11th Pan-American Congress of Applied Mechanics

PACAM XI

Nature and Technology side-by-side

Foz do Iguaçu, PR, Brazil

January 4 - 8, 2010

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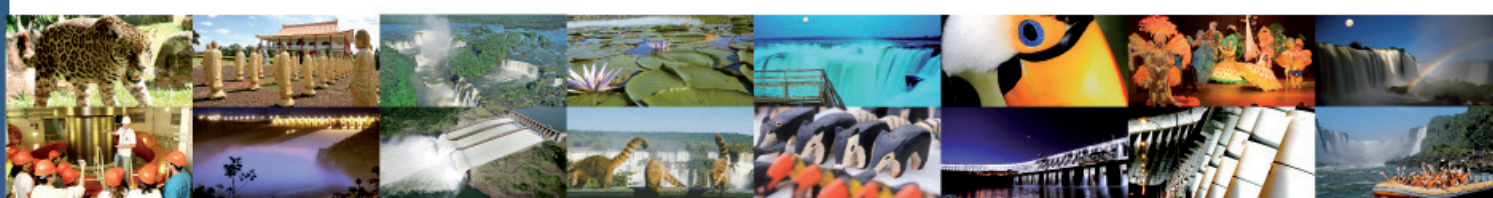

PACAM XI

ELEVENTH PAN-AMERICAN CONGRESS OF APPLIED MECHANICS

Book of Abstracts

Revised Edition

Foz do Iguaçu, PR, BRAZIL

January 4 -8, 2010

Book of Abstracts

Editor: Adair R. Aguiar

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WELCOME AND FOREWORD MESSAGE

Welcome to Foz do Iguaçu. Enjoy your time in this cosmopolitan city at the border of Brazil, Argentina, and Paraguay. The city attracts visitors from around the world for its natural and technological wonders. It is the place of both the third largest waterfall in the world, the Iguassu Falls, and the world´s largest hydroelectric plant in power output, the Itaipu Binacional (IB). Also, according to the American Society of Civil Engineers (ASCE), the Itaipu Dam is one of the Seven Wonders of the Modern World. We have planned technical visits to the Itaipu Dam during the period of the event.

The aim of the Pan-American Congress of Applied Mechanics (PACAM) series is to promote progress in the broad field of Mechanics by (1) exposing engineers and scientists, as well as advanced graduate students, to new research developments, methods, and problems in Mechanics, and (2) providing broad opportunities for personal interactions through means of formal presentations and informal conversations.

The Pan-American Congress of Applied Mechanics (PACAM) is held every two years, always in a Latin American venue, at a time when few other conferences are scheduled. The previous congresses are listed below.

In PACAM XI we have introduced the theme Nature and Technology side-by-side with the objective of calling the attention of all participants to Brazilian initiatives to promote technological development while preserving the natural resources. Some of these initiatives are sponsored by Itaipu Binational and consist of programs such as The Cultivating Good Water program. This program seeks to establish criteria and conditions to guide the company's social-environmental initiatives related to the conservation of natural resources. It is focused on the quality and quantity of water and on people's quality of life.

The PACAM XI program consists of concurrent sessions in the general areas and mini-symposia listed below. The mini-symposia are being organized by researchers from Europe and the Americas. Each session contains 20-minute talks, which are based on papers previously submitted and peer reviewed. The authors of these papers are originally from 36 countries of the Americas, Europe, Asia, and Africa. The abstracts of these papers are published here, in the Book of Abstracts, and the papers presented during the congress, which contain a maximum of six pages, will be published in the Proceedings of PACAM XI. These proceedings will be sent to the authors who presented the papers.

Best wishes to all PACAM XI participants. We hope for a successful and enjoyable meeting.

Adair R. Aguiar

Latin American Chair of PACAM XI

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AAM GREETINGS

The American Academy of Mechanics (AAM) is welcoming all participants to the 2010 Pan American Congress of Applied Mechanics - PACAM XI. Remarkably, it is already a fourth time that a PACAM is being held in Brazil! Organizing a congress is always a challenge, even when the setting is as spectacular as the Iguassu Falls.

Our thanks, therefore, go to the Latin and North American Congress Chairs, and especially to Prof. Adair Aguiar and his staff for extensive work and effort involved in making this meeting possible.

We also thank the sponsors for their support as well as the symposia organizers for all their time and effort in contributing to this conference. We wish you all a great visit to Foz do Iguaçu and a very successful congress.

We hope that you will find this meeting interesting, intellectually stimulating, and personally enjoyable.

Martin Ostoja-Starzewski
Chairman of PACAM Committee at AAM

HISTORY

PACAM	Year	Venue	Location	Latin American Chair	North American Chair
I	1989	PONTIFÍCIA UNIVERSIDADE CATÓLICA DO RIO de JANEIRO (PUC-Rio)	RIO de JANEIRO, RJ, BRAZIL	M. SOUZA, PUC-Rio	A. LEISSA, OHIO STATE UNIVERSITY
II	1991	UNIVERSIDAD TECNICA FEDERICO SANTA MARIA	VALPