input), fractional Fokker-Planck equations (α-stable Levy white noise input), and Kolmogorov-Feller equations (Poissonian white noise input) have been the subject of many research works. Approximate analysis technique in terms of moments or cumulants, stochastic averaging, finite element methods and so on, do not produce accurate results and in some cases the positivity of the probability density function is not guaranteed.
The new trends in this subject are the path integration method and the use of complex fractional moments for solving the three aforementioned equations. The former is very versatile and is able to find the PDF step-by-step starting from the Chapman-Kolmogorov equation. The latter is related to the use of new quantities called complex fractional moments that are neither else than the Mellin transform of the PDF.
Applications to barrier problems, vibro-impact system, and system with strong nonlinearity forced by different kind of white noise are presented, in order to show the capabilities of such new methods.

Beauty of particle simulations

Wed.
09:30–10:00
R Louka

Peter Eberhard

Institute of Engineering and Computational Mechanics, University of Stuttgart, Germany

Simulation became an indispensible tool in the modern design process and there are several well established methods available like the finite element method or grid-based computational fluid dynamics. However, there are situations where these well investigated methods have weaknesses or can even not be applied at all.
For these challenging problems meshless methods can be an interesting alternative enriching and completing the toolbox of the engineer. In this talk two methods, the Discrete Element Method (DEM) and Smoothed Particle Hydrodynamics (SPH), are introduced.
The methods are illustrated by a number of applications from different fields of engineering. Examples from fluid dynamics, from fluid-structure interaction, from material pro-

cessing and others are presented and challenges and limitations are shown. Although the presented methods are quite young compared to some of the well established computation methods they clearly already show their high potential. However, also some numerical problems and stability issues exist and concepts to overcome these challenges are introduced. The mechanics of particles became a very active area of research with own conferences, journals, and a lively research community and progress is fast.
Particle simulations are always time consuming and require a lot of resources and care. In order to reduce computation times, parallel computation is advisable and approaches running our simulations on super computers will be introduced briefly, too.

Orale presentations

MS 1
Nonlinear dynamics in MEMS/NEMS/AFM

Organizers: *D.B. Haviland* Sweden, *N. Kacem* France, *F. Najar* Tunisia, *S.M. Sah* Sweden

Scheduled:

Monday	*14:00–15:30*	Adam Park Hotel	**Room Louka**
Monday	*16:00–17:45*	Adam Park Hotel	**Room Louka**

The intermodulation spectral technique for measurement of mechanical response at the nanometer scale

Mon.
14:00–14:20
R Louka

D.B. Haviland[1], D. Forchheimer[1], D. Platz[1], E.A. Tholén[2], R. Borgani[1], P.A. Thorén[1], S.M. Sah[1]

[1] *Nanostructure Physics, Royal Inst of Technology (KTH), Stockholm, Sweden*
[2] *Intermodulation Products AB, Solna, Sweden*

We give an overview of Intermodulation Atomic Force Microscopy (ImAFM) [1] and application for measurement of mechanical response [2,3], surface potential [4], and tip-surface forces at the transition from static to dynamic friction. ImAFM is based on phase-coherent measurement of the mixing products, or intermodulation products of two or more drive tones applied to a nonlinear system. The method uses a unique multifrequency lock-in measurement method that eliminates cross-talk, or Fourier leakage between numerous, closely separated frequency bands [5]. The response amplitude and phase are simultaneously measured in 'real time' at multiple tones in a frequency comb, as many as 42 frequencies (i.e. 84 channel lockin).

For a nonlinear system, like an AFM cantilever tapping on a surface, the measured response is the result of very high-order intermodulation, or frequency mixing of the applied drive tones. Analysis of this intermodulation reveals the forces acting on the tip. ImAFM can be considered as a hybrid between the two main branches of dynamic AFM: frequency modulated AFM (FM-AFM) and amplitude modulated AFM (AM-AFM). The difference being that ImAFM actively modulates the harmonic drive force. The measurement reveals how the tip-surface interaction changes the drive modulation.

When ImAFM is preformed with a cantilever having a high Q resonance, high force sensitivity is achieved in the narrow band around resonance and tip motion is restricted to this band. The situation lends itself to analysis of tip-surface interactions in terms of dynamic force quadratures [6]. A direct transformation of the intermodulation spectrum reveals the oscillation amplitude dependence, of the forces that are in phase with the harmonic tip motion, and those which are quadrature to the motion, or in phase with the velocity. This transformation makes no assumptions as to the nature of the tip-surface interaction, allowing for detailed analysis and critical examination of the models commonly used to describe tip-surface interaction.

Recently, we have applied the amplitude-dependent dynamic force quadratures to show that the response in dynamic AFM on soft materials can not be understood in terms of the simple force vs. distance curves traditionally used in quasi-static AFM. We demonstrate how the visco-elastic nature of the soft-material surface, with a finite relaxation time due to its viscosity, lead to complex nonlinear dynamics of the coupled cantilever-surface system. We introduce a ‘moving surface model’ which allows us to simulate the surface motion, not measured in the experiment. The excellent agreement between the cantilever motion simulated with this model, and that measured in experiment, give us confidence that the model is correct. With this model we can extract the true elastic and viscous constants of soft material interface.

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Intermodulation and multifrequency kernel analysis in atomic force microscopy

Mon.
14:20–14:40
R Louka

D. Platz[1,2], D. Forchheimer[2,3], E.A. Tholén[3], D.B. Haviland[2]

[1] *Max Planck Institute for the Physics of Complex Systems, Dresden, Germany*
[2] *KTH Royal Institute of Technology, Stockholm, Sweden*
[3] *Intermodulation Products AB, Solna, Sweden*

High-quality-factor resonators are increasingly used in a wide variety of ultra-sensitive measurements of force mass and motion. High quality factor means that the oscillator can respond with large changes in oscillation amplitude or phase, to very small changes in a perturbing force. The dominant measurement paradigm for exploiting this enhanced sensitivity is based on driving the resonator with one pure tone near its resonance while monitoring the response to the perturbation as a change of amplitude or phase, or even a frequency shift when a feedback loop is used to lock the phase. In the field of atomic force microscopy (AFM), this measurement paradigm has been used to create images of surfaces by scanning an oscillating cantilever beam with a small tip at the end above a sample surface. This method allows for imaging with atomic resolution with very little back-action on soft and delicate material surfaces. However, the actual force between the tip and surface remains unknown due to the limited bandwidth around the resonance frequency of the cantilever. In this talk we show how frequency mixing, so-called intermodulation, can be used to make most efficient use of the available bandwidth. In contrast to conventional AFM, we apply a drive force to the cantilever that comprises more than one frequency component. Due to the nonlinear nature of the tip-surface interaction force, the cantilever motion exhibits additional frequency components at the mixing frequencies of the cantilever drive frequencies. These new frequency components can be placed inside a small band around the cantilever resonance frequency by an appropriate choice of the drive frequencies. We call this method intermodulation AFM and it has been demonstrated that the interaction force between the tip and the surface can be reconstructed by an analysis of the full spectrum of the cantilever motion. However, like in other multifrequency AFM techniques it is not understood how each individual frequency component is related to the tip-surface force. Here, we show that an individual frequency component can be interpreted as a weighted average of the tip-surface force and that the weighting kernel determines what information about the tip-surface force is encoded in each frequency component. We introduce a general method, called numerical kernel estimation, to determine the weighting kernels for arbitrary AFM modes. With this multifrequency kernel analysis (MKS) we are able to clearly define the information content in multifrequency AFM and to reveal the fundamental limits of force reconstruction. To demonstrate the capabilities of MKS we use it to unambiguously separate long and short range forces in multifrequency magnetic force microscopy and reconstruct the tip-sample interaction force from amplitude-modulated AFM measurements. The methods developed in this talk are not limited to AFM. We hope that these methods contribute to the transformation of AFM from a qualitative imaging modality into quantitative microscopy and that they find application in other measurements which exploit the enhanced sensitivity of a high-quality factor oscillator.

Collective dynamics of electrostatically coupled microbeams under parametric excitation

Mon.
14:40–15:00
R Louka

D. Bitar, N. Kacem, N. Bouhaddi

FEMTO-ST Institute, University of Franche-Comté, Besançon, France

The collective nonlinear dynamics of electrostatically coupled microbeams under parametric excitation is modeled and investigated, while including the main sources of nonlinearities up to the fifth order. The nonlinear equations of motion are solved using secular perturbation theory coupled with standing wave decomposition. Numerical simulations have been performed for two-beam system as a preliminary step before investigating large arrays. It is shown that, the frequency responses demonstrate the importance of the fifth order nonlinearity and the multimodal solutions. This model can be exploited to design arrays of MEMS with high performances.

An Experimental and theoretical investigation of electrostatically coupled microbeams

Mon.
15:00–15:15
R Louka

S. Ilyas, K.N. Chappanda, M.I. Younis

King Abdullah University of Science and Technology, KSA

The statics and dynamics of MEMS become more complex when coupled and interacting with each other. Considerable efforts have been directed towards understanding the complex static and dynamic behavior of coupled MEMS resonators in order to exploit them

efficiently or avoid them, when necessary [1,2]. Moreover, electromechanical coupling is popularly used in mixer and filters applications [2,3].
We present an experimental and theoretical investigation of the static and dynamic behavior of electrostatically coupled laterally actuated silicon based microbeams. The design of the device consists of two microbeams of the same width and thickness, but of slightly different lengths placed at a separating gap d between them, the two fixed electrodes spanning the full lengths of the beams on each side separated by a gap d. This arrangement allows for both of the beams to be separately actuated by applying potential difference among the beams and their respective electrodes (single beam actuation). The beams can also be actuated by providing potential difference among themselves (dual beam actuation).

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A combined time averaging and frequency mixing approach to parameter identification in nonlinear response

Mon.
15:15–15:30
R Louka

S.M. Sah, D. Forchheimer, R. Borgani , D.B. Haviland

Nanostructure Physics, KTH Royal Institute of Technology, Stockholm, Sweden

We present a method for identifying the parameters of a model describing the tip-sample interaction force in Intermodulation Atomic Force Microscopy (ImAFM). The method uses analytic expressions for the slow-time amplitude and phase evolution, obtained from time-averaging over the rapidly oscillating part of the cantilever dynamics. The slow-time behavior can be easily obtained in the experiment by down-shifting the measured intermodulation spectrum that results when a high-Q resonator is perturbed by nonlinearity. A direct fit of the theoretical expressions to the experimental data gives the best-fit parameters for the model. The method combines and complements previous work [1, 2] and it allows for computationally more efficient parameter mapping with ImAFM. Results for both simulation and experiment are shown.

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Control of global bifurcations in a noncontact atomic force microcantilever

Mon.
16:00–16:20
R Louka

V. Settimi[1], G. Rega[1], S. Lenci[2]

[1] *Department of Structural and Geotechnical Engineering, Sapienza University of Rome, Italy*
[2] *Polytechnic University of Marche, Ancona, Italy*

To improve microscope performances or avoid unwanted behaviors, several control techniques have been proposed in AFM literature. They are mostly based on feedback methods aimed at controlling local dynamics, so their effects on the overall dynamics are generally unknown. Recent studies have shown that the insertion of an external feedback control in a noncontact AFM model causes a generalized reduction of the stability region and a dangerous decrease of system safety in terms of basins of attraction robustness and integrity [1, 2]. Yet, in a practical stability perspective, an acceptable system-dependent residual integrity is needed to guarantee secure AFM operation.
Focusing on the preservation of dynamical integrity, a different control technique is applied to the AFM system with the aim to reduce the safe basin erosion which leads to the loss of safety. The method [3] consists of optimally modifying the shape of the excitation to delay the occurrence of the global events (i.e., homo/heteroclinic bifurcations of some saddle) which trigger the erosion (i.e., the sudden fall in the erosion profiles), thus obtaining an overall control of the dynamics and an enlargement of the system safe region in parameters space.
Usually, global bifurcations triggering erosion involve the stable and unstable manifolds of the hilltop saddle, for which the occurrence of homoclinic bifurcation can be analytically detected by the classical Melnikov method. Their control has proved to be effective in delaying erosion also when the fall of the profiles is likely due to other secondary bifurcations which involve internal saddles [4]. Such control procedure has been applied to the hilltop saddle manifolds of the AFM model under analysis, focusing the attention to frequencies around the fundamental resonance, which has revealed to be a critical region as regards the system dynamical safety. The obtained results have highlighted the ability of the technique in shifting the homoclinic bifurcation to higher values of the excitation amplitude, without anyway succeeding in delaying the basin sharp erosion [5]. This is due to the fact that the controlled bifurcation occurs too far before the fall down of the erosion profiles, thus vanishing the effect of the control.
Moreover, the arise of a periodic competing solution inside the potential well, which is a typical feature of several dynamical systems around resonance, points out the presence of other (cross-well) saddles whose manifolds can possibly undergo potentially dangerous bifurcations. Accurate numerical investigations of the behavior of the manifolds of both the hilltop and the detected internal saddles display the occurrence of other global bifurcations, i.e., two homoclinic bifurcations of the internal saddle manifolds and a heteroclinic bifurcation between hilltop and internal saddles manifolds. In particular, the last two events (i.e. homoclinic bifurcation of internal saddle and heteroclinic bifurcation of

internal-hilltop saddles) occur simultaneously and very close to the profile fall down; the study of the basins of attraction evolution reveals that they result to be directly related to the basins separation inside the potential well, which is the topological event responsible for the sharp reduction of the system integrity.
Analyses have been thus focused on the application of the control technique to the second homoclinic bifurcation involving the manifolds of the internal saddle, even if the impossibility of analytical treatment calls for a fully numerical approach both to detect the invariant manifolds and their bifurcations and to verify the effects of control. The numerical procedure consists in identifying a proper region in the state plane including the main global bifurcations, in numerically detecting the saddle stable and unstable manifolds, and in computing the manifolds distance, bearing in mind that a distance equal to zero corresponds to manifolds tangency, i.e. to the occurrence of the global bifurcation. The method has been tested on the homoclinic bifurcation of the hilltop saddle, already analyzed with the Melnikov method [5], and the numerical results have shown a good accordance with the analytical ones, highlighting the ability of the developed procedure to detect the value of the optimal superharmonic to be added for shifting the global bifurcation to a higher value of forcing amplitude. Its subsequent application to the homoclinic bifurcation of the internal saddle has proven effective in delaying the fall down of the erosion profile, thus increasing the overall system robustness in operating conditions.

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Nonlocal modeling of a Carbon Nanotube actuated by an electrosatic force

Mon.
16:20–16:40
R Louka

H. Ouakad[1], F. Najar[2], S. El-Borgi[2,3]

[1] *King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia*
[2] *Tunisia Polytechnic School, University of Carthage, Tunisia*
[3] *Texas A&M University at Qatar, Engineering Building, Doha, Qatar*

Carbon nanotubes (CNTs) are viewed as promising mechanical structures in the nanoscale which have attracted the engineers and researchers in this field mostly due to their amazing mechanical, chemical, thermal, and electrical properties. In order to take into account size dependence of such small sized structures, the use of nonlocal continuum theory is proposed where intrinsic length scales is taken into account. Based on the Eringen theory, a nonlinear nonlocal model of a clamped-clamped initially deflected CNT is developed in this study. Static and free vibration reponses are simulated and analyzed. The main objective of this work is to study the influence of CNT size and length scale parameter on the static and free vibration response to better understand their effect on the general behavior of the CNT.

Investigation of the nonlinear static and dynamic behavior of rectangular microplates under electrical actuation

Mon.
16:40–17:00
R Louka

S. Saghir[1], M.I. Younis[1,2]

[1] *King Abdullah University of Science and Technology KAUST, Thuwal, Saudi Arabia*
[2] *State University of New York at Binghamton, Binghamton, USA*

Microplates are important structural parts of Micro-Electro Mechanical Systems (MEMS) [1–3]. They make the flexible side of parallel plate capacitors of electrically actuated MEMS devices while the other side is a stationary electrode. In MEMS devices flexible microplates often undergo large deflections compared to their thickness. In such situations, linear plate theory cannot predict the behaviour of the plates correctly or accurately. Thus, we employ in this work the Von Karman type nonlinear plate equations [2]. A reduced order model (ROM) is developed using the Galerkin method to investigate the behaviour of MEMS microplates. Mode shapes of the undeflected microplate are used as basis function for ROM development [5].
First, the static behaviour of the microplates is investigated when applying a static voltage load V_{dc}. Convergence of the results with respect to the number of vibration modes retained in the ROM is investigated. To study the dynamic behaviour we apply a harmonic voltage load, V_{ac}, superimposed to V_{dc}. Microplates show hardening effect due to the cubic nonlinearity of mid-plane stretching. Secondary resonances, superharmonic and subharmonic, also show up at one half and twice the fundamental natural frequency. These secondary resonances are attributed to the quadratic nonlinearity, which comes from the actuating electrostatic force, whereas their hardening behaviour is due the cubic stiffness nonlinearity.

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Modeling and parametric analysis of a piezoelectric flexoelectric nanoactuator

Mon.
17:00–17:15
R Louka

S. Baroudi, A. Jemai, F. Najar

Tunisia Polytechnic School, University of Carthage, Tunisia

With the development of nanotechnology, nanoactuators have recently re-stimulated a surge of scientific interests in research communities. One of the interesting transduction mechanisms that showed high efficiency at the nanoscale was flexoelectricity. In fact, the flexoelectric effect in dielectric solids couples polarization and strain gradient, rather than polarization and strain for piezoelectricity, to convert mechanical stimulus into electricity and vice versa.

The objective of the current work is to develop a complete comprehensive electromechanical model of a nanobeam whose for piezoelectrically-actuated nanocantilever sensor in which both the flexoelectricity and piezoelectricity effects will be accounted for. Starting from the enthalpy density function, the Hamilton's principle is applied to drive the governing coupled equations with appropriate boundary conditions. Then, we solve the static and well as the eigenvalue problem associated with the coupled partial differential equations using a Galerkin procedure. The results show that a certain aspect ratio flexoelectric effect significantly increases the performance of the nanoactuator.

Nonlinear dynamic analysis of capacitive shunt micro switch using new actuation methods

Mon.
17:15–17:30
R Louka

S. Ben Sassi[1], M.E. Khater[2], E.M. Abdel-Rahman[2], F. Najar[1]

[1] *Tunisia Polytechnic School, University of Carthage, Tunisia*
[2] *University of Waterloo, Waterloo, ON, Canada*

This work targets static and dynamic investigations of a capacitive shunt micro switch electrically actuated using different actuation methods. First, we formulate the coupled electromechanical problem by taking into account the fringing effects and nonlinearities due to mid-plane stretching. Static analysis is achieved using the Differential Quadrature Method (DQM) and the pull in voltage is verified by means of the Finite Element Method (FEM). Based on Galerkin approximation, a single degree of freedom model is developed for the dynamic problem in association with the Finite Difference Method (FDM). In addition to the harmonic wave form signal, we apply novel actuation waveform signals to simulate the dynamic frequency response. Interesting outcomes can be deduced from the comparison between results given by the three actuation methods. The efficiency of the proposed methodology was proven through experimental tests.

Tapping mode in atomic force microscopes subject to low frequency harmonic excitations

Mon.
17:30–17:45
R Louka

M. Khadraoui, F. Lakrad

Faculty of Sciences Ain Chock, University Hassan II Casablanca, Morocco

Two models of atomic force microscopy (AFM) system, subject to a low harmonic frequency displacement of its base, are studied. The interactions between the AFM's cantilever tip and a sample are modeled by the Lennard-Jones forces in the first model. In the second model they are modeled by the Van der Waals and the Derjaguin -Muller -Toporov (DMT) forces. The Galerkin method is used to reduce the equation of motion to a one degree of freedom fast-slow dynamical system. The invariant slow manifolds are approximated and their bifurcations are investigated. Chart of behaviors of different modes of the AFM are determined. It is shown that two dynamic saddle-node bifurcations, during one period of the base oscillation, of the contact and the non-contact invariant slow manifolds are responsible for triggering the tapping mode. It is also shown that these dynamic bifurcations govern the contact time between the tip and the sample.

MS 2
Monitoring and diagnosis of structures and assemblies

Organizers: *M. Ichchou* France, *O. Bareille* France

Scheduled:

Tuesday *10:30–12:10* Adam Park Hotel **Room Tichka**

Identification of the operating parameters for the mechanical system using EMD algorithm

Tue. 10:30–10:50 R Tichka

J. Jonak[1], A. Machrowska[1], J. Podgórski[2], J. Bêc[2]

[1] *Faculty of Mechanical Engineering, Lublin University of Technology, Lublin, Poland*
[2] *Faculty of Civil Engineering and Architecture, Lublin University of Technology, Lublin, Poland*

The results of the research on the possibility of using the EMD (Empirical Mode Decomposition) algorithm to identify operating parameters of the mechanical system, which includes, among others, two dynamic elements coupled pneumatically are presented in the paper. Due to the nature of the construction and operation of such a system, some limitations in effective practical application of the described algorithm have been found. These problems are caused by difficulties in separation of components of the recorded signal with similar characteristic frequencies.
The purpose of the tests is to determine the applicability of EMD algorithm to identify operating parameters of the mechanical system, which is necessary to build a system for structure condition monitoring. The tested EMD algorithm has got a number of limitations, in particular that it is dedicated to the one-dimensional measurement data, has got limited resolution resulting from the fact that it is a so-called "dyadic" filter and there can be seen e.g. "energy leakage" phenomenon between IMF-**intrinsic mode functions** ("sieving" levels). As the result there is no successful separation of the characteristic frequencies for the elements.

Tensegrity structures optimization for vibration health monitoring requirements

Tue. 10:50–11:10 R Tichka

N. Ashwear, A. Eriksson

KTH Mechanics, Royal Institute of Technology, Stockholm, Sweden

Tensegrities are inherently non-linear cable-strut assemblies which find their stiffness and self- equilibrium states from the integrity between tension and compression. Their stiffness can be improved by regulating the level of pre-stress, using their lowest natural frequencies as indicators for their pre-stress [1]. In VHM, the lowest natural frequencies are used as indicators of damage presence [2]. It is well known that, the sensitivity of the natural frequencies to damage is the core of VHM. However, the natural frequencies are also affected by environmental conditions like wind, humidity and temperature changes.

Of particular importance is the change of the environmental temperature, and this is the most commonly considered environmental variable influencing the VHM algorithms [3, 4]. To avoid confusion when interpreting the results from VHM algorithms, there are two options: a prior understanding and knowledge of the behaviour of the healthy structure with temperature changes, or optimizing the design of the structure such that its natural frequencies are very little sensitive to the temperature changes. Most of the studies found in literature show that an increase in temperature leads to a decrease in structural frequencies. Xia and Chen [5] reviewed the effect of temperature on vibration properties of civil structures and gave some case studies. They concluded that, an increase in temperature leads to a decrease in natural frequencies. Their conclusion is in agreement with other studies regarding the relation between the temperature changes and natural frequencies. However, this is not the case for pre-stressed structures such as tensegrity structures [3]. In [3] we have investigated the influence of temperature changes on the natural frequencies of tensegrity structures, and concluded that, the temperature changes highly influence the natural frequencies. In this paper we investigate how a tensegrity structure can be optimized such that its lowest natural frequencies have a very low sensitivity to the temperature changes.

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Paris law state-parameter identification based on the Extended Kalman Filter

Tue.
11:10–11:30
R Tichka

M. Melgar[1], C. Gomez-Jimenez[2], L.D. Cot[1], C. Mabru[1], J. Martinez-Vega[3]

[1] *Université de Toulouse, Institut Clément Ader, INSA, Toulouse, France*
[2] *Université de Toulouse, INSA, Toulouse, France*
[3] *Université de Toulouse, INP, LAPLACE, Toulouse, France*

It is observed in many applications within the aerospace industry that the structural components are vulnerable to fatigue loading. Fatigue damage is one of the most probable modes of damage in aircraft structures. Currently, structural maintenance, also called damage tolerance approach, consists in regular predetermined inspections, integrated in the overall aircraft inspection timetable. This maintenance policy is a very conservative approach because uncertainties are taken into account by considering high safety factors on the inspection intervals. Moreover, parts of the structures still usable are scrapped even if no failure occurs. Finally, time-based inspections focus on selected parts of the structure and don't give a global status of the structure. The issue to improve operational reliability and reduce maintenance costs led to more cost-effective condition-based inspection approaches. Many investigations have been done on Structural Health Monitoring (SHM) systems and show that SHM is an appropriate tool for condition-based maintenance. On-board sensors and actuators assess structure health and allow to detect or predict damage. A more global health status of a structure could therefore be provided and maintenance actions could be decided accordingly.

This paper addresses the improvement of fatigue damage model in order to enable accurate damage prognostics.

On definition and evaluation of the wave electromechanical coupling factor

Tue.
11:30–11:50
R Tichka

Y. Fan[1,2], M. Collet[1], M. Ichchou[1], L. Li[2], O. Bareille[1], Z. Dimitrijevic[3]

[1] *Laboratoire de Tribologie et Dynamique des Systemes, Ecole Centrale de Lyon, FRANCE*
[2] *School of Energy and Power Engineering, Beihang University, Beijing, CHINA*
[3] *PSA Peugeot Citro, Vélizy-Villacoublay Cedex, FRANCE*

The strength of electromechanical coupling has important influences in many applications of piezoelectric structures, such as vibration control and wave attenuation. In terms of structural modes, the coupling factor can be estimated by the open-circuit (OC) and short-circuit (SC) natural frequencies. However, in terms of waves, few criteria are available. In this work, the wave electromechanical coupling factor (WEMCF) is proposed. Two means are explored to define the WEMCF.

The first definition is given by the difference between the OC and SC propagating frequencies under the same wavenumber. This definition is intuitive. But it works only for propagating waves, because band gaps may have different depth in OC and SC statuses. Consequently it is difficult to link the evanescent waves between OC and SC. For complex waveguide whose dispersion relations has wave veering, it is also difficult to link two propagating waves from the dispersion relations at OC and SC.

Alternatively, WEMCF can also be defined by the fraction of the electric energy in the mechanical energy at the OC status. This second definition works for both evanescent waves and propagating waves. It only requires the dispersion curves at OC so no efforts are needed to link the waves between OC and SC. Post-processing of the wave shapes and energy is needed, which might consume a lot of computational time for complex waveguides. Wave and finite element method with reduced scheme [1] is employed to analyze the dispersion curves and WEMCF. The energies can be calculated by the reduced model with a smaller number of degree-of-freedoms (DOF). This way to not only the calculation of dispersion curves but the computing of WEMCF can be accelerated.

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Tue.
11:50–12:10
R Tichka

On the use of the wave-finite element method to compute acoustic transmission loss

J.L. Christen, M. Ichchou, O. Bareille, A. Zine

Ecole Centrale Lyon, France

Sound transmission modelling is a very important topic in the industry, yet it is often still an open problem for complex geometries or materials. Several methods have been proposed for the computation of transmission loss through plate-like structures. Analytic models for thin and thick plates exist [1–3], and the analytic transfer matrix method [4, 5], enables to model isotropic plane layerings comprising elastic solids and poroelastic materials, relying on an analytical formulation of the problem in each layer.
The method presented in this work makes use of the powerful WFE framework [6], which enables to model an arbitrary layering with the finite element model of a single unit cell, which is just 1 element thick in the x and y dimensions if the medium is considered homogeneous. Using an analytical representation of the acoustic incident, reflected and transmitte fields, a closed form of the TL can be derived by using their respective amplitudes as force terms in the equilibrium equation of the plate, along with the acoustic impedance relations they satisfy in the fluid. The method is validated against the analytical model of an isotropic plane wave. The error on TL is less than 1dB below 20kHz. Results for a sandwich composite plate are then presented, which show that the antisymmetric deformation mode is well accounted.fTheFadvantage of thisdmethod isfthat it gives direct access to the displacement field inside the plate at each frequency. The displacement field is plotted for the sandwich case for three distinct frequencies: the coincidence, symmetric coincidence and a frequency in between For the mixed mode, symmetric and antisymmetric parts are present.

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MS 3

Nonlinear dynamics in spatially extended systems: theory and experiments/Rogue waves, solitons, and supervontinum in nonlinear fiber optics: Where are we now?

Organizers: *M. Tlidi* Belgium, *A.G. Vladimirov* Germany, *M. Taki* France, *S.V. Gurevich* Germany, *M. Clerc* Chile

Scheduled:

Monday	*14:00–15:30*	Adam Park Hotel	**Room Tinmel**
Monday	*16:00–17:45*	Adam Park Hotel	**Room Tinmel**
Tuesday	*10:30–12:10*	Adam Park Hotel	**Room Tinmel**
Tuesday	*14:30–16:15*	Adam Park Hotel	**Room Tinmel**

Delay-induced dynamics of localized structures in systems with spatial inhomogeneities

Mon.
14:00–14:20
R Tinmel

F. Tabbert, S.V. Gurevich

Insitute for Theoretical Physics, Münster, Germany

We are interested in the dynamics of localized structures subjected to time-delayed feedback in systems with spatial inhomogeneities. Therefore, a Swift-Hohenberg model that describes the behaviour of transversal patterns in a passive cavity in two spatial dimensions is combined with an additional time-delayed feedback term and an inhomogeneous gaussian injection beam.
We show that varying the delay strength, the delay time and the shape of the injection beam leads to various dynamical solutions including drifting solutions, pinned oscillatory structures and the formation of spirals. The onset of these different instabilities can be predicted analytically in terms of a linear stability analysis of the delayed systems.
A special focus lies on the competing effects of the symmetry breaking inhomogeneity, which has a pinning effect on the localized structure, and the drift-inducing modes, which can be destabilized by time delayed feedback. The interplay of these competing effects leads to an oscillatory motion of the structure which is studied both numerically and analytically.

Vector cavity solitons in semiconductor microcavities

Mon.
14:20–14:40
R Tinmel

E. Averlant[1], M. Tlidi[1], H. Thienpont[1], K. Panajotov[2]

[1] *Free University of Brissels, Brissels, Belgium*
[2] *Vrije Univ. Brussel, Belgium*

In this communication, I will present experimental, analytical and numerical description of vector Cavity Solitons (CSs) in Vertical-Cavity Surface-Emitting Lasers (VCSELs). The experiment has been performed in a 80μm multiple quantum well VCSEL, submitted to linearly polarized optical injection [1]. CSs are generated in this system by varying the optical injection power. Measurement of the Stokes parameters of the CSs show that they have a complex (i.e. not linear) polarization state.
To describe the experimental results, we used the VCSEL spin-flip model [2,3], a widely used model to describe the complex polarization behaviour of VCSELs under optical injection. To be able to describe CS generation in such devices, we added a term in these equations to account for diffraction. A linear stability analysis of this model is performed. Regions of coexistence of a homogeneous steady state with a Turing-Prigogine pattern are identified.
Numerical simulations of the modified VCSEL spin-flip model in such regions show good agreement with experimental results.

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Role of nonlinear diffusion and environment fluctuations in biological population patterns

Mon.
14:40–15:00
R Tinmel

E.H. Colombo, C. Anteneodo
Department of Physics, PUC-Rio, Rio de Janeiro, Brazil

Anomalous diffusion is a realistic feature in the dynamics of biological populations, we investigate its implications in a paradigmatic model for the evolution of a single species density. This standard model includes growth and competition in a logistic expression, and spreading is modeled through normal diffusion. Moreover, the competition term is nonlocal, which has been shown, through Fourier analysis, to give rise to spatial patterns. We found that the number of clusters inside the population is inversely proportional to the range of the interaction in competitive processes. Anomalous diffusion is further introduced generalizing the diffusion term, that becomes dependent on a power of the local density, yielding either subdiffusion or superdiffusion. We show that, for the subdiffusive case, the stationary distribution displays a fragmented population, in contrast with the superdiffusive case where homophilic behavior is observed. We analytically obtain the phase diagram (homogenous-patterned) relating the interaction range to the nonlinear diffusion term in the pattern formation process, with additional considerations where the population becomes fragmented or connected. We also address the impact of fluctuating environmental conditions. The environment is usually quantified through a set of parameters assumed to be constant in time and space. We point out that environment fluctuations change the stability condition. Assuming that environmental fluctuations can be approximated to a Gaussian white noise, we show how noise affects pattern formation and its temporal correlations.

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Nonlinear Bloch-waves of exciton-polariton condensates in periodic lattices

Mon.
15:00–15:15
R Tinmel

O.A. Egorov[1], I.Y. Chestnov[2], A.V. Yulin[3], A.P. Alodjants[2,3]

[1] *Friedrich-Schiller-Universität Jena, Germany*
[2] *Vladimir State University named after A. G. and N. G. Stoletovs, Vladimir, Russian Federation*
[3] *ITMO University, St. Petersburg, Russian Federation*

We review non-equilibrium dynamics of exciton-polaritons in an incoherently driven semiconductor microcavity with an embedded periodic lattice. We demonstrate a profound modification of the energy-momenta band structure of the condensate and formation of the swallow-tail-like loops evoked by strong nonlinear exciton-exciton interactions, pumping and dissipation. Different regimes of superfluid and oscillatory dynamics, governed by superposition of these nonlinear Bloch eigenstates, will be considered. In particular, within the framework of mean-field theory, we discuss new type of persistent current states describing nonlinear Bloch eigenstates of coherent exciton polaritons at the boundaries of Brillouin zone. We elucidate a strong influence of the dissipative effects and the feedback induced by the inhomogeneity of incoherent reservoir on the dynamics of the coherent polaritons. We also propose several schemes for experimental observation of the predicted effects.

Self-organization theories as explanation of fairy circle formation: Turing-pattern versus localized structures

Mon.
15:15–15:30
R Tinmel

D. Escaff[1], M.G. Clerc[2], C. Fernadez-Oto[3], M. Tlidi[3]

[1] *Universidad de los Andes, Las Condes, Santiago, Chile*
[2] *Departamento de Física, FCFM, Universidad de Chile, Blanco Encalada, 2008 Santiago*
[3] *Faculé des Sciences, Université Libre de Bruxelles, Bruxelles, Belgium*

Mysterious circular areas devoid of any vegetation are often observed in vast zones in southern Angola, Namibia, and South Africa. Since the unknown origin of theses structures, they are called fairy circles. Even through, many hypothesis have been proposed to explain its formation, none of them have been majority accepted by the community devoted to the topic. One subgroup of these theories is the ones that are based on the self-organization hypothesis. They attribute the fairy circles formation to the plant interaction due to different mechanisms as: competition for resources; facilitation or cooperative interaction; and seed dispersion. According to the self-organization hypothesis, all these interactions lead to a nonlinear evolution of the biomass, which explains its spatially heterogeneous distribution. There is, however, the tendency to confuse all the self-organization mechanisms into the same category: namely, the Turing's theory of morphogenesis. The aim of this talk is to establish a neat differentiation between two self-organization mechanisms: Turing-pattern versus localized states induced by strong nonlocal coupling. Compare them, and their predictions and implications for fairy circles formation.

Periodic structures induced by femtosecond laser pulses on metal surfaces

Mon.
16:00–16:20
R Tinmel

E. Gurevich
Ruhr-University of Bochum, Germany

Laser-induced periodic surface structures (LIPSS or ripples) can be found on the surface of metals, dielectrics and semiconductor materials processed with single and multiple femtosecond laser pulses. Although the physical background of this phenomenon is studied for more than 50 years, the underlying physical mechanisms are still a topic of discussion. There are two main approaches to the problem of LIPSS formation based on: (1) interference of the incident laser light and the surface plasmons, which manifests itself in a periodically-modulated surface temperature of electrons and ions and (2) development of hydrodynamic instabilities on the surface.

Here we compare the hydrodynamic and the plasmonic theories and look for possible mechanisms of the ripple formation. The question how the temperature profile can result in a periodically-modulated surface morphology in such a short time (less than 1 nanosecond) is addressed. Estimations made on the basis of different hydrodynamic instabilities allow us to sort out several mechanisms, which can bridge the gap between the temperature and the surface profile formation.

Allometric effects in a nonlocal model of localized vegetation patterns

Mon.
16:20–16:40
R Tinmel

J. Cisternas[1], D. Escaff[1], M. Tlidi[2]

[1] *Facultad de Ingeniería y Ciencias Aplicadas, Universidad de los Andes, Santiago, Chile*
[2] *Department of Physics, Free University of Brussels, Brussels, Belgium*

Several mathematical models for the development of vegetation patterns in water-limited regions have been proposed. These models have different levels of sophistication and capture the connection between biomass growth, soil humidity, surface water, light and other relevant variables. Our study considers the effect of allometry i.e. how the canopy and the roots grow with the biomass, and its effect on the localization of vegetation patterns in one and two-dimensional homogeneous media. This presentation will cover the development of efficient computational methods to analyze the destabilization of the base uniform state and the existence of stable localized solutions that appear as a result of "snaking" bifurcations.

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From stationary patterns to spatiotemporal chaotic textures

Mon.
16:40–17:00
R Tinmel

M. Clerc, G. Gonzalez, M. Wilson, V. Odent

Departamento de Física, FCFM, Universidad de Chile, Blanco Encalada, Santiago, Chile

Macroscopic systems subjected to injection and dissipation of energy can exhibit complex spatiotemporal behaviors as result of dissipative self-organization. Despite the substantive theoretical and numerical progress to characterize these behaviors, its experimental implementation has been almost sterile. In this talk, we will present a two-dimensional pattern forming set up, which exhibits a transition from stationary patterns to spatiotemporal chaotic textures, based on a nematic liquid crystal layer with spatially modulated input beam and optical feedback. Using an adequate projection of spatiotemporal diagrams, we determine the largest Lyapunov exponent. Lyapunov exponents allow us to characterize the transition to chaos. This exponent and Fourier transform lead to a reconciliation of

experimental observations and theoretical de-velopments in spatiotemporal complexity. In particular, we can distinguish between spatiotemporal chaos and amplitude turbulence concepts; which are usually merged.

Simulation of simultaneous photonic and phononic band gaps in Sapphire

Mon.
17:00–17:15
R Tinmel

H. Bentarki[1,2], M. Tlidi[2], A. Makhoute[1]

[1] *Faculté des Sciences. Université Moulay Ismail, Meknès, Marocco*
[2] *Faculé des Sciences, Université Libre de Bruxelles, Bruxelles, Belgium*

The existence of phononic and photonic structures has opened a new path in the field of acousto-optic devices, by trying to group the principle of photonic and phononic crystal in only one structure named phoXonic crystal. This structure will prohibit the simultaneous propagation of electromagnetic and elastic waves. Such a structure is useful for the putting place and the study of interactions between photons and phonons but also for the elaboration and the improvement of devices of the integrated acousto-optics, for example modulators or multiplexers.

In this work, we investigated the opening of simultaneous photonic and phononic band gaps in a simple square periodic array of holes drilled in Sapphire substrate. The investigations are focused in a first part on a photonic gap obtaining with a phononic gap in the same time making use of some specific parameters. In the second part, using a cavity defect in which the strong confinement of acoustic and optic waves enhances the interaction, we obtain photonic and phononic modes classified according to their symmetry (even or odd), also allowed bands in gaps, which has led to the propagation of waves appropriate. The frequencies of the localized modes in the first band gap are computed with a finite element method.

Photoionization with two colors of the hydrogen atom in a strong laser field

Mon.
17:15–17:30
R Tinmel

S. Chaddou, S. Chqondi, A. Makhoute

Faculté des Sciences, Université Moulay Ismail, Meknès, Marocco

More recently, sources of infrared radiation (IR) femtosecond, which are based on the use of a system of sapphire crystal (Sa) ions doped titanium (Ti), have known a significant growth. These laser sources allowed researchers to identify nonlinear phenomena when interacting atoms with strong fields such as multiphoton ionization, above threshold ionization (ATI) or the high harmonic generation (HHG).

We have studied the ionization of atoms in a single-cycle-pulse electric field based on the numerical calculations by solving the Time Dependent Schrödinger Equation (TDSE). We have developed a new numerical code for the simulation of the TDSE solutions. We have applied this code to the photoionization hydrogen combining two photons, infrared (low frequency) and one of its harmonics (high frequency). Spectra and angular distribution of photoionization of photoelectron from ionization of atom by a combination to two short pulses in XUV and IR range are theoretically and numerically considered.

Self-replication of localized vegetation patches in arid landscapes

Tue.
10:30–10:50
R Tinmel

I. Bordeu[1], M. Tlidi[2], M.G. Clerc[3], P. Couteron[4], R. Lefever[2]

[1] *Imperial College London, UK*
[2] *Université Libre de Bruxelles, Belgium*
[3] *Universidad de Chile, Chile*
[4] *IRD, UMR AMAP, France*

Desertification due to climate change and increasing drought periods is a worldwide problem for both ecology and economy. Our ability to understand how vegetation manages to survive and propagate through arid and semiarid ecosystems may be useful in the development of future strategies to prevent desertification, preserve flora-and fauna within-or even make use of scarce resources soils.

In this presentation, we will discuss a robust phenomena observed in semi-arid ecosystems, by which localized vegetation patches split in a process called self-replication. In this process the patch is affected by a modulational instability that deform the structure from its circular shape into an elliptical shape, process after which the tussocks split into two new structures. This growth mechanism is opposite to the desertification since it allows the repopulation of territories devoid of vegetation. We investigate these aspects by characterizing quantitatively, though a general interaction-redistribution model, the instability that lead to the self-replication phenomenon observed. The conditions required for this mechanism to take place and its role in the formation of extended patterns will be shown.
In addition we will show results from remote sensing analysis of the Andean highlands, where we will show not only the existence of self-replication in Festuca tussocks, but also some characteristics of the spatial distribution of the vegetation, which are signatures of an underlying self-organization process.

Bright and dark localized structures in the Lugiato-Lefever equation

Tue.
10:50–11:10
R Tinmel

P. Parra-Rivas[1,2], D. Gomila[2], E. Knobloch[3], S. Coen[4], L. Gelens[1,5,6]

[1] *Applied Physics Research Group, Vrije Universiteit Brussel, Brussels, Belgium*
[2] *IFISC institute (CSIC-UIB), Campus Universitat de les Illes Balears, Palma de Mallorca, Spain*
[3] *Department of Physics, University of California, Berkeley CA, USA*
[4] *Dodd-Walls Centre, and Physics Department, The University of Auckland, New Zealand*
[5] *KU Leuven Department of Cellular and Molecular Medicine, University of Leuven, Belgium*
[6] *Department of Chemical and Systems Biology, Stanford University School of Medicine, USA*

In this work we present a detailed analysis of the bifurcation structure of localized structures (LSs) and their different dynamical regimes in the Lugiato-Lefever equation in the presence of anomalous and normal chromatic dispersion. Such analysis is expected to also provide new insights into the formation and stability of frequency combs (FCs).
A FC consists in a set of equidistant spectral lines that can be used to measure light frequencies and time intervals more easily and precisely than ever before. Due to the shown duality between LSs and FCs in microcavities, we can gain information about the behavior of FCs by analyzing the dynamics of LSs.

In the anomalous dispersion case bright LSs are organized in what is known as a homoclinic snaking bifurcation structure. In contrast, in the normal dispersion regime dark LSs exist and they are organized differently, in a structure known as collapsing snaking. Despite the differences in bifurcation scenarios, both types of LSs present similar temporal instabilities. The similarities and differences between both scenarios correspond to two different unfoldings of the same set of codimension-two bifurcations that organize all the dynamics of the system. This work is expected to be useful to experimentalists working in the domain of FC generation as it provides a detailed map of the different dynamical regimes of LSs and FCs in microresonators. We will also show how higher order effects modify the previous scenarios.

Fairy circles under the sea: Pattern formation in meadows of marine plants

Tue.
11:10–11:30
R Tinmel

D. Ruiz[1], D. Gomila[1], T. Sintes[1], E. Hernandez-Garcia[1], N. Marbà[2], C. Duarte[3]

[1] *IFISC (CSIC-UIB). Campus Universitat Illes Balears, 07122, Palma, Spain*
[2] *Department of Global Change Research, IMEDEA (UIB-CSIC), Esporles, Spain*
[3] *Faculty of Marine Sciences, King Abdulaziz University, Jeddah, Saudi Arabia*

Pattern formation in distributions of terrestrial plants, driven by factors such as competition for water or nutrients or interactions with herbivores, has been a subject of intense research in the last years. Here we report on the observation from air images and from sonar data of analogous pattern forming phenomena in meadows of seagrasses, mainly *Posidonia oceanica* and *Cymodocea nodosa*, in the Mediterranean Sea. We derive a macroscopic model from the growth rules of these clonal plants that is able to provide an explanation to the observed patterns of circles, spots and stripes, and link the prevalence of one over the others to the conditions of the meadow. Beyond a qualitative description of the observed patterns, the model fits well measurements of the population density of *Posidonia* which show great variability close to the coast, where patterns typically appear. Our model also predicts an interaction range of about 20 to 30m, whose biological origin has yet to be identified.

Time-delayed feedback control of cavity solitons in a broad area vertical cavity surface emitting laser with saturable absorbtion

Tue.
11:30–11:50
R Tinmel

S.V. Gurevich[1], C. Schelte[1], M. Tlidi[2], K. Panajotov[3]

[1] *Univ. of Münster, Germany*
[2] *Univ. Libre de Bruxelles, Belgium*
[3] *Vrije Univ. Brussel, Belgium*

We are interested in spatio-temporal dynamics of cavity solitons (CSs) in a transverse section of a broad area vertical cavity surface emitting laser (VCSEL) with saturable absorbtion subjected to time-delayed optical feedback. In the absence of delayed feedback, a single branch of localized solutions appears in the parameter space, whereas in the presence of the delayed feedback the multistability of CS solutions emerges. In particular, branches of CSs fill the surface of the "solution tube" in the parameter space, which is filled densely with increasing delay time. Furthermore, the thresholds of the drift and

phase bifurcations as well as corresponding bifurcation diagrams are obtained by a combination of analytical and path continuation methods. In addition, we demonstrate that the delayed optical feedback can induce Andronov-Hopf bifurcation and a period doubling route to chaos. The results of analytical bifurcation analysis are in agreement with those obtained by direct numerical integration of the model equations.

Localized structures in nonlinear cavities with metamaterials

Tue.
11:50–12:10
R Tinmel

N. Slimani[1,2], M. Tlidi[2], A. Makhoute[1]

[1] *Faculté des Sciences. Université Moulay Ismail, Zitoune, Meknès, Marocco*
[2] *Faculé des Sciences, Université Libre de Bruxelles, Bruxelles, Belgium*

We consider an optical ring cavity filled with a metamaterial and with a Kerr medium. The cavity is driven by a coherent radiation beam. The modeling of this device leads to the well known Lugiato-Lefever equation with high order diffraction. It has been show that close to the zero-diffraction regime, high-order diffraction allows for the stabilization of dark localized structures. These structures do not exist without high-order diffraction.
In this communication, we perform a weakly nonlinear analysis in the vicinity of the first threshold associated with the Turing instability. This analysis allows us to determine the parameter regime where transition from super- to sub-critical bifurcation occurs. When the Turing instability appears subcritically, we show that bright localized structures of light may be generated in two-dimensional setting.

Dynamics of vector vortex states in polariton systems with pump and losses

Tue.
14:30–14:50
R Tinmel

A.V. Yulin[1], A.S. Desyatnikov[2], E.A. Ostrovskaya[3]

[1] *ITMO University, St. Petersburg, Russian Federation*
[2] *Physics Department, Nazarbayev University, Kazakhstan*
[3] *Research School of Physics and Engineering,The Australian National University, Australia*

The dynamics of non-resonantly pumped polariton condensates is studied within the framework of the standard model describing the condensates by the equations for two polarizations of coherent and incoherent polaritons. It is accounted that the coherent polaritons belonging to different polarizations interact to each other linearly and nonlinearly. The trapping and the excitation of the condensates are provided by a radially symmetric optical pump. We study the formation of the coherent polariton states with zero and non-zero angular momentum. It is shown that, depending on parameters, polarization components of the stationary states can have different vorticity (different angular momentum). Numerically found periodical, quasi-periodical and synchronous regimes of the dynamics of the condensates are discussed in the work. The considered model is given by

$$i\partial_t\psi_{1,2} = \left(i\left(n_{1,2} - \frac{1}{2}\right) - \nabla^2 + \left|\psi_{1,2}\right|^2 + \alpha\left|\psi_{2,1}\right|^2 + gn_{1,2} + hn_{2,1}\right)\psi_{1,2} + \sigma\psi_{2,1}$$

$$\partial_t n_{1,2} = P_{1,2} - \left(\Gamma + \beta\,\psi_{1,2}\right|^2\right)n_{1,2},$$

where α is the nonlinear interaction coefficient between different polarization of coherent polaritons, g, h are the coefficients of the blue shift of the coherent polariton because of incoherent polaritons, α is the coupling coefficient between coherent polaritons of different polarizations, which is the decay rate of incoherent polaritons.

Dissipative soliplasmons in active nonlinear plasmonic waveguides

Tue.
14:50–15:10
R Tinmel

A. Ferrando

Department of Optics, Universitat de València, Spain

We present a new dissipative nonlinear phenomenon based in the loss-gain balance between a linear and nonlinear mode. This phenomenon can be used as a new strategy to compensate plasmonic losses in nonlinear plasmonic waveguides. The key element to understand this mechanism is the so-called soliplasmon resonance. The soliplasmon can be visualized as a quasi-particle resonance that appears as a result of the resonant coupling between a linear surface plasmon-polariton and a nonlinear spatial soliton in metal/dielectric/Kerr structure. Besides the nonlinearity inherent to the soliton, this resonant system presents a distinctive nonlinear coupling, which makes the system rather exceptional even in the absence of loss and gain. We will analyze the implications derived from adding gain in the nonlinear medium in order to balance plasmonic losses in nonlinear plasmonic waveguides. We will demonstrate how the distinguishing combination of nonlinear propagation and nonlinear coupling, on the one hand, together with the introduction of gain in the Kerr medium to compensate for metal losses, on the other hand, permit the existence of self-sustained dissipative soliplasmons. We will also discuss how to use this new phenomenon to design active nonlinear plasmonic waveguides that ideally allow for the existence of infinitely long-range propagating surface-plasmon polaritons.

Brain-inspired dynamics in a micropillar laser

Tue.
15:10–15:30
R Tinmel

F. Selmi, F. Lelièvre, A. Golestani, L. Andréoli, R. Braive, I. Sagnes, G. Beaudoin, S. Barbay

Laboratoire de Photonique et de Nanostructures, CNRS, Université Paris-Saclay, France

Brain-inspired photonic systems represent an alternative path for computing and processing data at high speed and with possibly low consumption. We will present recent results on neuromimetic dynamics of a micropillar laser with saturable absorber. These lasers behave analogously to integrate-and-fire neurons, a model of neuron widely used in computational neurosciences. We demonstrate several important properties : relative and absolute refractory period [1], temporal summation [2] and discuss recent experiments on temporal dissipative solitons in these systems.

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Supercontinuum generation in optimized photonic crystal fibers at 1.3 μm for optical coherence tomography

Tue.
15:30–15:45
R Tinmel

L. Cherbi, M.L. Ferhat
University of Sciences and Technology Houari Boumediene, Algeria

Broadband sources of near-infrared supercontinuum radiation are currently in demand of many applications in the field of imaging. Optical coherence tomography (OCT) is one of the most innovative noninvasive cross-sectional imaging of tissue structure in biological system in the last decades. This technique is based on the principle of interferometry using a low-temporal-coherence source. This source with a wide spectrum permits us to achieve high axial resolution. This has opened up a wide interest in the development of optical fibers that can generate this kind of sources.
During the last years, researchers have worked on designing novel geometries of photonic crystal fibers (PCF) with the choice of many materials, this design can be used for the generation of broadband supercontinuum. *A.Hossain al* obtained flat and wide spectrum extending from 1250 nm to 1350 nm using a nonlinear noncircular silica core photonic crystal fiber. *Sotobayashi and Kitayama* obtained a 3 dB flat supercontinuum spectrum which spans from 1400 to 1700 nm. *G.Stepniewski et al* reported experimental work that demonstrates the SC generation with a spectral range from 900 to 1900 nm using a hexagonal structure of thermally matched oxide soft glasses PCF.
Recently, in our previous work, we described in details the procedure of the first method of supercontinuum generation using soliton compression . We generated a bandwidth of 100 nm extending from 1250 nm to 1350 nm in only a 26 cm fiber length. Actually and contrary to our previous work, and based on designed high nonlinear photonic crystal fiber with optimized dispersion around the pump wavelength 1.3 μm, we use the interplay between new other nonlinear effects: self-phase modulation, self-steepening and intrapulse Raman scattering to enhance the bandwidth of the supercontinuum. The supercontinuum covers a bandwidth of more than 260 nm extending from 1120 nm to 1390 nm in only 1.89 mm length of PCF. The obtained spectral bandwidth could contribute to enhance the OCT imaging axial resolution which can be evaluated to 2.8 μm in air, working at 1.3 μm center wavelength which is widely used in dermatology and ophthalmology fields.

Impact of time-delayed feedback on spatiotemporal dynamics including dissipative rogue waves

Tue.
15:45–16:00
R Tinmel

M. Tlidi[1], K. Panajotov[2], S.V. Gurevich[3], A.G. Vladimirov [4]
[1] *Université Libre de Bruxelles, Belgium*
[2] *Vrije Univ. Brussel, Belgium*
[3] *University of Münster, Germany*
[4] *WIAS, Berlin, Germany*

We investigate effect of the time-delayed feedback, and rogue wave formation in nonlinear optical cavities. For this purpose, we consider a broad-area semiconductor cavity subject to a coherent optical injection, a laser with a saturable absorber and the Lugiato-lefever models. In addition, we investigate the formation of extreme events such as rogue waves in nonlinear optics. This issue has witnessed a sudden acceleration in 2007 with the experimental evidence of this phenomenon in fiber optics. Since then, a huge amount of scientific production has been carried out. Often, the long tail probability distribution is the fundamental characteristics accounting for the generation of rogue waves. They correspond to large intensity pulses in the transverse directions of a resonant cavity. Various mechanisms have been proven to be responsible for the generation of rogue waves in spatially extended systems. We propose a new mechanism based on the optical delay feedback control.

MS 4

Nonlinear dynamics in spatially extended systems: theory and experiments/Rogue waves, solitons, and supervontinum in nonlinear fiber optics: Where are we now?

Organizers: *M. Tlidi* Belgium, *A.G. Vladimirov* Germany, *M. Taki* France, *S.V. Gurevich* Germany, *M. Clerc* Chile

Scheduled:

Monday	*14:00–15:30*	Adam Park Hotel	**Room Tinmel**
Monday	*16:00–17:45*	Adam Park Hotel	**Room Tinmel**
Tuesday	*10:30–12:10*	Adam Park Hotel	**Room Tinmel**
Tuesday	*14:30–16:15*	Adam Park Hotel	**Room Tinmel**

Cnoidal solutions of the higher order NLS-type PDEs of Kodama and Lugiato-Lefever

Tue.
16:50–17:10
R Tinmel

R. Conte[2,3], S. Coulibaly[1], A. Taki[1]

[1] *PhLAM, Université de Lille*
[2] *CMLA, ENS Cachan, CNRS, Université Paris-Saclay*
[3] *The University of Hong Kong*

We consider two higher order NLS-type PDEs of interest in nonlinear optics and fluid mechanics, proposed by Kodama and Lugiato-Lefever. By nonperturbative methods, we build particular closed form singlevalued solutions. In particular, we prove that these solutions are the only ones in the class of elliptic or degenerate elliptic functions (i.e. doubly periodic, rational in one exponential, or rational).

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Extreme events induced by spatiotemporal chaos in an extended microcavity laser with saturable absorber

Tue.
17:10–17:30
R Tinmel

F. Selmi[1], S. Coulibaly[2], Z. Loghmari[1], I. Sagnes[1], G. Beaudoin[1], M.G. Clerc[3], S. Barbay[1]

[1] *Laboratoire de Photonique et de Nanostructures, CNRS, Université Paris-Saclay, France*
[2] *Université de Lille, CNRS, UMR 8523 - PhLAM, Lille, France*
[3] *Facultad de ciencias FIJicas y Matemáticas, Universidad de Chile, Santiago, Chile*

Extreme events such as rogue wave in optics and fluids are often associated with the merging dynamics of coherent structures. We present experimental and numerical results on the physics of extreme events appearance in a spatially extended semiconductor microcavity laser with intracavity saturable absorber [1]. This system can display deterministic irregular dynamics only thanks to spatial coupling through diffraction of light. We have identified parameter regions where extreme events are encountered and established the origin of this dynamics in the emergence of spatiotemporal chaos, by studying the proportion of extreme events and the Kaplan-Yorke dimension of the attractor.

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[1] F. Selmi, S. Coulibaly, Z. Loghmari, I. Sagnes, G. Beaudoin, M. G. Clerc, S. Barbay, **Phys. Rev. Lett. 116**, 013901 (2016).

Fiber Bragg gratings with soliton-like profiles

Tue.
17:30–17:50
R Tinmel

S. Bugaychuk

Institute of Physics of the National Academy of Sciences of Ukraine, Kiev, Ukraine

We consider interaction of plane waves during their propagation in a long dynamical nonlinear medium with relaxation. The appropriate system combines the evolution equation for the medium and the coupled-wave equations, in which the coupling coefficients comprise the properties of the medium. The physical phenomenon involves two joint processes: (i) the formation of a dynamical grating in the medium under the action of the light interference pattern creating by the interacting waves, and (ii) the self-diffraction of these waves on this grating. We obtain that the whole dynamical system is reduced to the defocusing nonlinear Sohrodinger equation (NLS) on condition that a reflection geometry ensured. The solutions of this NLS describe a transformation of the grating amplitude profile in the medium. One of the example is a stationary regime, where the grating amplitude takes the shape described by the solution of the dark envelope soliton. At the same time, the interacting waves can get amazing properties during their self-diffraction on the grating, which has the soliton-like profile. Thus, in the case of the dark soliton

solution, the transmitted wave may be significantly amplified due to taking energy from the reflected wave.
Such properties, which have been obtained from the self-consistent task of wave interaction in a dynamical medium, appeared very suitable for applications in Bragg fibers, as the both processes are essential: an extended Bragg grating is created there, and the waves are diffracted on this grating. We consider variety of effects in Bragg fibers occurring during wave diffraction on non-uniform gratings. But the gratings possess the determined distributions of the amplitude envelope, which should match the soliton solutions of the NLS, that we have received in our self-consistent task.

From Kerr frequency comb to extreme events generation

Tue.
17:50–10:05
R Tinmel

S. Coulibaly

UFR de Physique, Université de Lille, France

Nonlinear medium inside externally driven passive cavities are known to generate a linear instability that consists on spontaneous appearance of periodic states: the modulational instability. Under the effect of the nonlinearities, this instability saturates giving rise to fully nonlinear solutions that are usually well described by multi-scale analysis and close to the onset of the instability. Here, we take advantage of a universal feature of such solution, that is, the triangular shape of the spectrum to construct an ansatz that describes the fully nonlinear periodic state. Hence, we were able to propose to a high accuracy an analytical description of this nonlinear solution in a fiber ring cavity. By computing the Lyapunov spectrum associated to this periodic state, we were able to single out a route to spatiotemporal chaotic regime in which rogue wave have been observed and later statistically studied.

Manipulation of spectro-temporal properties of short pulses with variable dispersion fiber

Tue.
18:05–18:20
R Tinmel

A. Bendahmane

Laboratoire Interdisciplinaire Carnot de Bourgogne, Université de Bourgogne, Dijon, France

This work explores the control of the spread of solitons in optical fibers. Solitons generally undergo stimulated Raman scattering which leads to a spectral shift imposed by the properties of the fiber and the pump laser. To overcome these limitations, we propose to add a new degree of freedom to the system using topographical fibers. The goal is to locally adapt the guidance properties to shape the pump pulse and energy into a soliton with adjusted spectro-temporal properties. In addition to the fundamental interest that these studies reveal about the robustness of solitons in the presence of strong variations of dispersion and nonlinearity, they present an applicative interest in the development of new sources of light whose color and duration could also be adjustable.

MS 5
Analytical and semi-analytical methods in nonlinear dynamics

Organizers: *J. Awrejcewicz* Poland, *R.H. Rand* USA, *K.W. Chung* Hong Kong, *M. Belhaq* Morocco

Scheduled:

Monday	*14:00–15:30*	Adam Park Hotel	**Room Toubkal**
Monday	*16:00–17:30*	Adam Park Hotel	**Room Toubkal**

Homoclinic-doubling bifurcation in the takens-bogdanov normal form with D_4 symmetry

Mon.
14:00–14:20
R Toubkal

K.W. Chung[1], B.W. Qin[1], M. Belhaq[2], A.J. Rodríguez-Luis[3]

[1] *City University of Hong Kong, Hong Kong*
[2] *University Hassan II, Casablanca, Morocco*
[3] *Universidad de Sevilla, Spain*

In the detection of homoclinic bifurcation of a perturbed dynamical system, Melnikov's method is a well-established rigorous approach. However, this method is not able to provide an analytical approximation of a homoclinic orbit. The investigation of homoclinic bifurcation is usually resorted to the use of a continuation package such as HomCont or MatCont.
In this talk, we consider the homoclinic orbits arisen in the following Takens-Bogdanov normal form with D_4 symmetry:

$$\ddot{u} = -\lambda u + \kappa\dot{u} + Pu^3 + Qu^2\dot{u} + Rv^2u + S v\dot{v}u + T v^2\dot{u} + U v\dot{v}\dot{u},$$
$$\ddot{v} = -\lambda v + \kappa\dot{v} + Pv^3 + Qv^2\dot{v} + Ru^2v + S u\dot{u}v + T u^2\dot{v} + U u\dot{u}\dot{v},$$

where u and v represent the amplitudes of two stable modes, $\lambda, \ldots, U$ are the system parameters and the dot stands for differentiation with respect to time. For $\lambda < 0$, $R = 3P < 0$ and $\kappa = Q = S = T = U = 0$, there exist three pairs of planar homoclinic orbits, namely $u = v$, $v = 0$ and $u + v = \sqrt{\frac{\lambda}{P}}$. For small perturbation of the system parameters, we apply a nonlinear time transformation (NTT) method to obtain the analytical approximations of these homoclinic orbits in the four-dimensional phase space. The NTT method is able to predict analytically the homoclinic-doubling bifurcation in which a 2-homoclinic orbit is spawned from a homoclinic orbit, giving rise to a period-doubling and a saddle-node bifurcation curve. The analytical finding is confirmed by comparisons to the results obtained by numerical simulations. The NTT method provides an algebraic approach to study the homoclinic bifurcations arisen in high-dimensional dynamical systems.

Parametric excitation of a delay limit cycle oscillator by periodically varying the duration of the delay

Mon. 14:20–14:40 R Toubkal

L. Lazarus, M. Davidow, R.H. Rand

Cornell University

In this paper we study the differential-delay equation

$$\dot{x} = -x(t - T) - \epsilon x^3 \tag{1}$$

where the delay T is taken to be time–dependent and given by

$$\text{delay} = T = \frac{\pi}{2} + \epsilon k + \epsilon \cos \omega t \tag{2}$$

For most forcing frequencies w of the delay, the system exhibits quasiperiodic behavior due to the coappearance of forcing-frequency oscillations together with the limit cycle of the oscillator. However, the system has a 2:1 resonance which results in a small region of parameter space about $\omega = 2$ where the oscillator behaves periodically.

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Effects of an arbitrary real elliptic parameter on stability charts of undamped and damped oscillators with elliptic-type parametric excitation

Mon. 14:40–15:00 R Toubkal

I. Kovacic, M. Zukovic

Centre of Excellence for Vibro-Acoustic Systems and Signal Processing, Faculty of Technical Sciences, University of Novi Sad, Serbia

The equation considered in this study is given by

$$\ddot{x} + 2\xi\,\dot{x} + (\delta + \varepsilon\,\text{cn}\,[t\,|m\,])\;x = 0, \tag{1}$$

where the excitation has the form of the Jacobi cn elliptic function cn $[t\,|m\,]$, and its elliptic parameter can have *any* real value. For $m = 0$, this equation turns into the well-know Mathieu equation. Thus, the aim here is to determine the effects of the elliptic parameter on the stability charts in the (δ, ε) plane and compare them with the one corresponding to the Mathieu equation. Three cases are recognized: Case I when m is negative, Case II when $0 \leqslant m < 1$, and Case III corresponding to positive m,when the cn function turns into the dn function.As the cn elliptic-type excitation can be interpreted as a certain multi-frequency excitation, the equation of motion (1) is treated by two semi-analytical methods: first, the cn elliptic function is replaced by the corresponding Fourier series;

second, Eq. (1) is transformed by introducing new time as the Jacobi amplitude. Then, harmonic balancing and Hill's determinants are utilized to determine the expressions for the transition curves. The results obtained are compared mutually as well with the solutions produced by using numerical integration in conjunction with Floquet theory, yielding the following conclusions: in Case I and II, the instability regions shift towards lower values of δ as m increases from negative values. In Case III, the instability tongues are oblique and move towards higher values of δ and m increases from unity. In general, the number of instability tongues on the fixed region of δ considered changes with m, too: in Case I and II, they become closely compacted as m increases, while in Case III the opposite holds.

Dynamics of periodically driven nonlinear coupled oscillators

Mon.
15:00–15:15
R Toubkal

P. Fritzkowski[1], R. Starosta[1], G. Sypniewska-Kamiñska[1], J. Awrejcewicz[2]

[1] *Institute of Applied Mechanics, Poznan University of Technology, Poznañ, Poland*
[2] *Department of Automatics and Biomechanics, Technical University of Lodz, Poland*

Vibrations of nonlinearly coupled oscillators are investigated analytically and numerically. Basically, a discrete one-dimensional chain-like system is considered with the Duffing-type nonlinearity, viscous damping and kinematic harmonic excitation. Equations of motion are presented in a non-dimensional form. Approximate analytical solutions are obtained by means of the Krylov-Bogoliubov method for the case of two and three coupled oscillators. The influence of particular physical parameters on dynamics of the system is discussed. The analytical solutions are compared with results of numerical simulations. The equations describing the phase di?erence between the neighboring oscillators are derived and solved to analyze the phenomenon of synchronization.

Next, the numerical studies are extended to chains comprised of many interconnected oscillators. For the system with weak and strong coupling, the character of vibration is determined (regular/non-regular), energy transfer between the system members is analyzed, and the phase locking effect is observed. It is shown how response of the dynamical system changes, if the ideal constraints are replaced with non-ideal ones, i.e. when a dry friction model is incorporated into the problem. The results are presented in the form of time-history plots, phase diagrams, Poincare maps and bifurcation diagrams.

Averaging in parametrically excited systems - A State space formulation

Mon.
15:15–15:30
R Toubkal

B. Pfau[1], T. Breunung[1], F. Dohnal[1], R. Markert[2]

[1] *Technische Universitat Darmstadt, Germany*
[2] *Alstom Switzerland Ltd, Baden, Switzerland*

Parametric excitation can lead to instabilities as well as to an improved stability behavior,according to whether a parametric resonance or anti-resonance is present. The beneficialeffect of a parametric anti-resonance is the opportunity to fully quench self-excited vibrations, this phenomena wasdiscovered by TONDL in [2]. In order tocalculate the stability domains andboundaries, the method of averaging is applied. Systems with non-

symmetric matricesareconsidered, which is a reason to formulate the problem in state space. The presentedworkextends existing methodstoa more general form.
An advantage of the formulation in state space is that time-independent damping coefficients donot have to be considered as small, which leads to a strict separation of time-varying andconstant matrices. As a result, the full information about the eigenvalues and eigenvectorsof the underlying time-invariant system is incorporated in the calculation. It turns out, thatthis approach enhances the first order approximation significantly. Furthermore, it allowsan easier and distinct handling of the averaging method, especially for systems with non-symmetric system matrices.
As examples, two systems are investigated. A generic mechanical system with a negativedirect damping coefficient (from [1]) and a rotor system mounted in journal bearings with adjustable geometry, which can stabilize the system. Forboth cases, analytical predictions and numerical results from FLOQUET theory match very well. It also shows the potential ofthe usage of parametric anti-resonances for vibration suppression.

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Using stochastic effects in fluid environments for minimal control

Mon.
16:00–16:20
R Toubkal

C. Heckman

Department of Computer Science University of Colorado, Boulder, USA

Recent years have seen the increased interest in the deployment of robots to track various physical, chemical, and biological processes in the ocean, *e.g.*, onset of harmful algae blooms, dispersion of hazardous contaminants, etc. However, a significant challenge of working in a geophysical fluid environment like the ocean is that it spans large physical scales, is stochatic, and time-varying. Furthermore, as roboticists, we have a tendency to view the ocean as a featureless expanse of open space. However, geophysical flows do exhibit coherent structure and these structures are important because they give us insight into the dynamics of the fluidic environment.
We are interested in the development of distributed control strategies for autonomous sensing and tracking of a specific class of coherent structures called Lagrangian coherent structures (LCS). LCS are the extensions of stable and unstable manifolds to general time-dependent flows [5] and divide the flow into dynamically distinct regions. For two-dimensional (2D) flows, LCS are analogous to ridges defined by local instability, and can be quantified by Finite-Time Lyapunov Exponents (FTLE). Recent work showed that time and fuel optimal paths in the ocean can coincide with a specific class of structures called Lagrangian coherent structures (LCS) [6,8]. Furthermore, LCS denote regions in the flow where more escape events occur [5]. This suggests knowing the locations of the

LCS boundaries can minimize sensor break out, or escape, from their monitoring regions and prolong their operational lifespan.
In our previous work [11], we developed a collaborative robotic control strategy for tracking stable and unstable manifolds in 2D flows and showed how the strategy can be used to track LCS boundaries in the ocean. In this work, we will consider the development of control strategies for autonomous underwater vehicles that can leverage knowledge of LCS locations and the underlying stochastic environment to determine time and fuel optimal paths from one LCS-bounded region to another. Recently, new mathematical methods have been developed to elucidate the effects of noise on dynamical behavior [1,2,3,4]. These methods accurately predict the expected switching time of robots between distinct basins of attraction. Moreover, the techniques predict the noise underlying the most probable escape path from a region. Building on these techniques, we present a controller that can identify the most likely routes to transport within a region of interest and actuate to follow these paths, or avoid them if the goal is to remain within the desired region. The result is a strategy that leverages the surrounding fluid dynamics and the inherent environmental noise that minimizes the overall control effort of the vehicle.

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URL: http://www.sciencedirect.com/science/article/pii/S0167278905004446.

Control of the nutation of a spinning top through rotation

Mon.
16:20–16:40
R Toubkal

H. Sheheitli[1], J.R. Touma[2]

[1] *Lebanese American University, Byblos, Lebanon*
[2] *Department of Physics, American University of Beirut, Beirut, Lebanon*

The spinning top is a classic paradigm for illustrating gyroscopic effects, the understanding of which is essential for the advancement of numerous technologies such as the flywheel for energy storage and inertial sensors for navigation. Inspired by planetary systems, where spinning bodies are often locked in spin- orbit resonance in what’s known as Cassini states, we study the dynamics of a spinning top driven by a turntable that rotates with a given angular speed Ω. The pivot point of the top is at a fixed distance from the center of the turntable. We show that such a setup leads to resonance where the spinning top is locked in a state of relative equilibrium: precessing with an angular speed equal to that of the turntable while maintaining a constant nutation angle. We examine how the existence and stability of these relative equilibria, along with the corresponding value of the nutation angle, depend on parameters such as the initial spin angular momentum and Ω. The analysis leads to conditions that allow the spinning top to be captured into resonance as Ω is slowly varied. This provides a mechanism by which the orientation of the spinning top, represented by the nutation angle, can be controlled by slowly varying the rotational speed of the turntable.

Passive linearization of nonlinear systems at resonance

Mon.
16:40–17:00
R Toubkal

G. Habib, C. Grappasonni, G. Kerschen

Aerospace and Mechanical Eng. Dept. University of Liège, Belgium

Many technological applications rely on linear properties of resonant vibrations, such as force-displacement proportionality and invariance of the resonant frequency. Although in most of mechanical systems these properties are well verified for small vibration amplitudes, they generally do not persist to even moderate amplitudes of oscillation, which activate the nonlinearities of the system. This phenomenon drastically limits the working range of many mechanical devices [1].

The most typical adopted approach to get rid of undesired nonlinearities is the feedback linearization [2], which consists in providing a force to the system, calculated in a feedback loop, that compensates the contribution of the nonlinearity. However, being an active control, it requires an accurate monitoring of the system state, an actuator and an external source of energy.

We propose an alternative, fully passive, approach to deal with undesired but unavoidable nonlinearities in mechanical systems. Our concept consists in adding supplementary nonlinearities into the system, in order to compensate the existing ones, to some extent. The accurate tuning of these nonlinearities allows to retrieve target linear properties, such as force-displacement proportionality or invariance of the resonant frequency, up to obtaining a nonlinear resonance, which resembles a linear one from many points of view.

First, an analytical procedure is developed to identify the nonlinear resonances of the system. The procedure exploits nonlinear normal modes [3] (NNMs), which describe the

undamped, unforced dynamics of the system near resonances. The NNMs are explicitly identified through harmonic balance approximation and a straightforward expansion.
In order to relate the NNMs to the forced damped dynamics, we consider the energy balance equation [4], which indicates that, during a full period of oscillation, the energy dissipated by the damping terms is equal to the energy introduced by the external forces. The combination of the NNMs and energy balance allows us to have complete (but approximate) information about the location of the resonant peaks in the force-frequency space.
The outlined procedure generates equations which explicitly display the contribution of the different nonlinearities of the system. This allows us to tune them conveniently, in order to retrieve the target linear properties.
The concept is experimentally validated on a mechanical structure, consisting of a cantilever beam with a nonlinear boundary condition and a doubly-clamped beam connected with each other.(Through anhaccurate designaof theigeometry ofothetdoubly-clamped beampit was possible to compensate the nonlinearity of the cantilever beam, in order to enforce force- displacement proportionality at the resonant peak.
Then, computing numerically the experimental model, another nonlinearity is introduced into the system, allowing to enforce also invariance of the resonance frequency for one mode of vibration. The resultant resonant frequency resembles that of a linear system in terms of shape of the curve, isochronicity and foce-displacement proportionality.

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Asymptotic analysis of the nonlinear shaft vibration

Mon.
17:00–17:15
R Toubkal

G. Sypniewska-Kamiñska[1], R. Starosta[1], J. Awrejcewicz[2]

[1] *Poznan University of Technology, Institute of Applied Mechanics, Poznan, Poland*
[2] *Technical Universityof of Łódź, Department of Automatics and Biomechanics, Poland*

Torsional vibrations belongs to major problems in designing the power transmission systems [1,2,3]. Two rotating and vibrating systems are considered in the paper. The systems consist of two or three disks fasten to the elastic shaft. The shaft is relatively light, so its mass may be neglected. Elastic properties of the shaft are nonlinear of the cubic type. One of the disks is under the action of the harmonically changing torque. The asymptotical Multiple Time Scale method is adopted to solve the mathematical model of the problem. The analytical solution gives possibility to qualitative analysis of the systems behaviour for various conditions. Our investigations are mainly focused on the shaft vibration near external resonance. The analytical approach allows us to detect an important dynamical transition in the non-steady state vibration, leading to the significant sudden change in the amplitude modulation with increasing of the values of the nonlinearity parameters. Intensive energy exchange between the system and external excitation is observed.

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On the treatment of delay terms in the slow flow of nonlinear differential equations with delayed self-feedback

Mon.
17:15–17:30
R Toubkal

S.M. Sah[1], R.H. Rand[2]

[1] *Nanostructure Physics, KTH Royal Institute of Technology, Stockholm, Sweden*
[2] *Cornell University, Ithaca, USA*

This work concerns the dynamics of nonlinear systems that are subjected to delayed self-feedback. Perturbation methods applied to such systems give rise to slow flows which characteristically contain delayed variables. We consider two approaches to analyzing Hopf bifurcations in such slow flows. In one approach, which we refer to as approach I, we follow many researchers in replacing the delayed variables in the slow flow with non-delayed variables, thereby reducing the DDE slow flow to an ODE. In a second approach, which we refer to as approach II, we keep the delayed variables in the slow flow. By comparing these two approaches we are able to assess the accuracy of making the simplifying assumption which replaces the DDE slow flow by an ODE. We apply this comparison to two examples, Duffing and van der Pol equations with delayed self-feedback.

MS 6

Deterministic and stochastic dynamics and control of nonlinear systems

Organizers: *J.M. Balthazar* Brazil, *M.E. Semenov* Russia, *P.B. Gonçalves* Brazil

Scheduled:

Monday	*16:00–17:45*	Adam Park Hotel	**Room Tichka**
Tuesday	*10:30–12:10*	Adam Park Hotel	**Room Toubkal**

Exploring the nonlinear stochastic dynamics of an orchard sprayer tower moving through an irregular terrain

Mon.
16:00–16:20
R Tichka

A. Cunha Jr[1], J.L. Palacios Felix[2], J.M. Balthazar[3]

[1] *Universidade do Estado do Rio de Janeiro, Brazil*
[2] *Universidade Federal do Pampa, Brazil*
[3] *Instituto Tecnológico de Aeronáutica, Brazil*

In agricultural industry, the process of orchards spraying is of extreme importance for pest control. The non control of pests can lead to problems such as: (i) reduction of quality in the agricultural products, which is bad for the consumer; (ii) partial or total loss of the plantation, which causes huge financial losses to the producer. In orchards spray process it is used an agricultural equipment, called sprayer, that consists of a reservoir and fans, these being mounted over an articulated tower, which is supported by a vehicle suspension [1]. This equipment is subject to a load of random nature, due to soil irregularities, which may hamper the proper dispersion of the fluid spraying. This work presents the construction of a consistent stochastic model of uncertainties to describe the non-linear dynamic behaviour of an orchard sprayer tower, subjected to random excitations due to soil irregularities. In this model, the mechanical system is described as an inverted pendulum over a vehicle suspension, and the random loadings are assumed to be a harmonic random process, with random amplitude and frequency [2, 3]. Uncertainties are take into account through a parametric probabilistic approach, where maximum entropy principle is used to consistently construct the distribution of the random parameters, and Monte Carlo method is employed to compute the propagation of uncertainties through the stochastic model. Numerical simulations show that this system may present periodic, and chaotic behaviour, and highlight large discrepancies in the stochastic system response, when compared with nominal (deterministic) model [2–4].

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Properties and approximation of the set of trajectories of the control systems with limited control recourses

Mon.
16:20–16:40
R Tichka

N. Huseyin[1], A. Huseyin [1], Kh.G. Guseinov [1]

[1] *Cumhuriyet University, Faculty of Education, Turkey*
[2] *Anadolu University, Department of Mathematics, Eskisehir, Turkey*

The control system with integral constraint on the control functions is studied. Note that these kind of control functions is inevitable, if the control recourse is exhausted by consumption such as fuel, energy, finance, food etc. (see, [2], [3] and references therein). It is assumed that the behavior of the system is described by an affine Volterra type integral equation which arise in different problems of theory and applications (see, [1] and references therein). Compactness and dependence of the set of trajectories on the system's parameters are studied. An approximation of the set of trajectories generated by all admissible control functions is given and an evaluation for the Hausdorff distance between the set of trajectories and its approximation is obtained.

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Parametric entrainment and phase-locking in a single layer graphene oscillators

Mon.
16:40–17:00
R Tichka

S. Houri[1], S.C. Bueno[1], W.J. Venstra[1,2]

[1] *Kavli Institute of Nanoscience, Delft University of Technology, Lorentzweg, The Netherlands*
[2] *Quantified Air Lorentzweg The Netherlands*

Single layer graphene (SLG) drum resonators offer exciting prospects as experimental testbeds for nonlinear and stochastic dynamics, in addition to showing promise for applications in gas sensing and molecular sieving [1,2].

In this work we demonstrate entrainment and injection locking of an SLG oscillator to an external parametric signal. The oscillator consists of a chemical vapor deposited SLG, transferred to a substrate that is patterned with 15 μm circular cavities. When the SLG is probed with a laser beam, interference occurs between the movable graphene flake and the fixed substrate underneath, causing the reflected intensity to be modulated by the drum position. Meanwhile, when the SLG drum moves from its rest position, it experiences an intensity- dependent photothermal force, which can be viewed as a position-dependent feedback force that acts on the drum. Such a feedback system has been explored before as a means to enable photothermal mode cooling and to induce self-oscillations in suspended SLG membranes [3,4]. In this work we focus on the latter, and a positive photothermal feedback is established, that results in self-oscillation of the SLG drum at a frequency of $fosc \approx 15$ MHz. These oscillations are detected as intensity variations of the reflected He-Ne laser beam, which is collected on a photodiode.

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The role of parameters of smallness in deduction of approximated theories for deterministic dynamics of beams

Mon.
17:00–17:15
R Tichka

E. Babilio[1], S. Lenci[2]

[1] *University of Naples, Naples, Italy*
[2] *Polytechnic University of Marche, Ancona, Italy*

The proposed contribution is focused on the derivation of approximated beam models from a general parent theory, which is deduced in a rigorous manner.
Indeed, models to describe the behavior of rods and beams can be constructed in very different ways, and in fact a number of them has been introduced and investigated over the years [1]. A compact classification includes beam theories in just two broad classes, namely intrinsic or induced theories ([2], p. 285).
In intrinsic theories, a finite number of strain parameters, depending on the arc-length coordinate along a base curve of the beam, allows characterizing the motion in a self-contained and internally consistent way. Although independently developed, some parts of intrinsic theories are often somehow inspired by three-dimensional theory. On the contrary, three- dimensional theory is at the base of induced theories, which are obtained as exact mathematical consequences of the three-dimensional parent through a generalization of projection methods used in the numerical solution of partial differential equations ([3], p. 603) or making use of asymptotic expansions in a slenderness parameter.

Hence, projection and asymptotic beam theories connect three-dimensional representation to that one-dimensional, although they can present difficulties in the formulation of appropriate one-dimensional constitutive laws in terms of known three-dimensional elastic constants and can be troublesome for applications-oriented engineers ([4], p. 5).

For constructing the parent beam model, which is adopted in the proposed contribution, some characteristics of intrinsic theories are mixed together with aspects of induced theories.

Basically, we treat the beam as a three-dimensional slender body, equipped with infinitely many rigid cross sections. The displacement field is assigned without any *a priori* assumption on the order of magnitude of displacements and rotations. However, we consider only deformed states that are planar and twist-less. Strains are got from the three-dimensional deformation gradient tensor, which also appears, together with the second Piola-Kirchoff stress tensor, into the definition of internal contact force and moments, which are cross- sectional averages of the three-dimensional stress field over the cross section.

As a constitutive law, we consider the isotropic Saint Venant-Kirchhoff relationship, however without requiring the material be homogeneous all over the beam, thus especially leaving room for functionally graded composites. Since kinematic assumptions we assign can be regarded as internal constraints [5] for the three-dimensional elastic problem we are dealing with, it is possible to assign the constitutive relationship only on those components of the stress tensor which are not constrained. Further, it is worth noting that we implicitly assume that strains are not too large, since otherwise the second Piola-Kirchhoff stress tensor, which is involved in the constitutive law, cannot appropriately treat possible changes in volume ([6], p.148).

After some calculations, the set of motion equations is deduced. It depends on axial and transversal displacements u, v and on the shear angle γ, which can be in principle of any order of magnitude. However, since in many real-world applications, displacements and rotations are not allowed to be larger than an assigned value, models accordingly approximated may be particularly useful. Further, approximated model, besides their computational advantages, may be able to furnish completely satisfactory informations on the state of beams within the engineering approximations.

In deriving approximated models, it is important to establish the order of magnitude of each term to understand which one is negligible and which other should be retained.

To this end, a parameter of smallness ε. is introduced and u, v, γ, and their derivatives, are replaced by suitably rescaled functions of order of unity times powers of ε.

In fact, different powers of ε are considered for different terms in equations, thus ε playing as multiple parameters of smallness. Indeed, such powers of ε play the relevant role in approximating properly inertial terms, axial strain, bending curvature and so on. By taking into account terms of same power of ε, a hierarchy of models is derived.

Finally, although our attention is mainly paid to deterministic dynamics, resulting approximated beam models can be adopted, maybe with some extent, to the stochastic case of dynamical systems subjected to the effects of noise.

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Non-planar motions of a string vibrating against a smooth unilateral obstacle

Mon.
17:15–17:30
R Tichka

H. Singh, A.K. Mandal, P. Wahi

Department of Mechanical Engineering, Indian Institute of Technology Kanpur, India

Earlier theoretical studies on string vibrations against smooth unilateral obstacle assumed planar motions [1–3]. The present paper analyzes the non-planar motions of strings vibrating against a smooth unilateral curved obstacle. In particular, we have studied the effect of the obstacle in determining the existence and stability of different types of string motions. We have assumed smooth wrapping and unwrapping of the string and hence, there is no loss of energy in impacts leading to a conservative system for which the governing equations have been obtained following the Hamilton's approach. The tensiono is assumed to vary with the string displacement due to stretching of the string which introduces nonlinear coupling between the perpendicular modes. The system of equations has been discretized using the Galerkin approach by assuming functional form of the approximating functions which satisfies all the geometrical boundary conditions. The mathematical model has been numerically investigated, in the presence as well as absence of obstacle, for different initial conditions and certain values of the non-linearity parameter.

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On nonlinear dynamic of a non-ideal Duffing system with fractional damping

Tue.
10:30–10:50
R Toubkal

V. Piccirillo[1], A.M. Tusset[1], G. Litak[2], J.M. Balthazar[3], A. Nabarrete[3], C. de Oliveira[3]

[1] *Federal Technological University of Paraná, Brazil*
[2] *Lublin University of Technology, Lublin, Poland*
[3] *ITA - Tecnologial Institute of Aeronautics, São José dos Campos, Brazil*

The study of problems involving the coupling of several systems was widely explored, in the last years, essentially in function of the change of constructive characteristics of the machines and structures. This paper deals with recent developments on some problems related to elastic structures, such as non-ideal systems, taking into account the full interactions of the vibrating systems, with the energy source of limited power supply (small motors).
By one hand, we can verify that the study of the vibrating systems when the external excitation was influenced by the response of the system had been considered a major challenge in theoretical and practical engineering research. It is also well known that structures supporting unbalanced machines capable of a limited power output are considered, as in the case of real motors and we know that the motion of a vibrating structure under the action of such energy source, it is accompanied by the interaction between these non-ideal motors and their supports. We remarked that when a dynamic system is driven by a power source such as a motor of limited power (NIS), we may have interaction between the motor output and the system response. This interaction manifests itself as a modification of the motor frequency or regime of operation near the resonance and changes in the stable-unstable portions of the dynamical system response. Since most of real motors are of limited power (NIS), the results here obtained render descriptions which are closer to the real situations encountered in practice and it has been considered a major challenge in theoretical and practical engineering research. Near resonance, an increase in power will usually be accompanied by an increase in oscillations amplitude without significant increase in frequency. Only after the maximum amplitude of oscillations has been reached will there be a significant alteration in the frequency.Sommerfeld observed such relationships between the alteration of frequency, amplitude of oscillations and motive power. Usually, this dynamic process is called *Sommerfeld effect,* that is the vibrations provide an "*energy sink*". One of the problems often faced by designers is how to drive a system through resonance and avoid the "energy sink" described by Sommerfeld. By other hand, Fractional damping is appearing in different contexts in any systems with memory and hysteresis. Such damping is defined by a fractional derivative in contrary to classical viscous damping term with the first order derivative. As the memory of the dynamical system induces extra degree of freedom for the phase space the standard methods of dynamical response analysis and system identification, which relies on the knowledge of system dimensionality cannot be used.

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Hysteretic damper based on the Ishlinsky-Prandtl model

Tue.
10:50–11:10
R Toubkal

M.E. Semenov[1,2,3], A.M. Solovyov[2], A.G. Rukavitcyn [2], V.A. Gorlov[1], P.A. Meleshenko[1,2]

[1] *Zhukovsky–Gagarin Air Force Academy, Starykh Bolshevikov, Voronezh, Russia*
[2] *Voronezh State University, Universitetskaya, Voronezh, Russia*
[3] *Voronezh State University of Architecture and Civil Engineering, Voronezh, Russia*

In recent time the problem of damping of oscillations with various nature (mechanical, electric etc.) plays a central role in connection with the development of the modern engineer sciences. In the mechanical vibrations the widely used damper is a linear viscous damper when the energy losses occur due to viscous friction. However this system has a low efficiency beyond the resonance frequencies. As a solution of this problem we can consider both the nonlinear viscous damper and the damper with hysteretic properties, namely we can compare the efficiency both of these models. Let us note that the hysteretic damper has a special fundamental interest due to its strongly nonlinear nature. It should also be noted that the hysteretic model of damper has an evident physical meaning in contrast to the nonlinear viscous model which nature is phenomenological.
In the presented work we consider the dynamics of the mechanical system under internal force with a damper taking into account the hysteretic nature of the damper. As a mathematical model of this hysteretic damper we consider the Ishlinsky-Prandtl model, namely we work in terms of the Ishlinsky converter. Such a converter is a kind of continual system of hysterons and can be presented as a system of parallel coupled nonlinear stops. The obtained numerical results (the results are obtained for a real material, namely for rubber) in the form of the force transfer function demonstrates the efficiency of the hysteretic damper in comparison with the nonlinear viscous damper.

Stochastic collocation-based finite element method in structural nonlinear dynamics

Tue.
11:10–11:30
R Toubkal

K. Sepahvand, S. Marburg

Department of Mechanical Engineering, Technische Universitӓt Mӥnchen, Germany

This paper presents the non-intrusive stochastic FEM techniques to nonlinear dynamic of structures with random parameters. The impact of the parameter randomness on structural responses has been investigated in which uncertain parameters and the structure responses are represented using the generalized polynomial chaos expansions with unknown deterministic coefficients and random orthogonal basis. The deterministic FEM model of the structure is used as black-box and it is executed on a set of random collocation points to predict the responses at each collocation point. Such predictions are adopted to provide deterministic nonlinear solvers the unknown coefficients of the approximated responses. The major advantage of the method is that it can be used for complicated nonlinear structural dynamic problems for which the deterministic FEM model has been already developed. The application of the method is applied to the nonlinear transient analysis of composite beam structures including uncertain material parameters and nonlinear random stiffness and damping. The sampling based stochastic simulation of such problem is too time-consuming. The results show that the proposed method can capture the large range of uncertainty in input parameters as well as in structural dynamic responses while it is very efficient in sense of computational time compared to sampling based methods.

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Homotopy analysis of piezoelectric energy harvesting from a geometrically nonlinear cantilever beam model

Tue.
11:30–11:50
R Toubkal

S. Shahlaei-Far, A. Nabarrete, J.M. Balthazar

Instituto Tecnológico de Aeronáutica - ITA, São José dos Campos, Brazil

Piezoelectric transduction for vibration-based energy harvesting plays an important role for remote/wireless sensor systems. This vibration-to-electric energy conversion mechanism uses the ambient vibration energy to power and/or to recharge such electronic components.

Usually, as in the case of resonance-based energy harvesting, the piezoelectric effect is achieved by fixing a cantilever beam with one or two piezoceramic layers on a host structure and using single excitation frequency. The piezoelectric effect converts mechanical strain induced in the layers into an electric current generating alternating voltage.

Requiring an energy harvester to harvest a reasonable amount of energy when the excitation frequency is low can be a difficult undertaking as the physical dimensions of the devices are small. Maximizing the harvested energy over a wide range of excitation frequencies is achieved by implementing nonlinear structural systems and using a double potential well function.

The nonlinear piezoelectric vibration energy harvesting from a vertical cantilever beam with a tip mass has been previously reviewed and a full description was given focusing on numerical and experimental investigations. The present paper makes use of the homotopy analysis method (HAM) to achieve accurate closed-form analytical solutions to this problem.

An inverted cantilever beam with piezoelastic patch and a tip mass is mounted vertically on an energy harvesting device and is subjected to transverse base excitations. Due to large deformations this geometrically nonlinear device exhibits highly nonlinear behavior such as multiple solutions, jump phenomena and bifurcations.

The homotopy analysis method is a nonperturbative analytical technique for solving differential equations. By means of an embedding parameter it transforms a nonlinear differential equation into an infinite number of linear differential equations to derive a family of solution series. It is valid for strongly independent of small or large parameters, provides a convenient way to adjust and control the rate and region of convergence of a solution series and allows the free choice of different base functions to approximate a nonlinear problem.

Applying the homotopy analysis method to the spatially discretized governing equation of motion, novel analytical solutions of the amplitude and phase of the generalized coordinate are derived to present nonlinear frequency responses and phase diagrams for a range of parameters and different values of the tip masses representing different beam configurations. The aim is to address the subject of piezoelectric energy harvesting from a purely analytical perspective emphasizing the capabilities of a first order approximation of HAM to present highly accurate solutions.

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The application of Wiener series to nonlinear random vibrations

Tue.
11:50–12:10
R Toubkal

D. Demetriou, R.S. Langley

University of Cambridge, UK

The paper investigates the behaviour of nonlinear systems under the influence of white noise (signal with constant power spectral density) forcing. Such systems are investigated using the Wiener series [1] representation; an elegant and not very widely used approach which represents the system response to white noise excitation as an orthogonal expansion. It is expected that results emerging from this research can be used in *predicting* the response of these systems, as well as in the *identification* of the nonlinearities characterising them. These can be achieved through the analysis of the Wiener kernels(Kernels are the generalisation of the impulse response function from linear systems to nonlinear systems.) which are a powerful tool for expressing the nonlinearities of a system. The most important results to be presented in this paper is the failure of Equivalent Linearization (EL) to predict the Wiener kernels of a nonlinear system, the reason behind this failure and finally, a suggestion of an improved approach for predicting the first Wiener kernel.

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MS 7

Mechanical, aeronautic, aerospace and naval structures: mathematical modeling, nonlinear and chaotic dynamical behaviors and control designs

Organizers: *J.M. Balthazar* Brazil *E.M. Jarzêbowska* Poland

Scheduled:

Tuesday *14:30–16:15* Adam Park Hotel **Room Louka**

The linear stability of the responses of axially moving beams supported by an intermediate spring

Tue. 14:30–14:50 R Louka

F. Kostekci
Department of Mechanical Engineering, Hitit University, Turkey

In the present paper, the stability investigation of the linear responses of axially travelling beams supported by an intermediate linear spring is performed numerically by means of searching linear complex eigenvalues. To this end, the boundary conditions and the dynamic equation of motion are obtained by means of the Extended Principle of Hamilton for the two-span Euler-Bernoulli beam. Assuming the harmonic solution of the governing differential equations of motion, the dispersion relation is derived. To have a nontrivial solution in conjunction with the dispersion relation, the frequency equation is obtained by letting the determinant of the matrix representing the coefficients of the equations of the boundary conditions be equal to zero. The aim of this contribution is to compute the complex values of the natural frequencies from the nonlinear frequency equation by means of Secant Method and Muller's Method for the beam supported by an intermediate spring. The real and imaginary parts of the complex eigenvalues versus constant axial transport speed curves are depicted in order to show the linear instability. Depending on the signs of the real and imaginary parts of the complex eigenvalues, the boundaries of the instability regions can be determined.

Multi-robot formation coordination control for collective missions

Tue. 14:50–15:10 R Louka

E.M. Jarzêbowska
Warsaw University of Technology, Institute of Aeronautics and Applied Mechanics, Poland

The paper presents a study of a mobile multi-robot formation (MRF) control problem. The robots are nonholonomic car-like vehicles and perform their mission while coordinating the formation shape when needed. The MRF control problem consists then of performing a mission and being able to reshape the formation. Control design is based upon the centralized strategy assuming that information from robot sensors enables determination of instantaneous relative position of each robot in the workspace, for example, by means

of cameras that watch and monitor the entire environment. Also, a decentralized formation control scenario is studied when each member of the formation has only information of its neighbors and not of the other robots in the formation. Altogether, three mission scenarios are presented using kinematics and dynamics based controllers.

Problems of controlling and coordinating an autonomous MRF gain popularity due to number of benefits of coordinated collective missions in comparison with a single robot mission or a human activity especially in a hazardous environment or when a task is distributed. Popularity of the MRF also comes from their numerous applications, e.g. transportation of payloads, reconnaissance, surveillance and rescue missions, cleaning and inspections in hazardous environment and many more [7–9]. In some situations, formation maintaining is not enough and a MRF may need to change its shape to conform a mission.

Different approaches to MRF modeling, coordination and control are presented in the literature. Usually, members of a MRF are modeled as kinematic or dynamic car-like mobile vehicles or as particle agents that form a swarm equipped with various sensing possibilities [4, 8].

There are three major approaches to formation control, i.e. behavior-based, leader-follower and a virtual structure formation control. In the behavior-based formation control [6], a desired set of behaviors is implemented to individual robots. By grading the behaviors, the overall behavior of a robot is specified. In the leader-follower control strategy [2, 5], followers follow the selected leaders and they position themselves relative to the leader. In the virtual structure control [1], a formation is considered as a single structure and desired motions are assigned to it. The formation in the virtual structure approach is rigid such that geometric relationships between robots have to be fixed during motion. Thus, this formation cannot reshape.

Formation reshaping control strategies were implemented in some studies together with the leader-follower approach. For example, in [2] a framework for cooperative control of a group of mobile robots that allows building a complex system from simple controllers is described. The switching between simple decentralized controllers allows formation reshaping while following a leader or performing a task. In [3] nonlinear control and the graph theory approach are used to study the formation control of mobile robots. The formation reshaping can be achieved by adding or deleting edges in the formation graph.

One of motivations for the presented work is that the problems with the control strategies in [2], [3] and also in other works are that their level of computational complexity grows with the increase of the number of robots in the formation. Also, new control algorithms are generated for different formation coordination schemes. They often suffer from complexity and often cannot be reused for other MRF when different tasks are specified. Also, many of them were never verified experimentally. In this work, a MRF coordination control as well as control of performing a desired task is designed using existing controllers at the kinematics and dynamics levels. The kinematics controllers employed are the input-output linearization and the Samson algorithm. They are simple in implementation and proved good performance in controlling single car-like robots. We examine them with regard to their potential applications for MRF. The dynamics controllers are based upon the generalized programmed motion equations method used successfully for a leader-follower control strategy for a fixed shape formation [5].

The other motivation is to study formation reshaping scenarios when a change of a leader is needed. It may happen though that a leader robot fails during a mission and another robot is to take its role. Three mission scenarios are presented for reshaping the MRF and changing a leader.
Results of simulation studies as well as detailed comparisons and discussions of implemented control methods, at the kinematics and dynamics levels, and controllers are presented in this work.

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Application of the Dahl friction model in the dynamics analysis of grab cranes

Tue.
15:10–15:30
R Louka

A. Urbas, A. Harlecki

Department of Mechanics, University of Bielsko-Biala, Poland

The method of dynamics analysis of grab cranes, which allows to take into account joint friction, is presented in the paper. The cranes modelled here can be built out of any number (n_l) of links, however, only (n_{dr}) links have their own drive which is considered in the flexible form. The cranes are sited on the ground by any number (n_s) of flexible supports modelled as spring-damping elements. Joint coordinates and homogeneous transformation matrices [1] are used to describe the geometry of the cranes. Equations of motion are derived on the basis of the formalism of Lagrange equations by using algorithms presented in monograph [2]. Joint forces and torques used to calculate friction torques in the revolute joints and friction forces in the prismatic joints are determined, in each integrating step of equations of motion, by using the recursive Newton-Euler algorithm [1]. For the requirements of the method proposed, models of revolute and prismatic joints were worked out. Friction coefficients are defined based on the Dahl model [3–5]. It allows to analyse the phenomenon of the pre-sliding displacements [6] in the phases of static friction. For large displacements, the Dahl model is equivalent to the Coulomb friction model.

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Asymptotically stable control for a nonlinear-based multirotor aerial vehicle model

Tue.
15:30–15:45
R Louka

I.A.A. Prado, D.F. de Castro, M.F.V. Pereira,
D.A. dos Santos, J.M. Balthazar

Instituto Tecnológico de Aeronáutica, ITA, Sào josé dos Campos, SP. Brazil

Multirotor Aerial Vehicles (MAVs) have motivated and stimulated many researches in different fields of knowledge such as sensors fusion [1], computer vision [2] and control strategies [3]. Although there is a massive amount of concluded and ongoing research works on MAVs, the design of control laws for such vehicles still has challenges to be overcome. Most of those challenges are related to design control laws that guarantee asymptotically stability, mostly because this system is nonlinear.

The Linear Quadratic Regulator (LQR) is a usual control strategy applied to MAVs [4], which requires a linear design model. Such linear model does not take into account the nonlinear phenomena that are present in the real operation of these vehicles. However, for a more effective control law nonlinearities have to be considered in order to avoid unstable regions of operation. One of the nonlinearities included in the motion equations is the gyroscopic effects resulting from the rotation of the rigid body and the four propellers [5].

Rafikov and Balthazar [6] showed that is possible to construct a linear feedback control law for a nonlinear dynamics that is globally asymptotically stable.

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Identification of nonlinearities in joints of a wing structure

Tue.
15:45–16:00
R Louka

M.S.M. Sani[1,2], H. Ouyang[3]

[1] *Faculty of Mechanical Engineering, Universiti Malaysia Pahang, Pahang, Malaysia,*
[2] *Automotive Engineering Centre, Universiti Malaysia Pahang, Pahang, Malaysia*
[3] *Dynamics Group, School of Engineering, University of Liverpool, Liverpool, UK*

Nonlinear structural identification is essential in engineering. As new materials are being used and structures become slender and lighter, nonlinear behaviour of structures becomes more important. There have been many studies into the development and application of system identification methods for structural nonlinearity based on changes in natural frequencies, mode shapes and damping ratios. A great challenge is to identify nonlinearity in large structural systems. Much work has been undertaken in the development of nonlinear system identification methods (e.g. Hilbert Transform, NARMAX, and Proper Orthogonal Decomposition), however, it is arguable that most of these methods are cumbersome when applied to realistic large structures that contain mostly linear modes with some local nonlinearity (e.g. aircraft engine pylon attachment to a wing). In this paper, a multi-shaker force appropriation method is developed to determine the underlying linear and nonlinear structural properties through the use of the measurement and generation of restoring force surfaces. One undamped mode is excited in each multi-shaker test. Essentially, this technique is a derivative of the restoring surface method and involves a non-linear curve fitting performed in modal space. A reduced finite element model is established and its effectiveness in revealing the nonlinear characteristics of the system is discussed. The method is demonstrated through both numerical simulations and experiments on a simple jointed laboratory structure with seeded faults, which represents an engine pylon structure that consists of a rectangular wing with two stores suspended underneath.

Modeling and position control of tethered octocopters

Tue.
16:00–16:15
R Louka

D.F. de Castro, I.A.A. Prado, M. de Freitas, V. Pereira, D.A. dos Santos, J.M. Balthazar

Instituto Tecnológico de Aeronáutica, ITA, Sào José dos Campos, SP, Brazil

Multirotor Aerial Vehicles (MAVs) have been the subject of many academic studies and have attracted a lot of attention from industry in recent years. MAVs have flight capabilities such as hovering, Vertical Take-Off and Landing (VTOL) and agile maneuvering capability, which cannot be achieved by conventional fixed wing aircraft. However, such vehicles have limited autonomy, which results in flights of at most some minutes.
A sub-category of aerial vehicles is tethered MAVs, which are anchored at a fixed point by a cable. While this limits their motion, it can also works as a power line, providing electrical power to the vehicle and enhancing its flight autonomy. Another advantage of this type of vehicle is its improved hovering capability, since it can be more robust to ambient wind, due to the tension exerted by the cable.
In recent years, tethered balloon [1] and tethered robot satellite [2] are quite common. However, there is little literature available addressing tethered MAVs. A strategy to control a tethered helicopter with a combination of classical PID control laws is provided by Sandino et *al* [3].
The cable provides more robustness against external disturbances due to the stabilizing properties of tether tension in translational dynamics. On the other hand, the tether tension produces an induced moment due to the offset between the point of application of the tension and the center of mass of the vehicle. Since this moment could be similar or larger in magnitude to the torque required to control the rotation of the vehicle in free flight, it must be properly accounted for this undesired rotational influence. This paper presents a modeling and position control strategy for tethered MAV. A viscoelastic model is considered for the cable, in order to reproduce its dynamic behavior. The controller is based on a saturated state feedback control, thus simplifying the controller.

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MS 8

Stability of rotating machines and energy harvesting

Organizers: *J. Mahfoud* France, *N. Kacem* France

Scheduled:

Wednesday *10:30–12:15* Adam Park Hotel **Room Louka**

Numerical study of mass and frequency ratios in a tunable auxiliary mass damper using a friction damper

Wed.
10:30–10:50
R Louka

E.L.C. Guerineau[1], H.T. Coelho[1], F.P.L. Neto[1], M.B. Santos[1], J. Mahfoud[2]

[1] *Mechanical Engineering School, Federal University of Uberlandia, Brazil*
[2] *LaMCoS, Universite de Lyon, CNRS, INSA-Lyon, France*

Auxiliary masses are frequently attached to vibrating systems by springs and damping devices to reduce the amplitude of vibration of the system. Depending upon the application, these auxiliary mass systems fall into one of two distinct classes. A Dynamic Vibration Absorber (DVA) is an auxiliary mass on a spring, which has a damping factor as lower as possible, once it is tuned to the frequency of the excitation force a system’s anti resonance is introduced on this frequency reducing the primary system’s vibration amplitudes. And, when it is necessary to provide damping, an auxiliary system is attached to the structure, so that, the auxiliary mass system works a particular form of damper. This system is called Damped Absorber or Auxiliary Mass Damper (AMD) and it is an extension of the DVA concept [1].

In fact, their function is to reduce vibration amplitudes without energy consumption, however within a narrow frequency band for which the AMD has been tuned, whatever will be the changes in the excitation nature or in the system parameters, its performance will drop drastically. To improve AMD’s robustness a feasible approach is a semi-active absorber (or adaptive, tunable), which changes its characteristics according to the necessities. Such a device has its physical parameters, also its impedance, as consequence adjustable and associated to a correct control law. It is possible to take advantage of this capacity to adapt the system to different variety of excitations, mitigating the excessive vibration. This way, the system becomes a Tunable Auxiliary Mass Damper (TAMD). Additionally, the necessary energy to tune the AMD is much less than the energy necessary to achieve the same attenuation using active actuators, once for the active systems the energy is expended to work against the excitation force.

The aim of this work is to demonstrate, numerically for the moment, the effectiveness of a new TAMD where the modularity is obtained by controlling the normal force of a smart friction spring.

M. Belhaq, M. Houssni & I. Kirrou, *3rd International Conference on Structural Nonlinear Dynamics and Diagnosis* (CSNDD 2016).

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Performances of a nonlinear electromagnetic vibration energy harvester under white noise excitation

Wed.
10:50–11:10
R Louka

C. Drezet, N. Kacem, N. Bouhaddi, E. Foltête

FEMTO-ST Institute, Applied Mechanics Department, UBFC, Besançon, France

Emergence of IoT (Internet of Things) and M2M (Machine to Machine) communication leads the way for a lot of innovations like WSN (Wireless Sensor Network). The nodes of WSN may be placed in an environment hostile to usual powering means (wires, batteries) and therefore alternatives are needed [1]. Energy harvesting aims to collect surrounding energy to power wireless modules, the energy can be present as electromagnetic radiation (light, radio wave), thermal gradient or mechanical movement [2]. In this study, we focus on vibration energy harvesting by the mean of electromagnetic transduction modeled by Lenz-Faraday law of induction. Usually, electromagnetic vibration energy harvesters (VEHs) are based on a single dof oscillator with base excitation and where the mass is a magnet vibrating in a copper coil; when excited at its resonance frequency, the VEH amplifies the vibration movement and converts mechanical energy to electrical energy.

Linear VEH has been widely studied and is well understood [3], several researchers proposed to add nonlinear cubic stiffness to enhance its performances and especially to widen its frequency band under harmonic excitation [4, 5]. Because most of the real life vibrations are random by nature, the behavior of nonlinear VEH under white noise excitation has been analytically studied under assumptions [6]. Using a numerical study, design rules are derived in order to improve the performances of nonlinear VEH under white noise in terms of harvested power and power density (power per unit of length).

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Upper bounds on the power available for harvesting from broadband excitation

Wed.
11:10–11:30
R Louka

D.H. Hawes, R.S. Langley

University of Cambridge, UK

With the large diversity in energy harvesters aiming to extract maximum power from broadband excitations, it is important to know what the maximum power achievable is. This paper derives new upper bounds on the available power for a harvester with general nonlinear stiffness coupled to an electrical circuit. White noise base excitations are known to input power proportional to the total oscillating mass of the system and the magnitude of the spectral density of the noise regardless of the details of the oscillating system [1]. This power will be split between undesirable mechanical damping and useful electrical damping with the form of the stiffness profile and device parameters determining the relative proportions in each dissipation mechanism.

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Nonlinear models for rotor AMB system drop

Wed.
11:30–11:50
R Louka

C. Jarroux Jr[1,2], R. Dufour[2], J. Mahfoud[2], B. Defoy[1], T. Alban[1], A. Delgado[3]

[1] *Thermodyn, GE Oil and Gas, Le Creusot, France*
[2] *Université de Lyon, CNRS, INSA-Lyon, Villeurbanne, France*
[3] *GE Global Research Center, Niskayuna, USA*

Rotor behavior onto Touch-Down Bearings (TDB) during a drop event is analyzed. In the case of Active Magnetic Bearings (AMB) shut down, the rotor drops onto TDB, providing

a non-linear transient motion where the amount of damping is a key parameter. In this paper, a comparison between several models of the damper device is carried out.

Energy harvesting from quasi-periodic vibrations in a delayed forced Duffing oscillator

Wed.
11:50–12:05
R Louka

Z. Ghouli[1], M. Hamdi [2], F. Lakrad[1], M. Belhaq[1]

[1] *University Hassan II-Casablanca, FSAC, Casablanca, Morocco*
[2] *University Mohammed I Oujda, FST-Al Hoceima, Morocco*

We explore quasi-periodic (QP) vibration-based energy harvesting in a forced nonlinear oscillator under time delay. The energy harvesting system consists in a delayed Duffing oscillator subject to harmonic excitation coupled to an electric circuit through an electromechanical coupling mechanism. We consider the case of primary resonance for which the frequency of the excitation is near the natural frequency of the oscillator. Application of the double-step perturbation method enables the approximation of the amplitude of the QP vibrations of the oscillator around the resonance. This amplitude is used to extract the average powers from the harvester device in the QP region. The influence of different system parameters on the performance of the QP vibration-based energy harvesting is reported and discussed. Results show that for appropriate values of parameters, large amplitude QP vibrations can be used for energy harvesting in broaden parameters away from the resonance peak. Numerical simulation is conducted to support the analytical predictions.

New approach in steam turbine rotor balancing procedure

Wed.
12:05–12:20
R Louka

G.A. Shneba

Belgrade University, Serbia

The activity of balancing refers to mounting a rotor on a balancing system performing the mass correction there, rather than in the rotors permanently installed location.
Field balancing involves in place, balancing in the rotors permanently installed location (in situ). It will generally produce better if the rotor is accessible in terms of vibration. However, balancing on a balancing machine mostly will produce a better balance. These two segments seem contradictory and need to be clarified. The balancing is better at measuring and correcting for unbalance, especially two planes or dynamic unbalance. It cannot compensate for field installation factors. Two-plane balancing on a balancing machine usually produces better result than two-plane balancing in the filed because the compounding filed installation factors are not present. Filed installation factors are bearing clearance, support stiffness and resonance, additional components added to the rotating assembly (such as coupling, key, and fastness), and alignment.
In this paper the original method was devolved for the steam turbine rotor balancing with a low surface hardness at journals of the main shaft.
It was necessary to design detachable ring adapter to protect the journal surface during rotation on the rolling elements of the balancing machine.
The complete design process and application also measurement and verification of the method is described in this paper.

MS 9
Special Session

Organizers: *K. Allali* Morocco, *M.E. Semenov* Russia

Scheduled:

Wednesday *10:30–12:15* Adam Park Hotel **Room Tinmel**

Heat removing under hypersonic conditions

Wed. 10:30–10:50 R Tichka

M.E. Semenov[1,2,3], V.A. Nesterov[4], I.E. Kuznetsov [1], A.M. Solovyov [2], P.A. Meleshenko [1,2]

[1] *Zhukovsky Gagarin Air Force Academy, Voronezh, Russia*
[2] *Voronezh State University, Universitetskaya sq. 1, Voronezh, Russia*
[3] *Voronezh State University of Architecture and Civil Engineering, Voronezh, Russia*
[4] *Moscow Aviation Institute (National Research University), Moscow, Russia*

Hypersonic motion plays an important role in modern engineer sciences. Such an interest is connected with the development of the modern air shuttles both for civil and military aviation. An important problem in hypersonic motion is a heat transfer, namely the heat removing from the heated parts of the shuttle. Herewith an important parameter which determines the efficiency of the heat removing process is a form of the front part of the shuttle. It should be noted that this problem has both fundamental and applied interest. In this work we analyze the process of heat transfer (heat removing) in the case of hypersonic aircraft (with a Mach number in the interval from 6 to 8) with the various forms of the front part. Modeling and simulation are based on the standard methods and models of aerodynamics together with the standard methods of thermodynamics and statistical physics as well as nonlinear analysis. We analyze also the various kinds of materials that determine an efficiency of the heat removing process.

Multiple solutions for a class of nonhomogeneous problems with critical exponent

Wed. 10:50–11:10 R Tichka

M. Massar

Faculté des Sciences et Techniques d'Al Hoceima, Maroc

In this paper, we study the existence and multiplicity of solutions for the problem

$$\begin{cases} -\Delta_{p_1(x)}u - \Delta_{p_2(x)}u - a(x)|u|^{m(x)-2}u = \lambda|u|^{q(x)-2}u + f(x,u) & \text{in } \Omega \\ u = 0 & \text{on } \partial\Omega, \end{cases}$$

The technical approach is mainly based on the variational method combined with the genus theory.

M. Belhaq, M. Houssni & I. Kirrou, *3rd International Conference on Structural Nonlinear Dynamics and Diagnosis* (CSNDD 2016).

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Liquid-liquid polymerization front under quasi-periodic gravitational modulation

Wed.
11:10–11:30
R Tichka

S. Assiyad[1], K. Allali [1], M. Belhaq [2]

[1] *University Hassan II-Casablanca, FSTM, Department of Mathematics, Mohammadia, Morocco*
[2] *University Hassan II-Casablanca, FS, Department of Physics, Casablanca-Morocco*

The influence of quasi-periodic gravitational modulation of polymerization front with liquid monomer and liquid polymer is studied in this paper. The model considered includes the heat equation, the equation for the concentration and the Navier-Stokes equations under the Boussinesq approximation. The linear stability analysis of the problem is conducted and by using numerical simulation, the convective instability boundary is carried out. Results obtained show that the convective instability threshold depends on the amplitudes and on the frequencies ratio of the quasi-periodic gravitational modulation. Effect of Prandtl number is also examined.

The onset of Darcy-Bénard instability in a horizontal porous channel with a free surface using a thermal nonequilibrium model

Wed.
11:30–11:50
R Tichka

A. Barletta[1], H. Lagziri[1,2], M. Cellia [1] and M. Bezzazi[2]

[1] *Alma Mater Studiorum Università di Bologna, Bologna, Italy*
[2] *Department of Physics, University of Abdelmalek Essaadi, Tanger, Morocco*

The Darcy-Bénard problem is the equivalent of Rayleigh-Bénard problem with a porous material. In several papers and books it is also well known as Horton-Rogers-Lapwood problem[1]. The classical Darcy-Bénard configuration is defined as a horizontal porous layer saturated with Newtonian fluid and confined between two isothermal walls heated from below. The existence of the porous material in thermoconvective region implies a new expression of the critical Rayleigh number. It is reformulated as a product between

the traditional Rayleigh number for the pure fluid and Darcy number. It is well-known as Darcy-Rayleigh number, R. By presence of the local thermal equilibrium condition, one energy balance equation is considered. In this case, the threshold value of the Darcy-Bénard instability is $R = 4\pi^2$ [4].The thermal boundary conditions can change to various combination between Dirichlet, Neumann and Robin boundary conditions. The same can also happen for the case of the hydrodynamic boundary conditions. Following Nield and Bejan [4], the critical value $R = 0$, can be observed while the boundary conditions are subjected to a uniform pressure and heat flux. Which implies that, changing the boundary conditions into isoflux or free surface forces the basic flow to be more unstable. On the other hand, the local thermal equilibrium can be relaxed when the temperature of the solid and fluid phases are not the same, in this case the energy equation for the porous medium is replaced by two equations, one for the solid phase and one for the fluid phase. Under this model, the criterion for the onset of convection in porous system depends on the effect of two nondimensional parameters: the inter-phase heat transfer parameter H, the thermal conductivity ratio of the fluid and solid phase γ. Broadly speaking, the local thermal equilibrium model can appear inside a porous medium either by letting $H \to \infty$ with $\gamma \approx O(1)$ or by letting $\gamma \to \infty$ with $H \approx O(1)$ [2]. Thus, to study the effects of isoflux boundary instead of isothermal with local thermal non equilibrium condition on the onset of instability, Yang and Vafai [3] modelled a standard formula of the heat flux by two mathematical approaches, called model A and model B. The first one defines the total heat flux as sum between Fourier heat flux of the solid and fluid phase, weighted by the volumetric fraction of each phase, while the second one equals the Fourier heat flux considered either in the solid or in the fluid phase. Usually, model A is used for the case of impermeable wall with higher thermal conductivity [3].

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MS 10

Model reduction methods dedicated to low/high frequency system dynamics

Organizers: *N. Bouhaddi* France, *M. Ichchou* France

Scheduled:			
Wednesday	*10:30–12:20*	Adam Park Hotel	**Room Tinmel**

Metamodel for nonlinear dynamic response analysis of damaged laminated composites

Wed. 10:30–10:50 R Tinmel

S. Mahmoudi, F. Trivaudey, N. Bouhaddi

FEMTO-ST Institute, University of Franche Comté, Besançon, France

Damage in composite structures can be classified in three forms, matrix cracking, fibre fracture and delamination. These forms of damage may not be visible from surface, but they may have a significant effect on the structure stiffness, its strength and its life-time. Hence, the damage assessment is the subject of several studies in the literature, especially with regard to techniques of detection, quantification and localization of the damage. Kachanov [1] proposed a first meso-modelling of damage which is introduced as the degree of reduction in the structure resistance and the loss of rigidity. For laminated composite structures, fibre rupture generally occurs in the final phase of layer rupture whereas matrix cracking is considered as the first damage mechanism and presents a common defect in laminated composites. Over the last decades, several methods of damage detection in composite materials are developed to analyse the damage mechanism and as a result to ensure the reliability and safety of service structures. Most of these methods are costly and they may need to take the structure out of service. Indeed, in some cases, the identification of damage can be considered as an inverse problem where the damage is determined with respect to its effects and the solution become not obvious to get. Thus, for reasons of simplicity, advanced identification techniques based on artificial intelligence methods such as artificial neural networks [2].

The principal aim of the current work is the development of a numerical metamodel to investigate the dynamic behaviour of damaged composite structures. Hence, a metamodelling for damage prediction and dynamic behaviour analysis of laminate composite structures is proposed, wherein the stress state in the structure is used as indicative parameters and artificial neural networks as a learning tool.

The dynamic behaviour is expressed through elasticity coupled with damage using a phenomenological macro-model for cracked composites structures made of polymer reinforced with long glass fibres. The damage is fully described by a single scalar variable whose evolution law is expressed through the maximum dissipation principle [3, 4]. Then, taking into account the nonlinearity induced by damage and using the classical linear Kirchhoff-Love theory of plates, the resulting nonlinear problem is solved in time domain.

M. Belhaq, M. Houssni & I. Kirrou, *3rd International Conference on Structural Nonlinear Dynamics and Diagnosis* (CSNDD 2016).

Several numerical simulations have been performed to generate a dataset consists of stress and damage states for various combinations of layer orientation and applied load. These data have been used to train a feed-forward neural network till the network learns to an acceptable level of accuracy. The trained ANN has been tested to predict the damage from the input stress state. The established ANN can learn effectively about the damage location and severity present in the composite structure and can predict reasonably well when tested with unknown data set. This approach provides a quick response for damage level prediction in online applications reducing significantly the computational costs.

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Vibration reduction of an elastic structure using shunted piezoelectric systems: new reduced order finite element models

Wed.
10:50–11:10
R Tinmel

W. Larbi, L.P. da Silva, J.F. Deü

Structural Mechanics and Coupled System Laboratory, CNAM Paris, France

Due to their capability of coupling mechanical stress and strain with an electric circuit, piezoelectric materials offer significant promise in a wide range of applications, such as energy harvesting, passive or semi-passive structural vibration damping, active vibration control and structural health monitoring. In this work, the specific application of passive structural vibration by means of shunted piezoelectric patches is addressed. In this technology, an elastic structure is equipped with one or several piezoelectric patches that are connected to a passive electrical circuit, called shunt. The piezoelectric patches convert a fraction of the mechanical energy of the vibrating structure into electrical energy, which is then dissipated by Joule heating via the resistors of the shunt circuits.

An efficient electromechanical finite element formulation for the dynamic analysis of smart structures with piezoelectric elements is first proposed. In this formulation, the electrical state is fully described by very few global discrete unknowns [1]: (i) the electric charge contained in the electrodes and (ii) the voltage between the electrodes. This formulation is well adapted to practical applications since realistic electrical boundary conditions, such that equipotentiality on the electrodes and prescribed global electric charges, naturally appear. The charge/voltage global variables are also intrinsically adapted to include any

external electrical circuit into the electromechanical problem and to simulate the effect of shunt damping techniques.
We present in this work various strategies to solve the problem using a modal projection approach. In this technique, the electromechanical coupled system is solved by projecting the unknown mechanical displacements on the truncated basis composed by the first structural normal modes while the few initial electrical unknowns are kept in the reduced system. The projection bases widely used in the literature are obtained using either short-circuited or open-circuited eigenvalue problems [2]. We propose in this work two new modal projection bases: (i) the combined basis formed by both the short- circuited and open-circuited modes, and (ii) the coupled basis formed by the electromechanical modes that take into account the effect of the inductances of the electrical shunts circuit. Numerical examples are finally presented in order to evaluate the effectiveness of the proposed new modal bases in comparison to the classic ones in terms of prediction of the vibration attenuation using piezoelectric shunt systems.

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Low cost metamodel for robust design of periodic nonlinear coupled micro-systems

Wed.
11:10–11:30
R Tinmel

K. Chikhaoui [1,2], N. Bouhaddi[1], N. Kacem[1], M. Guedri[2], M. Soula[2]

[1] *F EMTO-ST Institute, University of Franche-Comté, UBFC, Besançon France*
[2] *National High School of Engineers of Tunis (ENSIT), University of Tunis, Tunis, Tunisia*

To achieve robust design, in presence of uncertainty, nonlinearity and structural periodicity, a metamodel combining the Latin H ypercube Sampling (LHS) method for uncertainty propagation and an enriched Craig-B ampton Component Mode Synthesis approach (CB-CMS) for model reduction is proposed. Its application to predict the time responses of a stochastic periodic nonlinear micro-system proves its efficiency in terms of accuracy and reduction of computational cost.

Asymptotic basis to reduce dynamic problem of elaticvisco sandwich plate

Wed.
11:30–11:50
R Tinmel

F. Boumediene[1], E.M. Daya[2,3], J.M. Cadou[4], L. Duigou[4]

[1] *Faculté de Génie Mécanique & Génie des Procédés, USTHB, Alger, Algeria*
[2] *Université de Lorraine, Ile du Saulcy Metz Cedex, France*
[3] *DAMAS, University of Lorraine, Metz, France*
[4] *Université de Bretagne Sud, Lorient Cedex, France*

Viscoelastic sandwich materials are often used aspassivea solution to reduce vibration and noise in many domains such as automobile, aerospace, civil construction...
The dynamic analysis of this type of structures subjected to a harmonicload excitation is an old topic of research. It involves complex stiffness matrices. The complex term is principally due to the complex Young modulus [1] of the viscoelastic core. This issue has remained vantreleto researchers until now, because of its difficulty. The problem is that almost resolution methods need triangulation of stiffness matrix which is of complex type. This could lead to high computational cost in the case of large scale structures.
In this paper, a reduction method is combined to Asymptotic Numerical Method (ANM) [2] to compute viscoelastic sandwich plate response. The excitation is supposed harmonic. For numerical computation, structures are discretized using Finite Elements Method (shell element with eight degrees of freedom by node) [3].

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Multi-cracks identification based on the nonlinear vibration response of beams subjected to moving harmonic load

Mon.
11:50–12:05
R Tinmel

H. Chouiyakh[1], L. Azrar[1,2], K. Alnefaie[2], O. Akourri[1]

[1] *Faculty of Sciences and Techniques of Tangier, Abdelmalek Essaâdi University, Tangier Morocco*
[2] *Faculty of Engineering, King Abdulaziz University, Jeddah, Saudi Arabia*

The aim of this work is to elaborate a multi-crack identification procedure based on the nonlinear vibration response of beams under a moving harmonic load. Cracks are assumed to be open and modeled through rotational spring model. For beams with an arbitrary number of cracks the differential quadrature method is elaborated, the obtained nonlinear vibration responses are Huang Hilbert transformed in time and space domains. Multi-cracks positions and severities are investigated and the moving harmonic load characteristics may be optimized for a better identification process.

MS 11
Nonlinear PDEs and their dynamics

Organizers: *E.S. Titi* USA

Scheduled:				
	Tuesday	*14:30–16:15*	Adam Park Hotel	**Room Tichka**
	Tuesday	*16:50–18:55*	Adam Park Hotel	**Room Tichka**

Rearrangement Inequalities and applications in the classical and fractional settings

Tue.
14:30–14:55
R Tichka

H. Hajaiej

New York University, Pudong New District, Shanghai, China

The inequalities of Hardy-Littlewood say that certain integrals involving products of two or three functions increase under symmetric decreasing rearrangement. It is known that these inequalities extend to integrands of the form $F(u_1,...,u_m)$ where F is supermodular; in particular, they hold when F has non-negative mixed second derivatives $\partial i \partial jF$. This talk concerns the regularity assumptions on F and the equality cases. It is shown here that extended Hardy-Littlewood inequalities are valid for supermodular integrands that are just Borel measurable. Under some non-degeneracy conditions, all equality cases are equivalent to radially decreasing functions under transformations that leave the functionals invariant (i.e., measure-preserving maps for the Hardy-Littlewood inequality. The proofs rely on monotone changes of variables in the spirit of Sklar’s theorem.

We will also exhibit some applications of rearrangement inequalities in various domains ranging from nonlinear optics to quantum physics.

B-spline finite element method for dynamic deflection of beam deformation model

Tue.
14:55–15:20
R Tichka

M. Addam

Mohammed First University, ENSA Al Hoceima, Morocco

In this work, we solve the dynamic deflection of beam deformation model. We use the frequency-domain method to solve the considered transport problem, as a partial differential equation with non-homogeneous boundary conditions. The method employs the Fourier transform and consists of two stages. In the first stage the equations are transformed into an elliptic problem for the frequency variables. The numerical solutions of this problem are approximated using a Galerkin projection based on the B-spline finite element method. In the second stage a Gauss-Hermite quadrature procedure is proposed for the computation of the solution of the inverse Fourier transform. The frequency domain method avoids the discretization of the time variable in the considered system and it accurately resolves all time scales in deflection of beam deformation regimes. A similarly frequency-domain method and B-spline finite element analysis are used to solve the coupled Timoshenko transverse vibrating equations with non-homogeneous boundary conditions. Finally, several test examples are presented to verify high accuracy, effectiveness and good resolution properties for smooth and discontinuous solutions.

Continuous data assimilation for the three-dimensional Brinkman-Forchheimer-extended Darcy Model

Tue.
15:20–15:55
R Tichka

S. Trabelsi

KAUST, Thual, Saudi Arabia

In this talk, I will first introduce the three-dimensional Brinkman-Forchheimer-extended Darcy model of porous media. This model is believed to be accurate when the flow velocity is too large for Darcy's law to be valid, and additionally the porosity is not too small. Next, I will introduce a continuous data assimilation algorithm for this model. The algorithm is inspired by ideas developed for designing finite-parameters feedback control for dissipative systems, (see [1]). It aims to obtain improved estimates of the state of the physical system by incorporating deterministic or noisy measurements and observations. Specifically, the algorithm involves a feedback control that nudges the large scales of the approximate solution toward those of the reference solution associated with the spatial measurements. Eventually, I will show the convergence of the algorithmź solutions to the reference solutions (solution of the original mathematical system).

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The renewal equation with measure data

Wed.
15:55–16:15
R Tichka

E. Wiedemann, P. Gwiazda

Universitat Bonn, Germany

The renewal equation (or McKendrick-Von Foerster equation) is a simple and commonly used model of structured population dynamics. Results on the long-time asymptotics of this model were previously restricted to absolutely continuous initial data, although from the application viewpoint it is desirable to allow for general Radon measures. We show how certain techniques from the calculus of variations can be employed to overcome this restriction.

On ill-posedness of Euler system with non-local terms

Tue.
16:50–17:15
R Tichka

A. Swierczewska-Gwiazda

Institute of Applied Mathematics and Mechanics, University of Warsaw, Poland

The talk will concern the issue of existence of weak solutions to the Euler equations with pairwise attractive or repulsive interaction forces and non-local alignment forces in velocity appearing in collective behavior patterns.

We consider several modifications of the Euler system of fluid dynamics including its pressureless variant driven by non-local interaction repulsive-attractive and alignment forces in the space dimension $N = 2, 3$. These models arise in the study of self-organisation in collective behavior modeling of animals and crowds. We adapt the method of convex integration, adapted to the incompressible Euler system by De Lellis and Székelyhidi, to show the existence of infinitely many global-in-time weak solutions for any bounded initial data. Then we consider the class of dissipative solutions satisfying, in addition, the associated global energy balance (inequality). The discussed result is in a certain sense negative result concerning stability of particular solutions. It turns out that the solutions must be sought in a stronger class than that of weak and/or dissipative solutions. We essentially show that there are infinitely many weak solutions for any initial data and that there is a vast class of velocity fields that gives rise to infinitely many admissible (dissipative) weak solutions. We may therefore infer that the class of weak solutions is not convenient for analysing certain qualitative properties such as stability and formation of the flock patterns. However, we also show that the strong solutions are robust in a larger class of all admissible (dissipative) weak solutions leading to the possibility of establishing certain stability results of flock solutions. We establish a weak-strong uniqueness principle for the pressure driven Euler system with non-local interaction terms as well as for the pressureless system with Newtonian interaction. The talk is based on the following result:

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Existence results for some nonlocal transport equations

Tue.
17:15–17:40
R Tichka

O. Lazar

Instituto de Ciencias Matematicas- CSIC Madrid

In this talk, I shall discuss some new existence results of global or local solutions for some nonlocal transport equations. The main ingredients will be the use of new commutator estimates and other tools from harmonic analysis.

Measure-valued solutions to compressible models of fluid mechanics

Tue.
17:40–18:05
R Tichka

P. Gwiazda

Institute of Mathematics, Polish Academy of Sciences, Poland

Measure-valued solutions to hyperbolic conservation laws were introduced by DiPerna. He showed for scalar conservation laws in one space dimension that measure-valued solutions exist and are, under the assumption of entropy admissibility, in fact concentrated at one point, i.e. they can be identified with a distributional (entropy) solution. In other words, in this case the formation of fast oscillations, which corresponds to a measure

with positive variance, can be excluded. In many other physically relevant systems, however, no such compactness arguments are available, and existence of admissible weak solutions seems hopeless. In such cases, the existence of measure-valued solutions is the best one can hope for. For the incompressible Euler equations, DiPerna and Majda showed the global existence of measure-valued solutions for any initial data with finite energy. The main point of their work was to introduce the so-called generalised Young measures which take into account not only oscillations, but also concentrations. I will discuss the issue of weak - strong uniqueness of of measure-valued solutions in the sense of generalised Young measures.
In the second part of my talk I will discuss the model describing granular flows. The theory for gravity driven avalanche flows is qualitatively similar to that of compressible fluid dynamics. I will present one of the models describing flow of granular avalanches - the Savage- Hutter model. The evolution of granular avalanches along an inclined slope is described by the mass conservation law and momentum balance law. Originally the model was derived in onedimensional setting. Our interest is mostly directed to two-dimensional extension. Solutions of the Savage-Hutter system develop shock waves and other singularities characteristic for hyperbolic system of conservation laws. Accordingly, any mathematical theory based on the classical concept of smooth solutions fails as soon as we are interested in global-in-time solutions to the system.
Finally I will shortly describe the problem of weak - strong uniqueness of measure-valued solutions to compressible Navier-Stokes equations. The talk is based on the following results:

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[1] P. Gwiazda. On measure-valued solutions to a two-dimensional gravity-driven avalanche flow model. Math. Methods Appl. Sci. 28 (2005), no. 18, 2201-2223.

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[3] E. Feireisl, P. Gwiazda, A. Swierczewska-Gwiazda and E. Wiedemann. Dissipative measure-valued solutions to the compressible Navier-Stokes system, arXiv:1512.04852

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Blow-up profile for the complex-valued semilinear wave equation

Tue.
18:05–18:30
R Tichka

A. Azaiez

Paris 13 University, Galilée Institute, France

we consider a blow-up solution for the complex-valued semilinear wave equation with power nonlinearity in one space dimension. We first characterize all the solutions of the associated stationary problem as a two-parameter family. Then, we use a dynamical system formulation to show that the solution in self-similar variables approaches some particular stationary one in the energy norm, in the non-characteristic case. This gives the blow-up profile for the original equation in the non-characteristic case.

Finite number of determining parameters and applications into feedback control and data assimilation

Tue.
18:30–18:55
R Tichka

A. Azouani[1], E. Titi[2]

[1] *Mohammed First University, ENSA Al Hoceima, Al Hoceima, Morocco*
[2] *Texas A&M University, College Station, USA*

We introduce a feedback control scheme for stabilizing solutions of infinite-dimensional dissipative dynamical systems. For more reaching applications, we present a new continuous data assimilation algorithm based on our feedback controls ideas in the context of the incompressible two-dimensional Navier-Stokes equations. This algorithm allows the use of any type of measurement data for which a general type of approximation interpolation operator exists. Our main result provides conditions, on the finite-dimensional spatial resolution the collected data, sufficient to guarantee that the approximating solution, obtained by our algorithm from the measurement data, converges to the unknown reference solution over time.

MS 12

Multiple time scale dynamical systems

Organizers: *J. Starke* Denmark

Scheduled:

Monday *14:00–15:30* Adam Park Hotel **Room Tichka**

Localised travelling waves in a network of integrate-and-fire neurons

Mon. 14:00–14:20 R Tichka

J. Davis[1], D. Avitabile[1], K. Wedgwood[2]

[1] *University of Nottingham, UK*
[2] *University of Exeter, UK*

As a result of modern imaging technologies, waves and bumps of neuronal activity have been experimentally verified at a variety of spatial scales in the cortex. Spatially localised bumps of activity are known to be involved in mechanisms of orientation tuning in the visual cortex, the rat head direction system, and working memory. In the turtle visual cortex, the presentation of stimuli has been shown to evoke propagating waves of neuronal activity. Numerous mental processes including sleep and binocular rivalry are characterised through waves, as well as neurological disorders such as epilepsy and migraines. Simulations of a discrete spiking network of integrate-and-fire network are shown to exhibit a rich variety of bump and wave states. In particular we find a family of coherent pulsating wave states composed of multiple, synchronously firing neurons in a localised region of the spatial domain. A continuum assumption is then taken to construct analytical solutions of such waves solely in terms the mean wave speed and firing times. The stability of the multiple spike waves is analysed by perturbing around the firing times and an eigenvalue problem is solved and tested in the discrete regime. Numerical continuation is used to gain insight into the bifurcation structure of such waves investigated in terms of the parameters governing synaptic efficacy and connectivity. It is shown that multiple spike waves destabilise via a sequence of Hopf bifurcations. In addition, composite wave solutions are also found that match up in simulation to multiple spike pulses that have combined and coalesced. More recent work focussing on waves in more biophysically realistic, but less tractable neuron models will be presented too if time permits. speed and firing times. The stability of the multiple spike waves is analysed by perturbing around firing times and an eigenvalue problem is solved and tested in the discrete regime. Numerical continuation is used to gain insight into the bifurcation structure of such waves investigated in terms of the parameters governing synaptic efficacy and connectivity. It is shown that multiple spike waves destabilise via a sequence of Hopf bifurcations. In addition, composite wave solutions are also found that match up in simulation to multiple spike pulses that have combined and coalesced.

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Pedestrian dynamics from social force models

Mon.
14:20–14:40
R Tichka

P.G. Hjorth[1], C. Marschler[1], F. Schilder[1], J. Starke[2]

[1] *Department of Applied Mathematics and Computer Science, Technical University of Denmark*
[2] *School of Mathematical Sciences, Queen Mary University of London, UK*

Increasingly, to ensure the safety of crowds at mass events and in interactions with the built environment, an understanding of the various collective states for a crowd and the associated stability regions is crucial. In the so-called agent based models of crowd dynamics, pedestrians are modelled as mass points moving under the action of social forces, and reacting to forces from obstacles. Current agent based models have social force models with inflexible parameters and suffer from limited validity when applied to varying scenarios. We demonstrate here typical pathological cases of unrealistic stationary points and show how these arises in models using potential forces. To overcome this problem we propose, and numerically implement, a novel hybrid modeling approach which includes dissipation via a friction term, where pedestrian behavior is situation-dependent. Switching between equations of motion according to the relative location to an obstacle is an effective and more realistic approach to this type of modelling.

Control-based continuation of pedestrian flows

Mon.
14:40–15:00
R Tichka

I. Panagiotopoulos, J. Starke

Queen Mary University of London, UK

The motion of pedestrians on evacuation scenarios is investigated. The room to be evacuated is assumed to have a single exit which cannot be approached directly because of a triangular obstacle [1]. The behaviour of each individuum, i.e. whether to go left or right around the obstacle, is influenced by the shortest route to the exit as well as by the walking pattern of the pedestrians in a neighborhood around the individual. The collective behaviour of the pedestrians is investigated systematically by changing the position of the obstacle. Bistability and a hysteresis behaviour in the difference between fluxes on each side of the obstacle indicate the existence of an unstable pedestrian flow between the extreme cases where all pedestrians selected the same side of the obstacle. This parameter dependent behaviour and resulting qualitative changes are analyzed in detail. On the macroscopic level, the variable of interest is this difference of fluxes of the pedestrians although a mathematical description in closed form for this is not available. Motivated by [2], [3] where numerical bifurcation analysis is applied on a mechanical experiment with noisy data, a control-based tracking of the unstable equilibria of the flux is presented.

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Pattern formation in nonlinear systems of repulsive particles with symmetric and asymmetric interactions

Mon.
15:00–15:15
R Tichka

J. Starke[1], C. Marschler[2], Y. Gaididei[3], M. Peter Sørensen[2], P.L. Christiansen[2]

[1] *Queen Mary University of London, School of Mathematical Sciences, UK*
[2] *Technical University of Denmark, Denmark*
[3] *Bogolyubov Institute for Theoretical Physics, Kiev, Ukraine*

Particle systems with symmetric and asymmetric repulsion are studied. In most physical systems Newton's third law of actio-reactio is valid resulting in symmetric interactions. The asymmetric models are motivated for example by pedestrian flow in a corridor where the asymmetry describes that pedestrians in front, i.e. in walking direction, have a bigger influence on the pedestrian behavior than those behind. Transitions from one-lane patterns to different types of multi-lane behavior including multi-stability and a peristaltic motion are investigated [1].

Bibliography

[1] Marschler, C., Starke, J., Sørensen, M. P., Gaididei, Y., Christiansen, P.L. (2016). *Pattern formation in annular systems of repulsive particles*. Physics Letters A **380**, 166-170.

The quasi-periodic vibrations in the delayed forced Duffing oscillator

Mon.
15:15–15:30
R Tichka

I. Kirrou, M. Belhaq

Faculty of Sciences Ain Chock, University Hassan II Casablanca, Morocco

In this presentation, we explore the quasi-periodic (QP) vibrations in a delayed Duffing equation submitted to periodic forcing. The second step perturbation method is applied directly on the slow flow of the oscillator to derive the slow-slow flow around the primary resonance. The QP solutions corresponding to the nontrivial equilibrium of the slow-slow flow as well as its modulation envelope are predicted analytically. The influence of different delay and forcing parameters on the QP response is reported and discussed. The analytical results show that large-amplitude QP vibration induced by destabilization of limit cycle via Neimark-Sacker bifurcation occurs in a broadband of the excitation frequency and in large range of delay parameters.

MS 13
SHM and damage detection

Organizers: *S. Masri* USA, *G.R. Gillich* Romania

Scheduled:

Tuesday *10:30-12:10* Adam Park Hotel **Room Louka**

A Structural decomposition approach for detecting, locating, and quantifying changes in uncertain nonlinear systems

Tue. 10:30-10:50 R Louka

S.F. Masri
University of Southern California Los Angeles, California, USA

For reliable and practical application of structural health monitoring approaches in conjunction with dense sensor arrays deployed on ’smart’ systems, there is a need to develop and evaluate alternate strategies for efficient problem decomposition to rapidly and accurately determine the occurrence, location, level, and type of small changes in the underlying structural characteristics of a monitored system based on its vibrational signature. Furthermore, there is also a need to quantify the level of uncertainties in the identified system characteristics so as to have a measurable level of confidence in the parameters to be relied on for the detection of genuine changes (damage) in the monitored system. This study presents the results of two time-domain identification techniques applied to: (1) a full-scale 17-story building, based on ambient vibration measurements, and (2) an extensive experimental data set from a nonlinear test-bed structure tested at the Los Alamos National Laboratory. Data-driven nonparametric techniques are shown to be capable of reliably detecting changes in uncertain systems. Further, if the topology of the target system can be exploited, then the proposed data processing methodology is capable of confidently detecting the presence of nonlinearities, accurately locating the structural section where the nonlinear effects were observed, and providing an estimate of the severity of the nonlinearity .

Statistical analysis of reinforced concrete bridge defects for optimum maintenance planning and budgeting

Tue. 10:50-11:10 R Louka

A. Abdul-Ameer
The British University in Dubai, Dubai, UAE

Concrete degradation is arguably the main restriction on longevity of service life of buildings and infrastructure, most developed economies spend more on rehabilitation of existing structures than on new one. Concrete can be damaged by a range of chemical, physical and biological cause that include; fire, sea water, aggressive environment, corrosion of reinforcement, impact, bacterial attach to name a few. There is a continuing argument about the main cause of the premature deterioration of structures containing reinforced concrete, these range from inadequate specification, poor design and detail-

ing, poor workmanship and aggressive environment. By far the biggest cause of deterioration is the corrosion of the steel reinforcement, with its expansive byproducts that result in the cracking and spalling of concrete and can ultimately cause total service life failure of the structure if not checked and remedied. Maintenance engineers face an ever ending problem of when is the optimum time to intervene and rehabilitate a deteriorated structural element or whole structure. Budget restrictions and need to optimize the maintenance cycle. The paper will report on a large database of deterioration records of concrete bridges covering a period of over 60 years and include data from over 400 bridge structures. Statistical analysis were used to estimate the deterioration rates of various reinforced concrete defects in a rage of structural elements and bridge types and to arrive a mean service life of the structure, such service life data can then be used by the maintenance manager to budget and prioritize his maintenance work. This would replace the piece meal methods used currently and help justify maintenance budget asked for by maintenance engineers.

Early observation of modal parameter changes by an enhanced frequency evaluation algorithm

Tue.
11:10-11:30
R Louka

I.C. Mituletu, G.R. Gillich, I. Negru, N. Gillich

University of Resita, Romania

Nowadays, complex structural health monitoring systems (SHM) allow the observation and the analysis of many changes in the materials or the geometrical properties of a structural system. An important amount of these properties can be referred via the vibration waves by modal analysis. In this case, the signalizing of the healthy or the damaged state of structure is based on methods that consider frequency values or their shifts, which occur when one or several structural properties changes.

Fine frequency value identification is decisive to determine particularly small changes and thereby small cracks or damages in the early state. In the literature many methods to accurately find the frequency values are described and analyzed, most of them showing non-linear errors or big enough errors in interpretation. Therefore, even if the vibration-based damage detection method is very accurate, small frequency shift cannot be detected and afterwards considered in analysis.

To improve the frequency resolution graphical methods have been performed to decrease the error between the frequency values showed in the spectrum and those presumed as being real. Statistical methods were also employed to solve somehow the problem with the real frequency value, but even in this case the problem was not properly solved. As signal processing methods zero-padding, some windowing modes, zoom-FFT or frequency spectrum correction were designed, but not with a very important success.

Beside all these methods, here presented method is analytically simple, supposing the overlapping of spectra achieved from FFT, but with the difference of iteratively decreased number of samples from the original signal. Thus, the overlapped spectra have different frequency resolution and resulted spectrum has a much denser resolution. The newly achieved overlapped-spectrum shows important additions to spectral line number and makes more accurately identification of frequencies. Due to multiple spectra overlapping, the relevant frequency is accomplished under a lobe shape, and in the peak position of

this lobe the best frequency value can be clearly identified. With the help of these more accurate frequency values, modal analysis becomes more reliable and efficient. Method application assumes small frequency changes and the advantage of establishing more precisely the position and dimension of damage.
This method has been experimented in many different limit situations, when the time signal acquired was very short, fast damped and/or importantly distorted. The analysis of all results explicitly indicates an important assessment in the evaluation of frequency identification.
Taking in account relevant aspects, it was determined that the approached method shows a new development way in the vibration-based damage detection, allowing de possibility to perform more accurate evaluation of frequencies and, in this way, initiating new features in the domain.

Use of just in time maintenance of reinforced concrete bridge structures based on real historical data deterioration model

Tue.
11:30-11:50
R Louka

A. Abu-Tair
The British University in Dubai, Dubai, UAE

Concrete is the backbone of any developed economy. Concrete can suffer from a large number of deleterious effects including physical, chemical and biological causes. Large owning bridge structures organizations are facing very serious questions when asking for maintenance budgets. The questions range from needing to justify the need for the work, its urgency, to also have to predict or show the consequences of delayed rehabilitation of a particular structure. There is therefore a need for a probabilistic model that can estimate the range of service lives of bridge populations and also the likelihood of level of deteriorations it can reached for every incremental time interval. A model was developed for such estimation based on statistical data from actual inspection records of a large reinforced concrete bridge portfolio, the method used both deterministic and stochastic methods to predict the service life of a bridge, using these service lives in combination with the just in time (JIT) principle of management would enable maintenance managers to justify the need for action and the budgets needed, to intervene at the optimum time in the life of the structure and that of the deterioration. The paper will report on the model which is based a large database of deterioration records of concrete bridges covering a period of over 60 years and include data from over 400 bridge structures. The paper will also illustrate how the service life model was developed and how these service lives combined with the JIT can be used to effectively allocate resources and use them to keep a major infrastructure asset moving with little disruption to the transport system and its users.

Modal analysis of beams with open ad breathing cracks

Tue.
11:50-12:10
R Louka

G.R. Gillich, H. Furdui, V. Iancu, Z.I. Praisach

University of Resita, Romania

The paper analysis the different approaches to model cracked beams from the point of view of dynamic behavior and finally introduces a new vision about this topic. Most

researches present the problem of open and breathing cracks as being divergent For the open crack the moment of inertia in the damaged region is assumed to be constant, and obviously reduced in comparison with the healthy beam cross-section In contrast, for the breathing crack the cross-sectional moment of inertia in the damaged region is considered as time-varying one value being associated to the open state and another (bigger) one for the closed state. Thus, each state is characterized by an own relation between the restoring force and the displacement of the system, justifying the use of a bilinear model. In this case, the free undamped vibration of the beam with a breathing crack is composed of two half sine waves one having the period T_O and the other one T_C. By a deeper analysis of the phenomenon one can observe some inadvertencies in the actual, largely used, approach. The first question addresses the stored energy-frequency relation. If the frequency depends on the total energy of the system, and this energy is conservative in time (undamped vibration being assumed), the frequency of the two half sine waves should be the same since the energies are similar. This is not the case of the bilinear oscillator. A second issue regards the displacement time-history of a point located between the fixed end and the crack of a cantilever beam. Are these displacements identical? They obviously are, the free end suffering an additional displacement in the open state because of the additional rotation, the structure weakening due to damage permitting it. Many other questions, which are carefully treated in the paper, arise, all answers being against the use of bilinear oscillator to model breathing cracks.
In the paper the breathing mechanism of the transverse breathing crack in a beam is analyzed both theoretically as well as by means of the finite element method. A reliable relation providing the frequency change due to a breathing crack, which properly describe the manner of vibration of beams with these types of damage, is introduced. Similar studies were performed on a beam with an open crack, in order to highlight the effect of crack widening. It was found out that the behavior of the beam with breathing or open crack is alike, the difference consisting in an increased frequency drop for the last one, because of a supplementary stiffness decrease. Finally a relation providing the frequency change for the open crack, which in addition to the stiffness decrease considers also the loss of mass, is contrived. The frequency shifts due to a crack of several vibration modes, predicted with the introduced relations, can be used as a benchmark for damage detection and assessment.

MS 14

Optimization and reliability in structural vibrations

Organizers: *A. El Hami* France, *B. Radi* Morocco

Scheduled:			
Tuesday	*17:00-19:10*	Adam Park Hotel	**Room Louka**

Aero-structural wing design optimization using game theory

Tue. 16:50-17:10 R Louka

B. Abou El Majd[1], O. Ouchetto[1], J. Désidéri[2], A. Habbal[3]

[1] *Hassan II University, Casablanca, Morocco*
[2] *INRIA, Sophia-Antipolis Méditerranée Centre, France*
[3] *Department of Mathematics, University Nice Sophia-Antipolis, Nice, France*

This paper presents a framework for multidiscplinary design optimization. The aerodynamic performance is evaluated based on compressible Euler equations solver, and the structure is computed using an open source finite element software (Code Aster). We solve this multiobjective optimization problem using both symmetrical and hierarchical game to tackle the difficulties associated to the strong interaction between aerodynamics and structures. Our numerical results aim to test and analyse a number of algorithmic formulations of the aero-structural optimization problem. The test case corresponds to the optimization of the wing shape of a business aircraft (courtesy of Piaggio Aero Industries) in a transonic regime.
This study investigates the use of game theory to a multi-discplinary optimization (MDO) problem. We are placed in the case of two disciplines: aerodynamics and structures. The interaction between these disciplines is quite strong since the former provides the necessary loads to the latter in order to determine the displacement field of the structure. In return, the structure provides surface deflections that change the aerodynamic properties of the initial configuration. In this paper, we test and analyse a number of algorithmic formulations of the aero-structural optimization problem using both symmetrical and hierarchical game. The test case corresponds to the optimization of the wing shape of a business aircraft (courtesy of Piaggio Aero Industries) in a transonic regime.

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Reliability analysis of the aircraft wing using finite element/finite volume approaches

Tue.
17:10-17:50
R Louka

R. El Maani[1,2], B. Radi[1], A. El Hami [2]

[1] *LIMII, FST Settat, Settat, Morocco*
[2] *LOFIMS, INSA de Rouen, Saint Etienne de Rouvray, France*

Fluid-structure interaction (FSI) can be described as the coupling of fluid mechanics and structure mechanics. FSI problems possess the classical multi- physics characteristics which occur in many engineering applications such as aerodynamics, wave-propagation, wind turbines, bio-engineering, offshore structures and bridges. In general, FSI or multi-physics problems can be solved with either experimental or numerical simulations. The advance on Computational Fluid Dynamics (CFD) and Computational Structure Dynamics (CSD) has allowed the numerical simulations of FSI to be conducted rapidly. The simulations of multi-physics problems have become more important in the field of numerical simulations and analyses. In order to solve such interaction problems, structure and fluid models i.e. equations which describe fluid dynamics and structural mechanics have to be coupled.

Generally the technique for the simulation of FSI has two distinctive approaches: the monolithic and partitioned approaches. However, only the partitioned approach will be adopted in this paper for the FSI numerical example. The partitioned approach in general can be categorised into weakly or strongly coupled problems. The coupling can be divided into one-way or two-way coupling cases. Although there are many existing methods and techniques in FSI applications.

The focus of this paper is to analyze the fluid structure interaction of a three- dimensional wing of aircraft in air flow to determine it realistic behavior. The fluids and structures were modeled independently and exchanged boundary information to obtain aeroelastic solutions. The fluid was modeled using finite volume and the structure was modeled using finite element equations. The two disciplines were coupled to solve aeroelastic problems. The loads obtained from the pressures are applied to the original finite element model to obtain the displacements. ANSYS © is used as a pre-processing tool for creating the whole computational domain and volume mesh. The fluid flow is solved separately using Fluent © and coupled with structural code and for the structural model, ANSYS Mechanical © (modal analysis) is used in order to understand the dynamics of the structural and to determine the natural frequencies and its respective mode shapes.

Computer models are expressed and described with specific numerical and deterministic values, material properties are entered using certain values, the geometry of the component is assigned a certain length or width, etc. An analysis based on a given set of specific numbers and values is called a deterministic analysis. Naturally, the results of a deterministic analysis are only as good as the assumptions and input values used for

the analysis. The validity of those results depends on how correct the values were for the component under real life conditions. But in reality, every aspect of an analysis model is subjected to scatter. Material property values are different if one specimen is compared to the next. This kind of scatter is inherent for materials and varies among different material types and material properties, so for all these reasons a probabilistic study is used to determine the effect of one or more variables on the outcome of the analysis and Front of the complexity of this problem.
Reliability analysis was based on FORM and SORM [1, 2] approaches that take into account uncertainties related to parameters such as properties of the structure. The numerical study is performed using a code developed which couples MATLAB © and ANSYS © to evaluate the reliability of the structure.

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Uncertainty analysis of geared transmission friction system

Tue.
17:30-17:50
R Louka

A. Guerine[1,2], A. El Hami[1], L. Walha[2], T. Fakhfakh[2], M. Haddar[2]

[1] *LOFIMS, Mechanical Engineering Department, Rouen, France*
[2] *Mechanical Engineering Department, National School of Engineers of Sfax, Tunisia*

The study and analysis of the dynamic behavior of geared transmissions systems is a major interest in the industrial sector. Thus they allow overcoming the areas of instability and reducing vibration levels. Indeed, the negative consequences that may result from the instability of systems require designers to develop the most rigorous solution. This passes through a detailed study and analysis of the dynamic behavior of these systems before considering their actual implementation.
Several parametric studies have shown the great sensitivity of the dynamic behavior of gear systems. However, these parameters admit strong dispersions. Therefore, it becomes necessary to take into account these uncertainties to ensure the robustness of the analysis. Also there are several studies in reliability for vibration structures taking into account the uncertainties.
The mechanisms of transmission by gear tooth contact are characterized by the presence of friction coefficient that affects the vibration and noise of these systems. Parameter estimation is an important problem, because many parameters simply cannot be measured physically with good accuracy, such us the friction coefficient, especially in real time application.
The coefficient of friction is a very important factor for designing, operating, and maintaining the gear transmission. Indeed, the accurate estimation of this coefficient is difficult due to the effects of various uncertain parameters, e.g., materials of gears, roughness and contact patch size, etc. However, the friction coefficient admits a strong dispersion. Therefore, it becomes necessary to take into account these uncertainties in order to ensure the robustness of the analysis. A study of the nonlinear dynamic behavior will help to analyze stability and to predict the vibration levels according to the parameters variations.

Several methods are proposed in the literature. Monte Carlo (MC) simulation is a well-known technique in this field. It can give the entire probability density function of any system variable, but it is often too costly since a great number of samples are required for reasonable accuracy. Parallel simulation and proper orthogonal decomposition are some solutions proposed to circumvent the computational difficulties of the MC method.

Polynomial Chaos Expansion (PCE) is presented in the literatures a more efficient probabilistic tool for uncertainty propagation. It was first introduced by Wiener and launched by Ghanem and Spanos who used Hermite orthogonal polynomials to model stochastic processes with Gaussian random variables.

Polynomial Chaos (PC) gives a mathematical framework to separate the stochastic components of a system response from the deterministic ones. It used to compute the deterministic components called stochastic modes in an intrusive and non-intrusive manner while random components are concentrated in the polynomial basis used. The Polynomial Chaos (PC) method has been shown to be considerably more efficient than Monte Carlo in the simulation of systems with a small number of uncertain parameters.

In this paper, we propose a new method for taking into account uncertainties based on the projection on polynomial chaos. The new method is used to determine the dynamic response of a spur gear system with uncertainty associated to friction coefficient on the teeth contact. The simulation results are obtained by the polynomial chaos method for dynamic analysis under uncertainty. The proposed method is an efficient probabilistic tool for uncertainty propagation. The polynomial chaos results are compared with Monte Carlo simulations.

Robust flatness-based switching reconfiguration control using state flow machines of electronic throttle valve

Tue.
17:50-18:05
R Louka

H. Gharsallaoui, W. Gritli, M. Benrejeb

Université de Tunis El Manar, ENIT, Tunis, Tunisia

In this paper, a robust Fault Tolerant Control reconfiguration approach using State Flow Machines is proposed. In deed, this reconfiguration strategy is based on robust flatness-based switching control using state machines and flow charts. This approach is developed in discrete-time framework in order to track a reference trajectory starting from a flat output variable. For each model, a corresponding flatness-based controller is designed and consequently, a multi-controller structure is obtained. The switching flatness-based control is based on switching between identified Operating Models using state flow machines. The Luenberger observer's gains are determined using LMIs tools in order to identify the corresponding Operating Model. The localization of the current Operating Model is carried out by minimization of a performance test characterizing the distance between the system and the given operating ode. Study of the stability as well as the use of anti-windup devices related to switching between controllers; have been considered in the proposed approach.

The proposed approach is applied to the nonlinear system which is in our case of study an Electronic Throttle Valve using state flow machines modeling.

Optimization of the structure of wind turbine blades

Tue.
18:05-18:20
R Louka

S. El Mouhsine[1], A. Khamlichi[2]

[1] *Department of Physics, Faculty of Sciences at Tétouan, Morocco*
[2] *Department TITM , National School of Applied Sciences, Tétouan, Morocco*

A blade should enable optimum aerodynamic performance and withstand the aerodynamic forces over its length. These efforts are function of its geometrical characteristics, the profiles that make up the blade and the variable wind speed [1]. They also contain gyro, gravity, thermal and humidity terms [2].
During the design of wind turbine blades, special attention is given to the reduction of the weight and structural deformations. In particular, it is important to reduce the weight of the blades for reasons related to cost, transport, assembly and also to the solicitations resulting from gravity. However the decrease in weight makes blades to be more fragile and deformations produced by vibrations due to aerodynamic forces are increased. This can negatively influence the production of energy from the wind by the aeroelastic coupling which manifests, while increasing the blades fatigue which reduces their life [3]. The purpose of this work is to take into account these requirements that are antagonistic in nature in the design of the blades. The objective is to arrive at an optimal form of the structure of wind turbine blade based on the various intervening criteria [4]. These include essentially the limit states of resistance, stability of form and fatigue [5].
In this work, effect of geometry parameters that describe the different existing types of blades in the case of the standard wind turbines with rated power exceeding 1.2 MW were analyzed. The finite element method under Abaqus software was used to predict the structural behavior of the blade under static and dynamic conditions. Basic parameters associated to a given design were identified and the structural performance assessed with regards to strength and fatigue limit states [6].

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MS 15

Nonlinear dynamics of flexible structures: thermoelastic vibrations, rotating thin-walled beams, composite structures and delamination problems

Organizers: *J. Warminski* Poland, *E. Manoach* Bulgaria

Scheduled:

Tuesday	*14:30-16:15*	Adam Park Hotel	**Room Toubkal**
Tuesday	*16:50-18:20*	Adam Park Hotel	**Room Toubkal**

Numerical analysis of nonlinear model of rotatingompositec structure with piezoelectric actuator

Tue.
14:30-14:50
R Toubkal

A. Mitura, J. Latalski, J. Warminski

Lublin University of Technology, Departament of Apllied Mechanics Nadbystrzycka, Lublin, Poland

This paper presents a numerical analysis of a bflexicomposite beam structure, exhibiting the coupling between twisting, bending and transverse shear motions. In previous research [1] dynamics of the similar system has been examined cases of free vibrations as well as forced vibrations due to driving torque oscillations werediscussed. In current paper the foregoing research is extended and a piezoelectric actuator (Macro Fiber Composite) is added to the system. The proposed mathematical model of the atoractudescribes its electrical and mechanical properties by means of nonlinear constitutive equations. Governing equations of the flexible beam structure are derived and nexte obtainedth system of PDEs is solved by applying finite difference methods. The numerical results show the effectiveness of piezoelectric actuator to beam vibration reduction.

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Electro-mechanical coupling of rotating 3D beams

Tue.
14:50-15:10
R Toubkal

S. Stoykov, E. Manoach

Bulgarian Academy of Sciences, Acad. G. Bonchev Str., Bulgaria

A thin-walled beam of composite materials is considered. Some of the layers are assumed to be of piezo materials. The beam is considered to vibrate in space, hence the longitudinal, transverse and torsional deformations are taken into account. The bending deformations of the beam are modeled by assuming the Timoshenko's beam theory. Torsion is derived by considering that the cross section rotates as a rigid body but can deform in longitudinal direction due to warping. The warping function is computed preliminary by the finite element method. Then all cross sectional properties are obtained and inserted into the equation of motion. The equation of motion is derived by the principle of virtual work and discretized in space by the Ritz method.

The electro-mechanical coupling, that arise from the deformation of the piezo layers is included in the model, by considering the internal electrical energy and electric charge outputs. The piezo-electric constitutive relations are used in a reduced form.

The beam is assumed to rotate about a fixed axis with a constant speed. A setting angle is considered in the model, i.e. angle between the cross section and the plane of rotation. A hub radius is also included in the model. The beam is assumed to be rigidly mounted on a hub with given radius. The equation of motion is derived in a rotating coordinate system, but the influence of the rotation of the coordinate system is taken into account through the inertia forces. The acceleration of Coriolis is also included in the model.

Results in time domain are presented for different speeds of rotation and setting angles. An external harmonic excitation is considered. The influence of the speed of the rotation, of the excitation parameters and of the setting angle on the electrical output is presented and analyzed.

Soliton dynamics and interaction of vector Schroedinger equation

Tue.
15:10-15:30
R Toubkal

M.D. Todorov

Technical University of Sofia, Bulgaria

We analyze the dynamical behavior of the Manakov system in adiabatic approximation with external potentials. We show that the dynamics can be modeled by a perturbed complex Toda chain. Combining the analytic and numerical approach we focus also on the asymptotically free behavior, the bound state regime as well as on the mixed asymptotic regimes of the soliton trains and the transitions between them under the external potential.

When the integrable Manakov system is perturbed by cross-modulation it becomes a nonintegrable two- component Schroedinger equation called vector Schroedinger equation.The general model possesses very rich phenomenology and is quite complicate for analytic investigation. This is the reason to consider the finite-difference implementation of the vector Schrodinger equation. A plethora of results are obtained: the head-on and taking over collision interactions of the solitary waves for arbitrary (elliptic) polarization and various initial phase differences. The quasi-particle behavior of propagating and interacting solutions in conditions of rotational polarization is examined. We find that the total mass, pseudomomentum and energy are conserved while the local masses, individual and total polarization depend strongly on the initial phase difference. We also find out that the polarization angle of the quasi particles can change independently of the interaction.

Coupled thermoelastic vibrations of functionally graded beams undergoing rapid heating

Tue.
15:30-15:45
R Toubkal

E. Babilio[1], A. Cecere[2], A. Cutolo[1], M. Fraldi[1]

[1] *DiSt, University of Naples Federico II, Naples, Italy*
[2] *Department of Industrial Engineering, University of Naples Federico II, Naples, Italy*

Thermally-induced vibrations are a matter of many kind of structures of practical interest. For instance, thermally-induced vibratory phenomena have been experimentally observed, as well numerically investigated, during pulsed laser forming of thin metal plates [1]. Pulsed laser heating is also responsible of vibration of micro-scale beam resonators [2, 3].

The analysis of the dynamic behavior of such phenomena was first investigated by Boley [4], in case of beams operating in micro-gravity space environment. When a spacecraft or an orbiting satellite crosses from the earths shadow into sunlight, the solar radiation heating produces rapid changes in the thermal loading, which is responsible of time dependent bending moments and transverse shear forces on appendages and booms, which typically are lightweight structures having high flexibility with low frequency and damping characteristic [5]. The thermally-induced bending moment produces initial thermal deflection of such flexible structures. Then, because of periodic deflection-related changes of sunlight incidence angle, the deflection is accompanied by fluctuating moment, inducing vibrations, which degrade system operations of booms, often carrying a payload for measurement. Further, if the frequency of the thermally-induced vibration becomes close to the natural frequency, the resonance phenomenon appears as thermal flutter, a self-excited vibration of increasing amplitudes, which even may lead to the failure of the structural member ([6], p. 475).

Indeed, the analysis of the dynamic behavior of such structures covers a crucial role in the design of systems to operate in space environment. However, the phenomenon of thermally- induced vibrations could not be correctly analyzed by a conventional thermal stress analysis, which ignores the inertia effect and the coupling between temperature and strain fields [7].

In problems in which thermal effect induces vibrations of a slender body, thermal conductivity, material stiffness and mass density play an important role. If correctly selected these properties could improve the material robustness to oscillation and thermal loads. Hence, the question is if indeed does exist a certain combination of those material properties which can help to damp or even eliminate oscillations.

The answer to such an important question, both from a theoretical and a practical point of view, can be searched in the circle of functionally graded materials (FGMs), which are a special class of composites, that can be fabricated by varying the percentage content of two or more materials. As a result, a continuous variation of material properties from one surface to another can be achieved in the final product. The gradation in the properties of the materials allows to suit various goals of engineering applications. As an example, by combining a ceramic and a metal, the smooth transition between a pure component to the other may result in a multi-functional material combining the advantageous high temperature properties and thermal resistance of the ceramic with the fracture toughness and strength of the metal [8].

With this ideas in mind, the proposed contribution is focused on the theoretical and numerical analysis of a functionally graded cantilever beam undergoing thermally-induced vibration. The beam is modeled using Rayleigh beam theory and the material gradation is taken along the cross-sectional thickness. The thermo-mechanical coupling is taken into account and the motion equations are written under the hypothesis of moderately large deflections. The influence of the gradation, in terms of thermal conductivity, material stiffness and mass density, on the stability and vibrational behavior is investigated. The results are compared with those available in the literature.

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Wind tunnel study of axial force variation in guys of flexible mast models

Tue.
15:45-16:00
R Toubkal

J. Bêc, E. Błazik-Borowa, T. Lipecki

Lublin University of Technology, Faculty of Civil Engineering and Architecture, Lublin, Poland

The paper presents a study of axial force variation in guys of flexible mast models under the wind load, and indicates that the structure of the wind has a significant effect on their values. This issue and others (see [1, 2]) related to the wind action on masts, are very important for designers of such structures [3].

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Boundary layer solution of the static problem of an inclined risers conveying fluid

Tue.
16:00-16:15
R Toubkal

F. Alfosail[1], A.H. Nayfeh[2,3], M.I. Younis[1]

[1] *King Abdullah University of Science and Technology, Thuwal, Saudi Arabia*
[2] *Virginia Polytechnic Institute and State University, Blacksburg, U.S.A*
[3] *Department of Mechanical Engineering, University of Jordan, Amman, Jordan*

Studying the riser static configuration during installation (i.e., laying and drilling operations) is essential for avoiding static failure of the pipe by buckling [1].This motivated many researchers to focus more on solving the governing differential equation either analytically or numerically using either the finite difference (FD) or the finite element (FE) technique [2]. In this study we solve analytically the static problem of inclined risers conveying fluid. The inclined riser static differential equation is based on the Euler- Bernoulli beam equation with an initial deflection due to self-weight. We use the boundary layer perturbation technique of the method of matched asymptotic expansion to solve the differential equation. In contrary to previous research work [3, 4], in the boundary layer analysis we take into consideration the effects of the nonlinear mid-plane stretching, applied tension, and internal velocity assuming clamped ends configuration. The boundary layer perturbation method is used to treat the bending rigidity near the ends of the riser. In addition, a Newton-Raphson numerical method is used to find the value of the mid-plane stretching corresponding to each applied tension and internal velocity.

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Nonlinear dynamics and control of a rotating thin-walled beam

Tue.
16:50-17:10
R Toubkal

J. Warminski, J. Latalski, L. Kloda

Faculty of Mechanical Engineering, Lublin University of Technology, Lublin, Poland

Dynamics of a rotating composite beam attached to a hub and controlled by an active element is studied in the paper. The considered beam is modelled as a thin-walled structure made of composite material [1]. A specific structural laminate configuration has been designed in such a way that a coupling between selected deformation modes takes place [2]. The obtained specific structural properties of the thin-walled rotating beam give a possibility for control of coupled modes by just a single actuator. In order to reduce the vibrations of the system, induced by external excitations like driving external torque supplied to the rotor or forces acting directly on the blade, a various control strategies are studied [3–5]. Effectiveness of the proposed linear or non-linear control methods are tested taking into account the dynamic properties of the full system composed of the beam and hub subsystem as well. The solutions are obtained by numerical and analytical methods. For selected cases experimental test are performed as well.

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Vibration based methods for damage detection in structures

Tue.
17:10-17:30
R Toubkal

E. Manoach[1], J. Warminski[2], L. Kloda[2], A. Teter[2], S. Samborski[2]

[1] *Institute of Mechanics, Bulgarian Academy of Sciences, Sofia 1113, Bulgaria*
[2] *Department of Applied Mechanics, Lublin University of Technology, Lublin*

Vibration based damage detection methods are among the most popular and promising approaches for health monitoring of structures. In this work a critical review of differ-

ent methods for damage detection methods of structures is presented. The theoretical bases of the most popular methods based on the changes in the modal properties of the structures are deduced. The review includes the modal displacements, the mode shape slopes, the modal curvatures and the strain energy methods. Different variants of these methods are discussed. The efficiency of all these methods is compared by using a finite element analysis of intact and damaged beams and plates. The methods are tested experimentally by using a scanning laser vibrometer to measure the modal properties of specially prepared composite structures with delaminations. All this methods are compared with the damage detection method based on the analysis of the Poincare maps of the motion of the structures (E. Manoach, et. al, Int. J. Mech. Sci. 2012). The experimentally obtained data for the modal properties of the healthy and damaged composed beams are used to reconstruct the motion of the beam subjected to a harmonic loading and a new, improved version of the Poincare maps damage index is suggested. Conclusions concerning the advantages and the applicability of the considered methods are deduced.

Dynamics of a one-dimensional beam-like model for composite tubes with foam core

Tue.
17:30-17:50
R Toubkal

A. Luongo, I. Scognamiglio, D. Zulli

M&MoCS - University of L'Aquila, Italy

Tubular composite beams are widely used in the application industry. In particular, in the automotive field, tubes constituted by a thin metallic skin and a thick soft core made of PVC or metallic foam are often used to exploit the high strength to weight ratio; there, the foam has the task of avoiding local instabilities and thwarting the ovalization of the cross section. For this kind of structure, a one-dimensional, homogeneous, beam-like planar model is proposed, taking into account the ovalization of the cross section as well as its warping due to shear. The coarse (macro) configuration variables are the displacement of the axis line, the global rotation of the cross section (as in Timoshenko beams), as well as two variables describing the amplitudes of both ovalization and warping shape functions, as driven by the GBT idea [1]. As a consequence, the virtual power principle provides the balance equations, which turn out to depend on classical force and couple measures of one-dimensional beams, as well as bi-forces and bi-couples which spend power on the distortion velocity field [2, 3]. The constitutive law of both the skin and the core are assumed linear elastic, and the elastic energy of an equivalent three-dimensional beam provides the response function. In particular, the three-dimensional (micro) model introduced for identification purpose is assumed as constituted by longitudinal fibers, circumferential ribs as well as transverse membranes, in order to simulate the effects of both skin and core [4]. The dynamic-elastic problem is then solved using a perturbation method, in case of different forcing conditions, and bifurcation analysis is carried out to evaluate the critical conditions and the post-critical behavior. Validation of the proposed model is done after comparison of the outcomes with those relevant to a corresponding FEM model, and, finally, a control strategy aimed at mitigating vibrations is defined, by means of the use of layers of piezo-electric materials.

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Dynamics of a circular mindlin plate under thermal and mechanical loadings

Tue.
17:50-18:05
R Toubkal

A. Warminska[1], E. Manoach[2], J. Warminski[3]

[1] *Department of Thermodynamics, Fluid Mechanics and Aviation Propulsion Systems*
[2] *Institute of Mechanics, Bulgarian Academy of Sciences, Sofia, Bulgaria*
[3] *Department of Applied Mechanics Lublin University of Technology, Lublin, Poland*

Thermal loadings play an important role in dynamics of structural elements, in particular if they operate close to critical - bifurcation points. Due to varied temperature selected dynamic phenomena can be changed [1]. In many cases a heat process is much slower than the mechanical oscillations. Therefore, the methodology for a modal reduction and then the for obtaining a solution, can be simplified. The modal reduction and an effect of the temperature on beams oscillations is presented in [2, 3]. The elevated temperature can cause buckling which leads to post-buckling oscillations of structures subjected to mechanical and thermal loadings.
In this paper we present a reduced model of a nonlinear thermoelastic circular Midlin plate. Dynamics of the plate is analysed under thermal and mechanical loadings. The importance of the elevated temperature around the selected resonance conditions is presented and the nonlinear characteristics with bifurcation points are computed. The investigations are developed in order to clarify the influence of the thermal loadings on the response of the plate.

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Dynamics of a rotating composite box beam with surface bonded piezoelectric actuators

Tue.
10:05-18:20
R Toubkal

J. Latalski

Lublin University of Technology, Faculty of Mechanical Engineering Nadbystrzycka, Lublin, Poland

The presented research discusses the dynamics of a composite beam with embedded active elements that is attached to a rotating hub. The considered beam is modelled as a thin-walled structure made of multi-layer laminate; active elements are piezoelectric actuators surface bonded onto the host composite material. In the mathematical model of the blade structure non-classical effects like shear deformation, cross-sectional rotatory inertia and cross-section warping effects are taken into account. Moreover, the model of the system accounts for a nonlinear constitutive relation between the electric displacement and the electric field. The assumed specific lamination scheme of circumferential asymmetric stiffness of the cross section results in a strong coupling of specimen lead-lag bending and twisting. This structural property allows controlling both coupled modes by just a single actuator. A system of partial differential equations for the discussed structure is derived. Next, this system is solved by an assumed mode method and the eigenvalues and eigenmodes are obtained. Within this analysis resonance curves, as well as time histories of generalized displacements have been plotted. Numerical examples presented in the paper confirm the significance of physically nonlinear effects in piezoelectric material that should not be arbitrary disregarded in design, without a proper evidence.

MS 16

Dynamics of non-smooth systems

Organizers: *M. Wiercigroch* UK, *M. Jeffrey* UK

Scheduled:			
Wednesday	*10:30-12:20*	Adam Park Hotel	**Room Toubkal**

The illusion of noise in nonsmooth systems

Wed. 10:30–10:50 R Toubkal

M. Jeffrey

University of Bristol, UK

Systems that have discontinuities (through e.g. stick-slip or impact) can encounter singularities the inject extreme geometric sensitivity. This comes as either a breaking of determinism, or a mixing of transients. Thus we present a curious property of discontinuities, that simple local phenomena can strongly affect global behaviour in a way that mimics, and would be mistaken for, noise.

Periodic solutions with one sticking phase per period (1SPP)

Wed. 10:50–11:10 R Toubkal

H. Le Thi[1], S. Junca[1], M. Legrand[2]

[1] *Université de Nice, France, & Team Coffee, INRIA, Sophia-Antipolis, France*
[2] *Department of Mechanical Engineering McGill University, Montréal, Québec, Canada*

Periodic motions with sticking phase of a two degree-of-freedom vibro-impact spring mass model with perfect elastic impact and without source term are motivated and presented.

Periodic solutions with sticking phase have been observed in some continuous models of vibro-impact systems [2]. To study this complex phenomenon, we consider a discrete n degree-of-freedom (dof) system. Since the sticking phase does not occur for a one dof system with perfect elastic impact and without source term, we consider the two dof vibro-impact system and find that it is the simplest model in which sticking phase occurs. In particular, we study the existence of periodic solutions with sticking phase of a model consisting of two springs and two masses:

$$\begin{cases} \mathbf{M}\ddot{\mathbf{u}} + \mathbf{K}\mathbf{u} = \mathbf{r}, \\ \mathbf{u}(0) = \mathbf{u}_0, \quad \dot{\mathbf{u}}(0) = \dot{\mathbf{u}}_0, \\ u_2(t) \le d, \\ R(t) \le 0, \quad (u_2(t) - d)\, R(t) = 0 \quad \forall t, \\ \dot{\mathbf{u}}^\top \mathbf{M}\dot{\mathbf{u}} + \mathbf{u}^\top \mathbf{K}\mathbf{u} = \mathbf{E}(t) = \mathbf{E}(0), \end{cases} \tag{16.1}$$

M. Belhaq, M. Houssni & I. Kirrou, *3rd International Conference on Structural Nonlinear Dynamics and Diagnosis* (CSNDD 2016).

where

$$\mathbf{M} = \begin{bmatrix} m_1 & 0 \\ 0 & m_2 \end{bmatrix}, \qquad \mathbf{K} = \begin{bmatrix} k_1 + k_2 & -k_2 \\ -k_2 & k_2 \end{bmatrix}, \qquad \mathbf{u}(t) = \begin{bmatrix} u_1(t) \\ u_2(t) \end{bmatrix}, \quad \mathbf{r} = \begin{bmatrix} 0 \\ R(t) \end{bmatrix}$$

m_j, k_j, u_j, $\dot{u}_j$ and $\ddot{u}_j$ represent the mass, stiffness, displacement, velocity and acceleration of the mass j, $j = 1, 2$, respectively. The gap d is defined between the obstacle and the equilibrium position of the second mass. $R(t)$ is the reaction force of the wall acting on mass 2 at the time of impact.
A necessary condition for a sticking phase to occur is the existence of a contact with zero velocity ($\dot{u}_2^-(t) = 0$). Moreover, sticking phase appears when the displacement of mass 1 reaches d with the positive velocity and it happens as long as the position of the mass 1 still greater than d [1]. All the periodic motions with one sticking phase per period are computed. The key unknown parameter is the duration s of free flight phase which appears as a root of a nonlinear equation. When s is known (numerical computation), the period, the sticking time and the associated solution are explicitly derived. A number of numerical experiments of 1SPP solutions are also explored and a relationship between periodic solutions with 1SPP and a special set of periodic solutions with 1 impact per period [3] is established.

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Periodic window replications in the two-parameter space via non-smooth perturbation

Wed.
11:10–11:30
R Toubkal

S.L.T. de Souza[1,2], I.L. Caldas[2]

[1] *Universidade Federal de Sao Joao del-Rei, Ouro Branco, MG, Brazil*
[2] *Instituto de Fisica, Universidade de Sao Paulo, SP, Brazil*

In recent years, a vast quantity of work has been done analysing nonlinear systems in two-dimensional parameter spaces [1-3]. As a result, noticeable periodic windows, such as Arnold tongues and shrimp-shaped structures, have been identified embedded in the chaotic regions for various systems, such as two-gene model [3], impact oscillator [4], tumour growth model [5], Chua's circuit [6,7], and Red Grouse population model [8].
Several interesting properties of dynamics are associated with periodic windows, whose distributions appear highly organised in parameter space, like period-adding and Fibonacci-type sequences [3]. In addition, it is important to emphasise another quite interesting property involving periodic windows and control of chaos that was identified by

Medeiros and co-workers [9]. They have shown that weak periodic perturbations used to control chaos provoke replications of shrimp-shaped structures.

In this paper, applying a non-smooth perturbation [10], we report replication of shrimp-shaped structures for the Duffing oscillator. This kind of perturbation has been successfully used as control strategies to suppress chaotic behaviours for different types of dynamical systems including smooth and non-smooth oscillators. We consider here the Duffing oscillator whose equation of motion with the non-smooth perturbation $(k|\dot{x}|)$ is given by:

$$\ddot{x} + \beta\dot{x} + x = F cos t + k|\dot{x}| \tag{16.2}$$

We characterise the evolution of the periodic windows in two-parameter space by using the Lyapunov exponents. We have shown that the effectiveness of the non-smooth perturbations as control method is associated with replication of shrimp-shaped structures in two-parameter space.

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Modularization of dynamics for a class of feedforward networks

Wed.
11:30–11:50
R Toubkal

C Bick[1], M.J. Field[2]

[1] *Department of Mathematics, Exeter University, Exeter, UK*
[2] *Imperial College London, UK, Rice University, Houston, USA*

In the setting of systems biology, Alon and Kastan [1] have developed the idea of a network motif - a small network configuration that occurs frequently in (large) biological networks. The identification and description of relatively simple and small dynamical units, such as non-linear oscillators or motifs, suggests a modular and reductionist approach to network dynamics: identify building blocks, connect together to form networks and then describe dynamical properties of the resulting network in terms of the dynamics of its components. Quoting from the introduction to Alon's book on systems biology [2]

"Ideally, we would like to understand the dynamics of the entire network based on the dynamics of the individual building blocks"

This approach to network dynamics has a limited range of applicability to classical network dynamics modelled by a single system of nonlinear analytic differential equations. However, many networks of interacting dynamical systems that are of interest in contemporary science and engineering do not fit naturally into the classical model. For example, connectivity may vary, there may be switching between dynamical equations and thresholds, and individual nodes may 'stop' and later restart (a phenomenon that cannot happen in a classical network of analytic equations). At a deeper level, changes in network evolution may be event driven and there may be no intrinsic global time (synchronizing clock). Finally, the network may have a function: getting from a set of initial states to a set of prescribed final states in final time. Successful running of the network may require adaptation, distributed control and the avoidance of dynamical deadlocks (states where dynamics is permanently stalled before reaching the desired final state).
We have developed [3] a theory of asynchronous networks that gives a theoretical and conceptual framework for the study of network dynamics where nodes can evolve independently of one another, be constrained, stop, and later restart, and where the interactions between different components of the network may depend on time, state, and stochastic effects. Potential applications range from engineering to neuroscience. Typically dynamics is piecewise smooth and there are relationships with Filippov systems [4,3].
In this talk, we describe one of the main results from [3]: a spatio-temporal factorization of dynamics theorem for a class of (nonlinear) functional asynchronous networks of feedforward type that enables a complete description of network dynamics in terms of dynamical properties of component subnetworks. As well as discussing some of the related issues, such as dynamical deadlocks, we indicate some of the natural questions that arise from this work - most notably the description and analysis of bifurcations that break the feedforward structure of the network.

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Perturbation method of determining the spectrum of Lyapunov exponents for non-smooth systems

Wed. 11:50–12:05 R Toubkal

M. Balcerzak, A. Dabrowski, J. Wojewoda, A. Stefanski

Division of Dynamics, Technical University of Lodz, Lodz, Poland

An efficient algorithm for calculating the complete spectrum of the Lyapunov exponents was independently formulated both by Benettin et al. [1] and Shimada and Nagashima [2]. These techniques allow for the calculation of the complete spectrum of the Lyapunov exponents both for maps and for phase flows and they can be successfully used for many dynamical systems, both autonomic and non-autonomic. But a range of its use is limited by the condition of continuity of the system equation of motion in the complete time range analyzed. Discontinuity in this equation usually causes significant perturbation of the derivative (Jacobi matrix) computation along the system trajectory and then large errors of obtained results occur or calculation of Lyapunov exponents is even impossible. In the real world there are many dynamical systems with discontinuities. Among them mechanical systems with impacts, dry friction or piecewise linear stiffness characteristics are of most importance. In such cases the linearization of the equations of motion must be accompanied by a clear statement of the conditions and the transition functions while the trajectory is passing through the discontinuity [3]. Another class of methods for the LEs calculation employs reduction of the dynamics of the phase flow determined in the N-dimensional phase space to a lower dimensional discrete map, e.g. a Poincaré map or an impact map [4], a local map [5,6] etc. Then, the Lyapunov exponents of such a mapping are determined using classical above-mentioned approaches. Tha main application problem here lies in defining the Jacobi matrix of the mapping, where consecutive iterations are not explicitly defined by the known difference equation but they are reconstructed from the flow. The example of such a map-based approach is the method by Galvanetto [7] who applied implicitly defined maps for calculation of the two largest Lyapunov exponents of the 2-DoF stick-slip system or the algorithm for impact oscillators formulated by Souza & Caldas [8] which exploits the so-called transcendental maps that take into account the solution to integrable differential equations, between impacts, supplemented by transition conditions at the instants of the impact.

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Analysis of the dynamics of a piecewise-smooth oscillator with a play

Wed.
12:05–12:20
R Toubkal

A.S.E. Chong[1,2], Y. Yue[3], M. Wiercigroch[1]

[1] *Centre for Applied Dynamics Research, School of Engineering, University of Aberdeen, AB24 3UE, Aberdeen, Scotland, UK. a.chong@abdn.ac.uk; m.wiercigroch@abdn.ac.uk*
[2] *Facultad de Ciencias Naturales y Matemáticas, Escuela Superior Politécnica del Litoral, P.O. Box 09-01-5863,Guayaquil, Ecuador. achong@espoleduec*
[3] *Applied Mechanics and Structure Safety Key Laboratory of Sichuan Province, School of Mechanics and Engineering, Southwest Jiaotong University, Chengdu, 610031, China. leyuan2003@sinacom*

The oscillator with a play numerically analysis in the present work was studied by Kleczka et al. [4] and its physical model and restoring force characteristics are shown in Figure 1. That study [4] put attention to sudden unexpected changes of the chaotic dynamics referred to as crisis, making use of foundations of the works by Grebogi et al. [2] and Ueda [9], in which the collision of an unstable periodic orbit and a coexisting chaotic attractor was shown to cause the crisis phenomena. For the same system [4], Luo et al. [5] numerically investigated the global chaos, whereas Wiercigroch [10] provided further overview of the system dynamics through codimension-one bifurcation diagrams. Moreover, the analysed model holds relation to those for the analysis of gear-pair systems involving backlash, whose description and dynamical studies can be found in the works of Kaharaman et al. [3], Theodossiades et al. [8] and de Souza et al. [7]. Irregular responses, including crises and intermittent chaos are part of the results presented in such studies. An oscillator with a symmetrical trilinear spring and subjected to harmonic excitation was studied by Natsiavas [6], where an exact solution for periodic, symmetric responses and its stability analysis were developed.
The analysis undertaken in the present work was carried out by means of a software for non-smooth system which we are developing and is provisionally named ABESPOL. In addition, to conduct path following our software is supported by the continuation core COCO [1], which supplies general-purpose routines for continuation and bifurcation analysis of smooth and non-smooth dynamical systems.

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Poster presentations

Posters Session: listed by alphabetical orders

Scheduled:

Monday	*15:30–16:00*	Adam Park Hotel
Tuesday	*16:15–16:50*	Adam Park Hotel

Study of vertical modes evolution of submerged multilayered plane media with the S matrix formalism

K. Aissam[1], A. El Bouhmidi[2]

[1] *Ecole Nationale des Sciences Appliquées - Al Hociema, Morocco*
[2] *Déprt. Energétique et Matériaux, Ecole Supérieure de Technologie - Salé, Morocco*

A periodic media may be of interest for purposes such as wave guiding, filtering or resonator modeling. The dispersion equations of a periodic media composed of N periods, each one made of N isotropic (solid or fuid) plates are obtained using a transfer matrix method. Perfectly bonded conditions between plates and no viscosity are considered. It is well known that the dispersion curves exhibit stop bands in which no propagative modes exist and pass bands in which they are detected. At low frequency, vertical modes can be found with dispersion curves that are vertical in a wide wave number domain. They belong to the family of the structure modes which depend on the number N of periods and appear in the pass bands. The other family is named the period modes; they depend only on the characteristics of a period and not on the number N. Another way to study the structure modes consists in the calculation of the reflection coefficient of the structure immersed in a fluid carried-out by two differents methods, stiffness matrix method and transfert matrix method. It exhibits minima which are linked to the establishment of guided modes in the plates. We are interested in periods composed of two layers, which exhibit a high acoustic impedance contrast. A numerical comparative study of the stability of the two methods of calculating the reflection coefficient will also be shown.

Forced flexural vibration of cracked composite beam under moving load by using semi-analytical method

Y. Adjal, R. Benzidane , Z. Sereir

Faculté de Génie Mécanique, Département de Génie Maritime, Oran, Algérie

Nowadays the composite materials have used widely in the construction of aircraft structures; these structures are subjected to different excitations which may cause damage. For this reason our research presents a technique aimed to identify the damage in fiber-reinforced composite beam subjected to moving load. The presence of a crack in structural elements leads to an energy concentration near to the crack region and introduce a local flexibility which affects its dynamical characteristic. Due to this fact, the dynamic response assumed to be reasonable technique for damage identification in cracked beam. The discrete spring model has been used for modeling the crack, including the stress

intensity factors, in which the composite beam is assumed to be divided into two sub-beams at the crack position, connected together by the additional equivalent spring. Free flexural vibration of a cracked composite beam is solved by using semi-analytical method called differential transform method (DTM). However, the modal expansion theory is used in this study for solving the differential equation related to flexural forced vibration. A parametric study has been carried out in order to investigate the influence, of crack depth and crack location on the transverse displacement of cracked composite beam under harmonic excitations. The obtained results show that the response amplitudes of a cracked beam changes with the varying of crack depth and location. The obtained results show the influence of several parameters, such as fiber angle, crack depth ration, crack position and load velocity on the amplitudes of transverse displacement; however. The dynamical behavior of composite beam with a lower flexural rigidity is more sensitive to presence of a crack. The vibration amplitudes are more sensitive when the crack depth increases. In addition to these numerical results, the dynamic response is more significantly affected when the crack located near to fixed end. As a consequence, the evaluation of dynamical response of cracked beam subjected to moving harmonic excitation can be used as an appropriate technique for damage detection in composites structures.

Prediction life of horizontal rotors by natural frequency evolution

H. Aknouche[1], S. Lecheb[2], M. Bouamrene[1], A. Chellil[2]

[1] *Université M'hamed Bouguarra Boumerdes , Algérie*
[2] *Université M'hamed Bouguarra Boumerdes, Algérie*

Detection of crack shaft in a rotating machine is one of the most challenging problems in equipment predictive maintenance. In the available literature, various crack detection methods have been applied to study the dynamic behavior of a cracked shaft. This study concerned with the dynamic behavior of the rotor. We have also studied the different types of transverse cracks and the different methods that have been applied for shaft crack diagnosis. We have also studied the forces applied to the rotor and the movement in order to determine the stress, strain and mode shapes. Was also addressed in this note to study the issues of cracks in three-dimensional in solid objects by using ABAQUS software which based to finite element to give the results. The six first natural frequencies of rotor were decreased after cracking in the shaft critical zone, and this reduce is non-linear; however the corresponding displacements were increased. Also the stress and strain increased with crack initiation. This reduces of mode shapes frequencies can be used indicator for diagnostic and predicted the life time of rotor.

Heat explosion in porous media using radial basis functions

K. Allali, Y. Joundy, A. Taik

FSTM, University Hassan II-Casablanca, Mohammedia, Morocco

The analysis of the interaction between natural convection and the heat explosion in a fluid-saturated porous media in rectangular domain is presented. Numerical simulations

are performed using the Radials Basis Functions method (RBFM). Our objective is dedicated to reporting results related to the route to chaos when the time derivative term in the Darcy's equation is being considered. In the formulation of the problem, use is made of the Darcy model with the Boussinesq approximation coupled with the nonlinear heat equation.

Analysis of the effect of an obstacle on the wind energy potential

N. Amahjour, A. Khamlichi

University Abdelmalek Essaadi, Tetouan, Morocco

Assessment of the wind energy potential for a given site requires a primitive evaluation of wind speed for a specified period of time. Wind speed distribution depends on the type of air flow in the atmospheric boundary layer and varies as function of the altitude and the site topography [1]. It is also affected by the presence of obstacles, the curvature radius of obstacle, the roughness of the ground and temperature.
In this study, circular motion of the atmosphere that is induced by the existence of an obstacle having the form of a hill is investigated by using a 2D model. The hill profile was approximated by a half-ellipse curve. Computational fluid dynamics (CFD) was performed for the turbulent air flow modelled by the Navier Stokes equations coupled with the K-å turbulence model [2,3]. The boundary conditions at the ground level were described by a wall law. The other applied boundary conditions were a logarithmic velocity profile at the input [4], a uniform speed on the upper edge of the domain and a uniform pressure in the outlet area. To solve the equations, COMSOL software that is based on the finite element method was used.
Accuracy of the model was examined as function of the location of the boundary fixing the truncated computational domain and the mesh size used. The obtained results were compared to those of a flat ground without obstacles. A noticeable reduction of the extractable wind energy resulted for a wind turbine which placed downwards of a hill like obstacle.

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On the vibration complex modes of a cantilever beam

M.A. Aouadi, F. Lakrad

Faculty of Sciences Ain Chock, University Hassan II Casablanca, Morocco

Modal analysis using real modes of vibration is widely used in structural engineering. However, complex modes of vibration are less used because of their identification difficulty and reliability. In the present work, three methods of complex modes identification are applied to an experimental model of a cantilever beam. These results are compared to a theoretical model of the cantilever.

Comparison of static and dynamic analyses for a regular masonry-infilled reinforced concrete frame

S. Attajkani, A. Khamlichi

Faculty of Sciences, Tetouan, Morocco

In addition to the frame resistance, seismic capacity of a building depends significantly on the infills they stuff it. These last were recognized to increase the global lateral stiffness and resistance of reinforced concrete buildings. In particular, the infill was found to govern to large extent some particular phenomena that are habitually encountered in the field of seismic engineering such as weak story and short column. For regular buildings, prediction of the seismic demand which yields the collapse limit state can be performed by means of a static nonlinear analysis approach, called pushover. In the context of this analysis, the infill can be represented by equivalent diagonal struts which work essentially in compression mode. Characteristics of these struts depend on the thickness of the infill wall and also on the mechanical properties of both the infill and the frame members surrounding it.

The seismic response of masonry buildings is particularly difficult to characterize due to its nature, the presence of site effects, damping, the non-linear behavior of the structure, the relevance of execution defects and many other factors. But, it is stated in most codes for earthquake safety assessment that either push-over method or non-linear time integration methods can be used. This last is complex, time consuming and hardly available for current practitioner [1].

In this work, regular masonry-infilled reinforced concrete frames are considered. Comparison is performed between pushover analyses and the fully dynamic method. Both were executed by using ZeusNL software. The static methods included two different approaches depending on the code used RPS2000 [2] or EC8 [3]. Different earthquake spectra which are consistent with the data that was used for the static methods have been tested. The obtained results have shown that for regular structures the dynamic analysis can be substituted by the equivalent static method with a good accuracy.

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Simulation methods for joining of tools with complex geometries by high temperature brazing

D. Bartout

Département Maintenance Industrielle, ESTS, Université Mohammed V, Rabat, Morocco

This study presents a finite element modeling (FE) of the temperature field and residual stress during high temperature brazing process of tool components with cooling channels and asymmetric geometry. The thermo-mechanical analysis was developed by using the commercial software ANSYS. The thermal and mechanical material properties are introduced as temperature dependent functions, due to the material phase changes (austenite-martensite) occurring in the steel X20Cr13 during brazing. The results indicate that the model can effectively predict the stress and the temperature distribution during the brazing process. The stress, strain and temperature distribution can be analysed and it can be estimated if the brazing cycle is convenient or not. In this work the influence of different cooling rates on the component stresses are presented. Measuring of the temperature has shown that the temperature distribution in the component during cooling is inhomogeneous which can cause great stress intensity in the component and finally lead to failure. The experimental results can be implemented in a FE-simulation in order to provide recommendations for the optimization of the process and the control of residual stresses in the joint.

Nonlinear vibration of buckled shallow cylindrical panel by an asymptotic numerical method

L. Benchouaf[1], E.H. Boutyour[2]

[1] *Faculty of Sciences and Technology, Hassan 1 University, Settat, Morocco*
[2] *Faculty of Sciences and Technology, Hassan 1st University, Settat, Morocco*

In this work, geometrically nonlinear free vibrations of thin elastic shallow cylindrical panel with rectangular planform in pre-buckling or post-buckling configuration have been investigated by an asymptotic numerical method. The static behavior of the structure is first computed. Based on the von Karman theory, the nonlinear strain-displacement relationship is used to calculate the elastic strain energy. Using the harmonic balance approach and Hamilton's principle, the equation of motion is converted into an operational formulation. The coupled nonlinear static and dynamic problems are transformed into a sequence of linear problems having the same stiffness matrix, which can be solved by a classical finite element method. A continuation technique is also used to get the whole solution. Numerical results are compared to those available in the literature and convergence of the solution is shown for various curvature ratio and different boundary conditions.

A refined hyperbolic shear deformation theory for free vibration analysis of functionally graded beams

A. Bessaim[1,2,3], M. Sid Ahmed Houari[1,3], A. Tounsi[1,2], E. Adda Bedia [2]

[1] *Université de Sidi Bel Abbes, Faculté de Technologie, Département de génie civil, Algeria*
[2] *Laboratoire des Matériaux et Hydrologie, Université de Sidi Bel Abbes, Sidi Bel Abbes, Algérie*
[3] *Faculté des Sciences et Technologie, Université de Mascara, Algérie*

In this paper, a new quasi-3D hyperbolic shear deformation theory for free vibration analysis of functionally graded beams is developed. By dividing the transverse displacement into bending, shear and thickness stretching parts. The present beam theory approach accounts for both transverse shear and normal deformations and satisfies the zero traction boundary conditions on the surfaces of the beam without using shear correction factor. A comparison with the corresponding results is made to check the accuracy and efficiency of the present theory.

Semi-analytical method, for determining the larage amplitude free vibration behaviour of C-C-C-SS and C-S-C-S symmetrically laminated rectangular composite plates!!!

H. Bhar[1], R. Benamar [1], B. Harras[2], O. Baho[2]

[1] *Ecole Mohammadia d'Ingénieurs, Université Mohammed V, Rabat, Morocco*
[2] *Laboratoire de Génie mécanique. FST de Fès, Route d'Immouzer, Morocco*

In recent years the use of laminated composite plates has considerably increased. They are used especially in aerospace, marine, and naval structures, where the deflections are no longer small, thus the analysis must be extended to include the non-linear terms due to the axial strain produced by large deflections.

In the current investigation the main objective is to find semi analytical solutions for the first non-linear mode shapes of the (C-C-C-SS) and (C-S-C-S) composite plates at large vibration amplitudes. The theoretical model is based on the classical plate theory, Hamilton's principle and the Von Karman geometrical nonlinearity assumptions. Assuming the out-of-plane displacement as a double trigonometric function, the in plane displacement components are found by solving the nonlinear equations of motion expressed in terms of displacements. The first non-linear mode shape is examined. The effect of non-linearity on the non-linear resonant frequencies and the non-linear fundamental mode shape and associated bending stress patterns at large vibration amplitudes is investigated. The validity of the present approach is established by comparing the results with those available in the literature.

Energy harvesting of nonlinear damping system under time delayed feedback gain

A. Bichri, I. Kirrou, M. Belhaq

Faculty of Sciences Ain Chock, University Hassan II Casablanca, Morocco

This paper presents the application of delayed feedback velocity for optimizing the harvested power in cubic nonlinear damper system. We consider a harvester consisting of a nonlinear single degree of freedom system (spring-masse-damper) subjected to a base excitation near the primary resonance. Analytical investigation using the multiple scales method is performed to obtain approximation of the amplitude response. This amplitude can be used to extract the average power. Results show that for appropriate values of the feedback gain, energy harvesting is more efficient at resonance compared to the cubic nonlinear damper system without time delay.

Analysis of the dynamic behavior of bridge

H. Boubel[1], O. Elmrabet[2], M. Rougui[3]

[1] *Research Assistant, LEME, EST sale-University Mohammed V, Rabat, Morocco*
[2] *Research Assistant, LEME, EST sale-University Mohammed V, Rabat, Morocco*
[3] *Professor, LEME, EST sale-University Mohammed V, Rabat, Morocco*

Soil-structure interaction plays an important role in seismic response massive structures, bridges and buildings resting on lose ground. The goal of this work is to analyze has the assistance of a digital modeling the influence of the interaction ground-foundation-structure on the seismic answer of the bridges. Initially, a simplified modeling is proposed or the interaction ground-foundation is represented by linear springs. Then,one has the results of a three-dimensional modeling of differences finished integral in the same analysis the various components of the system, has to know the ground, the foundation and the structure and fascinating of account on the linearity of the ground.

This study is applied to a crossing bridge over river BOUTYOUS at the PK 635 + 200 of the National Route 12 in the city Zagora (Morocco). In particular we are interested in the interaction foundation soil structure is an important phenomenon to consider for a good assessment of the vulnerability of structures.

In this work, we propose to determine the frequency and mode of a multi-span bridge. The proposed approach is based on the modal method, which differs from other approaches in the decomposition of the function defining the natural modes. This technique is simple in its implementation and avoids the mathematical calculation of large size. The necessary functionalities for the non linear analysis of the structures are used in the developed program of calculation.

Analyses with ANSYS demonstrated that for conditions of support, the distribution of displacements and the fundamental frequency for each type of soil change according to its mechanical properties. This returns us to the seismic design phase bridge structures that must never omit the phenomenon Sol-Structure Interaction. This work also shows that the proximity of the fundamental frequencies of the soil structure and strongly influences the soil-structure interaction.

The connections flexibility effect on the dynamic behavior of steel structures

S.H. Boukhalkhal[1], A.Y. Rahmani[2], S. Koriga[1]

[1] *LBE laboratory, University of technology Houari Boumediene, Alger, Algeria*
[2] *Department of Civil Engineering, Blida 1 University, Blida, Algeria*

The Dynamic nonlinear behavior of steel buildings with semi-rigid nodes have long been recognized as an important factor in the design and analysis of these structures. Several methods of modeling of steel structures with semi-rigid connections feature of the assembly have been presented. The majority of these studies, however, focused on the study of their response under incremental monotonic loads.
On the other hand, the effect of the nonlinear behavior of the connections on the response of the structure is more apparent in cyclic and dynamic loading conditions.
In this study, a model having a finite element able to adequately simulate the flexibility of the semi rigid connections in the case of cyclic (seismic) loading. This model is based on the use of a non-linear spring element to represent the non-linear behavior of the connections.
The performed comparative study of the structure with rigid connections and semi rigid connections allowed us to highlight the influence of the semi rigid assembly on the seismic response of steel structures, this influence is appear in the main dynamic characteristics as periods of vibration, energy dissipation and displacement inter-story (drift). This work was extended also to study the influence of semi rigid connections on the seismic behavior of tall and irregular structures.

Solution of inverse scattering problem associated to multistatic radar system

M. Boutkhil[1], A. Driouach[1], A. Khamlichi[2]

[1] *Department of Physics, Faculty of Sciences at Tétouan, Morocco*
[2] *Department TITM, National School of Applied Sciences, Tétouan, Morocco*

In the field of radar, the physical quantity of interest is not usually directly observable, but must instead be deduced from measurements that are connected with the desired quantity by some relationships. Such problems of determining causes or conditions given the consequences are termed inverse problems. As a key problem in radar that falls in this category, one can consider measurement of the radar cross section as function of aspect and frequency by using Maxwell's equations to infer the shape and constitution of the target [1]. Another inverse problem consists of using the information acquired by multistatic radar in order to estimate the location and motion of the target.
This work deals with the problem of inverse scattering by a target with the aim to retrieve the position and the velocity of the target, given the intensity and phase of the electromagnetic waves scattered by this object [2]. Assuming the surface cross section to be known as well as the intensity and phase of the scattered waves, the target position and velocity were reconstructed through performing deconvolution of each radar ambiguity function [3]. Use was made of multiple independent measurements from the target in terms of time-of-arrival, angle-of-arrival and frequency-of-arrival [4].

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Aeromechanical stability for the rotor blade vibration analysis with adaptive composite damper

A. Chellil[1], S. Lecheb[1], A. Nour[1], S. Chellil[1], M. Khobizi[1], H. Mechakra[1], H. Kebir[2]

[1] *Dynamic of Engines and Vibroacoustic Laboratory, F.S.I., M.B. Boumerdes University, Algeria*
[2] *Roberval Laboratory, UMR CNRS-UTC 7337, Université de Technologie de Compiègne, France*

The ground resonance instability is a result of a resonance of the blade regressive lag mode frequency with one of the fuselage mode frequencies. for solving this type problems, a viscoelastic damper is added at the links rotor-blade. As a means of active control of vibration and noise in rotary blade, two different approaches have been considered in the literature. The first is the blade pitch angle control introduced in the non-rotating frame through the swash plate, termed higher harmonic control (HHC). The second approach is an individual blade control (IBC) technique, which has been proposed by Kretz [1] and Ham [2]. In this technique, by mounting actuators either on the swash-plate or on the individual blade, each blade can be independently actuated on its flap, pitch, and lead-lag degrees of freedom. Incorporating smart structures technology into this technique can result in a highly effective means of reducing vibrations in helicopter blades.

To this effect, three main directions have been investigated in developing a "smart" rotor using adaptive structures. The first direction involves the incorporation of flaps actuated by piezo ceramic beam elements [3], resulting in a change of the airfoil affective camber. The second approach uses distributed actuators attached under the blade skin or piezoelectric fibers in a composite blade to control the blade twist [4], Rotor blade–lag damper system is of significant interest in the design and manufacture of helicopters previous modeling of this combined system has been purely numerical which has proved challenging [5].

Initially, these models were linear zed or simplified models of the damper's dominant characteristic behavior. More recently, Eyras [6] has developed a parametric model of the damper, based on an assumed piecewise linear force–velocity profile. Simulations carried out using this model when excited by recorded flight data have enabled designers to improve the modeling of the nonlinear behavior present in the blade–lag damper system, in above aeroelastic analysis of helicopter rotor blade [7], the influence of fuselage on vibration motion of rotor blade has not been taken into account. In reality, fuselage motion is known to have an influence on hub loads [8,9]. Coupled rotor-fuselage models are therefore needed to investigate the rotorfuselage interaction and many researchers have proposed various methods.

Numerical calculations on the model developed in [10] taking into account the aeroelastic interaction prove that the elastomeric damper of viscoelastic type produces better results compared to other hydraulic damper.
The reduction of helicopter vibration is becoming increasingly important to the helicopter structure, due to increasingly higher cruise speeds and improved comfort objectives. The adaptive damper technique has been shown to be capable of reducing fuselage vibration during steady flight conditions, and also maintaining reduced vibration levels during severe manoeuvres. The work is based on modeling by finite element method the blade with viscoelastic damper by applying an aerodynamic force. To realize this modeling we have used the numerical simulation by ABAQUS software to analyze the aerodynamic forces of the helicopter blade ; it calculates the frequencies and Eigen valuer, stress, strain and the displacement, however the stress increased with crack propagation. Numerical calculations prove that the elastomeric damper of viscoelastic type produces better results compared to other ordinary systems.

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Approximate procedure for seismic evaluation of structures

B. Chikh, Y. Mehani, M. Hadid

[1] *National Center for Applied Research in Earthquake Engineering, Hussein Dey, Algiers, Algeria*
[2] *National School of Built and Ground Works Engineering, Kouba, Algiers, Algeria*

Methods of the estimation of the seismic demands of nonlinear structures require a sort of iterative procedures, no matter the elastic or inelastic response spectra are used in the procedure. Many studies dealt with the development of different inelastic spectra with the aim to simplify the evaluation of inelastic deformations and performance of structures. Recently, the concept of inelastic spectra has been adopted in the global scheme of the performance-based seismic design through capacity-spectrum methods (CSM).For instance, the modal pushover analysis (MPA) has been proved to provide accurate results for inelastic buildings to a similar degree of accuracy to the response spectrum analysis (RSA) in estimating peak response for elastic buildings.

In this paper, a simplified nonlinear spectral analysis is made to the original MPA is proposed. The proposed procedure, which is applicable to multi-degree-of-freedom MDOF systems uses an inelastic spectrum and gives peak responses consistent with those obtained when using the nonlinear time history analysis (NL-RHA).The accuracy of the proposed procedure is verified against the nonlinear time history analysis results of a 9-story steel building. The comparison showed that the new method is capable to provide accurate peak response.

Nonlinear response of a shallow arch subject to resonant and low harmonic frequency excitations under various internal resonances

A. Chtouki, F. Lakrad

Faculty of Sciences Ain Chock, University Hassan II Casablanca, Morocco

In the present work Quasi-Periodic (QP) and burster solutions of a two degree of freedom shallow arch model, excited by resonant external harmonic forcing and subject to an imposed slow harmonic motion of its support, are investigated. The cases of 1:1 and 1:2 internal resonances are studied. Charts of behaviors are obtained analytically using the multiple scales method. Numerically the Lyapunov exponents are computed to determine chaotic dynamics. It is shown that the low parametric frequency excitation may suppress chaos from wide regions of control parameters.

Numerical and theoretical modeling of unsteady flows for compressible fluid in rigid conducts

M. Driouich[1], K. Gueraoui[2], M. Sammouda[2]

[1] *Mohammed First University, ENSA Al Hoceima, Morocco*
[2] *Faculty of sciences, Mohammed V University, Rabat-Agdal, Rabat, Morocco*

The main objective of our work is to establish a numerical code for studying the flow of molten polymers in deformable pipes. Using an iterative numerical method based on

finite differences, we determine the profiles of the fluid velocity, the temperature and the apparent viscosity of the fluid. The numerical code can also be applied to other industrial applications. Injection molding is the most widely used process for developing in series plastic parts. It involves injecting melt and warm polymers in cold mold. Thus, the polymer undergoes significant transformations thermomechanical that determine the quality of the finished product. Modelling the state of the polymer in the mold will provide considerable assistance to moulder during the determination of casting parameters.

The injection molding cycle is usually divided into three phases: filling phase, compaction phase and cooling phase. The present study focuses on the first phase of this process that is the dynamic phase of transfer of material inside the mold. The injection of polymers is a technique for manufacturing parts or objects that is still poorly controlled in terms of research. This technique, however, must meet an urgent industrial demand. It is in the case of thermoplastic polymer melt initially in the form of powder or pellets in an injection molding machine and force it to flow in the molten state into a mold fixed to the press. The polymer is then cooled in the shape of the footprint. The basic parameters of the transformation are: temperature, pressure, velocity, volume and time. The study of thermal phenomena occurring during the implementation cycle by injection of polymers is of fundamental interest and technological obvious. Indeed, Thermoplastic polymers consist of macromolecules easily deformable in a flow. It follows that the structure and morphology of these polymers depend largely on the conditions shaping injection in particular, the pressure, cooling rate and the intrinsic characteristics of the material.

The experimental determination of thermo physical quantities of polymers in industrial conditions allows control of the production process through rational use of thermal energy leading to increased production rates and improved quality of parts produced.

The objective of our study is to monitor the rheological parameters of molten polymers in rigid cylindrical conducts while considering simultaneously a two dimensional and non-stationary compressible flow and a pseudo plastic thermo-dependent law to model the rheological behaviour of the molten polymer. In this study, the apparent viscosity is assumed to be independent of pressure.

Analysing the effect of large rotations on the seismic response of structures subjected to foundation local uplift

N. El Abbas[1], A. Khamlichi[2], M. Bezzazi [1]

[1] *Department of Physics, Faculty of Science and Techniques Tangier, Tangier, Morocco*
[2] *Department TITM, ENSA Tetouan, Tetouan, Morocco*

This work deals with seismic analysis of structures by taking into account soil-structure interaction where the structure is modelled by an equivalent flexible beam mounted on a rigid foundation that is supported by a Winkler like soil. The foundation is assumed to undergo local uplift and the rotations are considered to be large. The coupling of the system is represented by a series of springs and damping elements that are distributed over the entire width of the foundation [1-3]. The non-linear equations of motion of the system were derived by taking into account the equilibrium of the coupled foundation-structure system where the structure was idealized as a single-degree-of-freedom.

The seismic response of the structure was calculated under the occurrence of foundation uplift for both large and small rotations. The non-linear differential system of equations was integrated by using the Matlab command ode 15s. The maximum response has been determined as function of the intensity of the earthquake, the slenderness of the structure and the damping ratio. It was found that considering local uplift with small rotations of foundation under seismic loading leads to unfavorable structural response in comparison with the case of large rotations.

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Fluidification of stochastic Petri nets by continuous Petri nets

N. El Akchioui, N. Benaya

FSTH-University Mohamed premier -Morocco

Reliability analysis is often based on stochastic discrete event models like Markov models or stochastic Petri nets. For complex dynamical systems with numerous components, analytical expressions of the steady state are tedious to work out because of the combinatory explosion with discrete models. The contribution of this paper is to approximate the steady state of mono T-semiflow stochastic nets by mean of continuous Petri nets according to a modification of the maximal firing speed vector definition. This result is then used to accelerate convergence of stochastic simulations.

Hybridization effect of free vibration of cross-ply laminated beams with various boundary conditions

N. El Meiche[1], I. Mechab[1], H. Abbad[2], R. Mohamed Krachai[1]

[1] *Département de Génie Civil, Université de Mascara, Mascara, Algérie*
[2] *Département, de Génie Civil, Université de Sidi Bel Abbes, Algérie*

The present study deals with the vibrations response of cross-ply laminated beams under different boundary conditions. Our work is based on high order shear deformation beam theory. The equations are obtained by use of Hamilton principle. The boundary conditions are considered at the edges of beams with various combinations. The frequencies of vibration are free and obtained by applying the Ritz method where the three displacement components are specified in a series of simple algebraic polynomials. Numerical results predicted for different ratios of length / thickness are illustrated and compared with the results available in the scientific literature.

Hybridization effect of buckling in cross-ply composite laminates on elastic foundation

N. El Meiche[1], I. Mechab[1], H. Abbad[2], R. Mohamed Krachai[1]

[1] *Département de Génie Civil, Université de Mascara, Mascara, Algérie*
[2] *Département, de Génie Civil, Université de Sidi Bel Abbes, Algérie*

This paper presents the effect of hybridization material on variation of critical buckling load with different cross-ply laminates plate resting on elastic foundations of Winkler and Pasternak types subjected to combine uniaxial and biaxial loading. Governing equations are derived from the principle of virtual displacement; the formulation is based on a new trigonometric shape function of displacement taking into account transverse shear deformation effects vary parabolically across the thickness satisfying shear stress free surface conditions. These equations are solved analytically using the Navier solution of a simply supported. The influence of the various parameters geometric and material, the thickness ratio, and the number of layers symmetric and antisymmetric hybrid laminates material has been investigated to find the critical buckling loads. The numerical results obtained through the present study with several examples are presented to verify and compared with other models with the ones available in the literature.

Adaptive control of a variable-speed wind turbine using RBF Neural Network

E. El Mjabber[1], A. Khamlichi[2], A. El Hajjaji[1]

[1] *Department of Physics, Faculty of Sciences at Tétouan, Morocco*
[2] *Department TITM, National School of Applied Sciences, Tétouan, Morocco*

Wind turbines are devices that convert the wind energy to electricity. A variable speed wind turbine (VSWT) can achieve maximum energy conversion efficiency over a wide range of wind speeds. The control strategy in VSWT depends on the rated wind speed, at which the generator power of wind turbine reaches its rated value [1]. Without control, wind speed fluctuations impede the wind power system to extract the maximum power from the wind. These fluctuations provoke variations of the generated electrical power and reduce quality of generated energy while increasing negatively the fatigue loads.
In order to maximize power extraction by VSWT, advanced control of the generator torque is required. Various methods have been introduced for this purpose, Haraoubia et al. [2] and Boukhezzar [3].
In this work, a controller based on Radial Basis Functions (RBF) for network adaptation is considered [4]. The adaptive Neural Network (NN) control approximates the non-linear dynamics of the wind turbine based on input/output measurement and ensures smooth tracking of optimal tip speed-ratio at different wind speeds. The robust NN weight updating rules are obtained using Lyapunov stability analysis. The wind turbine system and this controller were modeled and a program to integrate the obtained coupled equations was developed under Matlab/Simulink software package. Then, performance of the controller was studied numerically.
The proposed controller was found to effectively improve the control performance against large uncertainty of the wind turbine system. Comparison with Nonlinear Dynamic State

Feedback Control with Kalman Filter controller was performed [3], and the obtained results have demonstrated the relevance of this RBF-ANN based controller.

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Contribution to the analysis of the dynamic behavior of earth dam

O. Elmrabet[1], H. Boubel[2], M. Rougui[3]

[1] *Research Assistant, LEME, EST sale-University Mohammed V, Rabat, Morocco*
[2] *Research Assistant, LEME, EST sale-University Mohammed V, Rabat, Morocco*
[3] *Professor, LEME, EST sale-University Mohammed V, Rabat, Morocco*

The presented word has for objective to study the dynamic behavior of the earth dam (AL WAHDA) with central core of sealing (clay), built in the province of Ouazzane, Morocco. The study will take into account the influence of soil-structure and fluid-structure interaction on the variation of displacement, frequency and deformation modes of the dam. We consider the nonlinear behavior of materials constituting the dam body. We discuss the difference of behavior by comparing the result of linear dynamic and nonlinear dynamic analysis of finite element method. We show the importance of taking into account the interaction soil-structure and fluid-structure under dynamic loads.
The finite element software ADINA was used. The target dam has a crest length of about 1600m and height of 88m. It is modeled in 3D finite element. The analysis was divided into three major parts; in the first step, a modal analysis is made to follow the variation of the deformation modes of the structure with and without interaction dam-foundation. The second step consists in calculating the initial stress due to gravity loads, and after that, dynamic analysis is performed. By comparing the results got for the case of the dam alone and those obtained for the system dam-foundation, one notice that the taking into account of the foundation tends to lengthen the vibration's periods of dam. The results also indicate that the displacement's variation, distribution of stresses and strains at the dam's crest were governed by its shape (height, width) and the mechanical properties of the foundation soil (stiffness, density). Considerable development was recorded in the domain of dynamic analysis in the linear elastic case, but in the non-linear domain, many researches are still in development to establish tools and models for the engineer, in order to better describe the seismic behavior and take the necessary solutions. A special attention is given to the stress and pressure distribution on the upstream face of the dam.

Using time delay to improve energy harvesting in hybrid vibrational energy harvesting systems

M. Belhaq[1], M. Hamdi[2]

[1] *University Hassan II - Casablanca, Morocco*
[2] *ENSA Al Hoceima, University Mohammed I, Morocco*

The present paper explores energy harvesting in the general class of hybrid energy harvesters in which the nonlinear forced mechanical subsystem is coupled to both piezoelectric and electromagnetic energy harvesting mechanisms [1]. We focus our attention on the effect of time delay introduced in the mechanical subsystem on the performance of such an energy harvester system. The influence of different system parameters on the performance of the energy harvesting is reported and discussed. Results show that for appropriate values of coupling parameters, time delay can improve energy harvesting performance. This work is motivated by a recent paper in which the effectiveness of using time delay to enhance energy extraction in the pure van der Pol oscillators [2] was established.

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Biomechanics of natural fiber green composites as internal bone plate grafted

A.M. Hashim[1,2], K.E. Tanner[2], J.K. Ulaiwe[3]

[1] *College of Engineering, Al-Qadisiyah University, Diwaniyah, Iraq*
[2] *School of Engineering, University of Glasgow, Glasgow, UK*
[3] *Department of Materials Engineering, University of Technology, Baghdad, Iraq*

Plates for long bone fractures are a major element of internal fixation technique includes various important developments in designs, materials, and implementation process during the last century. The main purpose of this paper was to introduce a new series of green composites as a plate for bone fracture applications. These green composites offer many advantages over traditional composites and biocomposites based on synthetic polymers. In current work, the new green composites bone plate based on two types of bi opol ymers involves biopolymethylmethacrylate thermoplastic material and bioepoxy thermosetting material reinforced with randomly oriented coir natural fiber at different weight fractions (5, 10, 15, and 20%) were fabricated by hand lay-up technique. Eight forms of green composites; treated and untreated corn biopolymethylmethacrylate groups A and B respectively, treated and untreated coir bi opol ymethyl methacryl ate groups C and D, treated and untreated corn bioepoxy groups E and F respectively, treated and untreated coir bioepoxy groups G and H respectively were investigated. The mechanical properties were tested (tensile, and compact tension) under a flow of phosphate buffered

saline PBS at 37 °C has been reported which is compared with that obtained using the ANSYS solution. The experimental results showed that the green composites group A have the best mechanical properties than other groups under PBS condition while the green composites group H have the weak mechanical properties due to pl asti zati on by soaked in PBS solution. Also, this work investigate the study of tensile properties distribution of corn and coir natural fiber by using Wei bul l statistics to quantify the degree of variability in fiber strength. Single-fiber tensile and microscopy tests were performed to determination the tensile properties (tensile strength and modulus of elasticity) and fiber cross-sectional area respectively. The experimental results showed that both corn and coir natural fiber have a good tensile strength and modulus of elasticity. All natural fiber are treated with 1% NaOH.

NOTE: all mechanical tests are carried out at school of science and engineering – University of Glasgow – Scotland – UK under supervision of **Professor Elizabeth Tanner (**Professor of Biomedical Materials – Biomedical Engineering - University of Glasgow).

Effect of atmospheric stability on the estimation of wind power potential

M.M. Ichenial[1], A. El Hajjaji[1], A. Khamlichi[2]

[1] *Department of Physics, Faculty of Sciences at Tétouan, Morocco*
[2] *Department TITM, National School of Applied Sciences, Tétouan, Morocco*

In this work, the impact of atmospheric stability on vertical wind and temperature profiles are analyzed in order to assess accurately wind potential energy for the site evaluation. In the literature, different methods were used to study the degree of stability of the atmosphere. These methods include the Richardson number, the Monin-Obukhov length, the standard deviation of horizontal wind, the temperature gradient method, the potential temperature gradient, the Pasquill-Tunner Method (PTM) and the Pasquill-Gifford Method. Focus is here on the similarity theory of Monin and Obukhov which plays an important role in treating experimental data on regards of surface-Layer turbulence. According to the theory of Monin and Obukhov, all the parameters of wind velocity and temperature fields in the surface layer of the atmosphere are determined by the value of height z, the shear stress, the turbulence heat flux H and the buoyancy parameter β. The dissipation, the flux variance and eddy-covariance methods, derived from the turbulent kinetic energy and temperature variance equations were used to estimate surface fluxes of momentum and sensible heat. This enables to express the Monin and Obukhov criterion and to analyze atmospheric stability.

Based on the Monin-Obukhov, Pasquill-Tunner and Pasquill-Gifford methods, a Matlab program was developed to determine atmospheric stability. The two Weibull parameters of the wind speed distribution function, the shape parameter k and the scale parameter c were computed from the wind speed data for Illinois. Wind data, consisting of hourly wind speed records for a 2-year period, were measured in the Argonne National Laboratory station. The suitability of the distributions is judged by the discrepancies between the observed and calculated values of the monthly average wind speed. The results show the general availability of wind energy potential across Illinois as it is affected by the atmospheric stability issue.

Design and analysis of composite skew plate bending

L. Ikharrazene

Mohammed First University, ENSA Al-Hoceima Morocco

The use of laminated composite in many engineering applications has been expanding rapidly in the past four decades due to their higher strength and stiffness to weight ratios when compared to most metallic materials. In particular, laminated composite skew plates are frequently used in various engineering applications and have spread economical applications in different area of science including aerospace, marine, mechanical, and modern highways. For example, enormous amounts of money and resources are invested every year in design and construction of new roads. The use of composite skew plates in bridge constructions can lead to the economical solutions and enable the construction of straight, aesthetic and safe highways needed to carry on increasing speeds of present-days traffic. Despite this practical interest, problems of skew plate bending have not yet been correctly addressed in the literature. relatively little is to be found in the engineering literature regarding composite skew plates, partially due to the lack of analytical solutions and to the numerical difficulties encountered with regard to modelling composite plate behaviour specially when dealing with a highly skew angle. Therefore, the design of composite skew plates is at present based on numerical data provided by computational models, and influenced by comparisons with rectangular and square plates which can be solved analytically. A high quality numerical approximation of skew plate behaviour is obtained by the use of a numerical approach like BEM, FEM and FDM.

Reinforcement of RC structure by carbon fibers

B. Kissi[1], Y. Riyad[2], I. Mrani[2], A. El Ghoulbzouri[3], M.A. Parron[4]

[1] *Hassan II University, ENSAM Casablanca, Morocco*
[2] *Chouaib Doukkali University, FS El-jadida, Morocco Energetics and mechanics laboratory*
[3] *National School of Applied Sciences of Al Hoceima, Morocco*
[4] *University of Cadiz, Spain*

In recent years, rehabilitation has been the subject of extensive research due to increased spending on building work and repair of built works. In all cases, it is absolutely essential to carry out methods of reinforcement or repair of structural elements, and that following an inspection analysis and methodology of a correct diagnosis.
This research focuses on the calculation of the necessary reinforcement sections of carbon fiber for structural elements with reinforced concrete in order to improve their load bearing capacity and rigidity. The different results obtained revealed a considerable gain in resistance and deformation capacity of reinforced sections without significant increase in the weight of the rehabilitated elements.

Fracture and dynamic behavior of leaf spring suspension

S. Lecheb, A. Chellil , H. Mechakra, S. Attou, H. Kebir

[1] *Laboratory of Engines Dynamics and Vibroacoustics, University of Boumerdes, Algeria*
[2] *Laboratory Roberval, University of Technology Compiègne, UTC, France*

The main function of leaf spring is to isolate road induced vibrations, it is subjected to millions of load cycles loading to fatigue failure. The objective of this work is to make safe operating, from this we use a FEA to locate the most stressed areas and predict where the crack initiation occur in leaf spring, and visualize the modes shape of this structure. In parallel we calculate Stress Intensity Factor for verified a not fast fracture occur. However the stress increased with crack propagation, the naturals frequencies are calculated under crack propagation condition, as conclusion the naturals frequencies are decreases versus crack growth and this reduce is nonlinear.

Non-linear free transverse vibrations of clamped beams carrying two or three concentrated masses at various locations

A. Rahmouni[1,2], R. Benamar[2]

[1] *Université Mohammed V-Agdal, Ecole Mohammadia des Ingénieurs, Rabat, Maroc*
[2] *Université Hassan II Casablanca, Ecole Supérieure de Technologie, Casablanca, Maroc*

In a recent work, a discrete model for geometrically nonlinear transverse free constrained vibrations of beams with various end conditions has been developed and validated via comparison with known results corresponding to nonlinear vibration of continuous beams. It is extended here to clamped beams carrying two or three concentrated masses at various locations and subjected to large vibration amplitudes. The discrete model used is an N-dof (N-Degrees of Freedom) system made of N masses placed at the ends of solid bars connected by springs, presenting the beam flexural rigidity. The large transverse displacements of the bar ends induce a variation in their lengths giving rise to axial forces modeled by longitudinal springs causing nonlinearity. The calculations made allowed application of the semi-analytical model developed previously for nonlinear structural vibration involving three tensors, namely the mass tensor m_{ij} , the linear rigidity tensor k_{ij} and the nonlinearity tensor b_{ijkl} presenting the effect of the change in the bar lengths. The addition of two or three concentrated masses studied here induces a change in the mass matrix, compared with the uniform beam case. By application of Hamilton's principle and spectral analysis in the modal basis, the nonlinear vibration problem is reduced to a nonlinear algebraic system, examined for increasing numbers of dof using an explicit method, developed previously for non-linear structural vibration. Applications are made to cases of practical interest and comparisons are made with previously published results.

Seismic fragility assessment of typical buildings in the city of Algiers (Algeria)

M. Remki, F. Kehila

National Center of Applied Research In Earthquake Engineering CGS, Dey Algiers, Algeria

In seismic risk mitigation, fragility functions of existing buildings play a fundamental role. In this paper, we evaluate the performance, the seismic vulnerability and the damage of reinforced concrete frame and URM masonry buildings, typical of the city of Algiers (ALGERIA). An analytical procedure for the derivation of fragility curves is proposed. The capacity spectrum method and seismic damage potential for the city, starting from capacity and fragility curves, are then discussed. Different tools regarding the determination of capacity curves of different existing structural system by using a non linear structural analysis are implemented and explained. Four damage states are defined for both structural systems. The earthquake action is expressed in terms of spectral values and the seismic quality of the buildings; the probabilities of the damage states are obtained considering a lognormal probability distribution. An ADRS format has been used for the studied area where a significant damage is obtained for mid-rise and high-rise masonry buildings.

A hyperbolic shear and normal deformation theory for deflection and stresses of FGM sandwich plate

H. Saidi, A. Tounsi , A.E.A. Adda Bedia, A. Benachour

Université de Sidi Bel Abbes, Faculté de Technologie, Algérie

In the present paper, the static analysis of functionally graded sandwich plates subjected to thermo mechanical loads is studied. In this model, the displacements vary as a hyperbolic function through the thickness of the plate and satisfy stress boundary conditions on the top and the bottom of the plate.
The material properties of the sandwich plate faces are assumed to be graded in the thickness direction according to a simple power-law distribution in terms of volume fraction of material constituents. The core layer is still homogeneous and made of an isotropic material. The governing equations of equilibrium for FG sandwich plates can be obtained using the virtual work principle, and the closed form solutions are obtained by using Navier technique. The accuracy of the present analysis is ascertained by comparing it with various results available in the literature. The influences played by side-to-thickness ratio, aspect ratio and volume fraction distributions are investigated.

Vibration analysis of functionally graded nanobeams based on the nonlocal refined shear deformation beam theory

M. Sid Ahmed Houari[1,3], A. Bessaim[1,2,3], A. Tounsi[1,2], E. Adda Bedia [2]

[1] *Département de Génie Civil, Université de Mascara, Mascara, Algérie*
[2] *Département, de Génie Civil, Université de Sidi Bel Abbes, Algérie*

In this work, the size-dependent free vibration analysis of functionally graded (FG) nanobeams is investigated on the basis of the nonlocal continuum model. The material properties of FG nanobeams are assumed to vary through the thickness according to the power law. In addition, Poisson's ratio is assumed constant in the current model. The nanobeam is modelled according to the a new quasi-3D hyperbolic shear deformation theory with small deformation and the equilibrium equations are derived using the Hamilton's principle. The present beam theory approach accounts for both transverse shear and normal deformations and satisfies the zero traction boundary conditions on the surfaces of the beam without using shear correction factor. The Navier type solution is developed for simply-supported boundary conditions. The effects of nonlocal parameter, aspect ratio, various material compositions on the vibration responses of the FG nanobeams are discussed.

On-line vibration monitoring of bearing faults in induction machine using Cyclic Spectral Analysis

F. Tafinine

LTII Laboratory, University of Bejaia, Electrical Department, Bejaia 06000, Algeria

The asynchronous machine is considered as a robust and low cost machine, it is an essential component in most of today's manufacturing and production industries. Nevertheless it may present some electric or mechanical defects. While electric defects are not very frequent for asynchronous motors, mechanical defects are rather numerous and can be due to the motor or the involved load. On-line vibration monitoring and diagnosis for rotating machinery equipment is required. System maintenance cannot realize its full potential if it is only limited to preventive approaches. An early diagnosis of a developing fault is necessary to allow maintenance personnel to schedule repairs prior to an actual failure which can induce significant financial loss.

Extensive work has been performed with the aim to develop methods able to detect and identify fault conditions in electrical machines.

A new signal processing technique for incipient real time bearing fault detection based on Cyclic Spectral Analysis is presented in this paper. The exploitation of cyclostationarity has recently been proved extremely fruitful to conceive high accuracy diagnostics tools. Vibrations produced by faulty rolling-element bearing are essentially random cyclostationary. In order to detect these defects it is customary to demodulate the signal in different frequency bands in the entire frequency axis. This method is the classical technique in the spectral analysis (PSD). The C*yclic Spectral Analysis* can replace this empirical procedure with a rigorous methodology to quickly find the characteristics of the faults.

Cyclostationarity encompasses a subclass of nonstationary signals which exhibit some cyclical behaviour; it ideally fits the property of many rotating and reciprocating machine vibrations, due to the inherent periodic modulations that these sustain during operation. The traditional spectral analysis is not appropriate for non-stationary vibration signals and for an *online* diagnosis. The performance of the proposed technique is examined by a series of experimental tests with different bearing conditions. Test results show that this signal processing technique is an effective automatic bearing fault detection method, which is especially useful for non-stationary features extraction; it gives a good basis for an integrated induction motor condition monitor.

The new diagnosis procedure overcomes the disadvantages related to motor parameters dependency. In contrast to the usual vibrations signal spectral analysis, the proposed diagnosis method allows also the ability to extract *automatically* the characteristic frequencies that distinguish the motor operating modes.

A high-order technique for nonlinear dynamical problems

A. Timesli[1,2], A. Hamdaoui[1], B. Braikat[1]

[1] *Faculté des Sciences Ben M’Sik, Université Hassan II Casablanca, Maroc*
[2] *ENSA Al Hoceima, Maroc*

The non-linear equations which modelize the physical phenomena are often difficult to resolve. In reality, they are always instationary and non-linear. Generally, we use the finite element method for the discretization of spatial domain and an implicit or explicit integration scheme for the treatment of the temporal derivatives. The iterative methods are used to compute the solution of the obtained non-linear problem. An alternative solution for the instationary non-linear problems is the use of high order algorithms based on Asymptotic Numerical Method (ANM). These algorithms are based on four mathematical techniques: a time discretization, a homotopy transformation, a perturbation technique and a space discretization [1]. The time integration is performed by classical implicit schemes (Euler implicit for problems with a first order time derivative and Newmark for second order). The Asymptotic Numerical Method has been known since 1994 (see detail in reference [2]). This method allows us to obtain the solution of a non-linear problem by using a power series.
In this paper, a high order algorithm is developed for solving instationary linear and non-linear problems without time integration scheme. The principle is based to expand the time variable in power series with respect to a path parameter "a" as the other unknowns. This new approach allows us to obtain the total solution under quasi-analytical form in many time steps.

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Exact soliton solutions for a higher order cubic-quintic nonlinear Schrödinger equation

H. Triki
Faculté des Sciences, Université Badji Mokhtar, Annaba- Algérie

Optical solitons are localized electromagnetic waves that propagate in nonlinear media with dispersion and/or diffraction without any change in shape or intensity due to the delicate balance between the dispersion (or diffraction) and the nonlinearity effects. Optical

solitons in Kerr nonlinear media have been the subject of intense current research motivated by their important applications to high-capacity fiber. The model equation which describes the light wave envelope is given by the well known nonlinear Schrödinger equation. This equation is completely integrable by the inverse scattering transform. This means that it is possible to find both solitary wave and multi-soliton solutions. However, as one increases the intensity of the incident light power to produce shorter (femtosecond) pulses, non- Kerr nonlinearity effects become important and the dynamics of pulses should be described by the NLS family of equations with higher order nonlinear terms.
Based on the subsidiary ordinary differential equation method, we derive some new exact analytic soliton solutions for a higher order dispersive cubic-quintic nonlinear Schrödinger equation that describes the propagation of femtosecond pulses in nonlinear optical fibers. These kinds of solutions may be useful to explain some physical phenomena related to wave propagation in a nonlinear Schrödinger system supporting high order nonlinear and dispersive effects.

Using time delay to improve energy harvesting in hybrid vibrational energy harvesting systems

M. Belhaq[1], M. Hamdi[2]

[1] *Laboratory of Mechanics, University Hassan II - Casablanca, Morocco*
[2] *Faculty of Science and Technology-Al Hoceima, University Mohammed I, Morocco*

The present paper explores energy harvesting in the general class of hybrid energy harvesters in which the nonlinear forced mechanical subsystem is coupled to both piezoelectric and electromagnetic energy harvesting mechanisms [1]. We focus our attention on the effect of time delay introduced in the mechanical subsystem on the performance of such an energy harvester system. The influence of different system parameters on the performance of the energy harvesting is reported and discussed. Results show that for appropriate values of coupling parameters, time delay can improve energy harvesting performance.
This work is motivated by a recent paper in which the effectiveness of using time delay to enhance energy extraction in the pure van der Pol oscillators [2] was established.

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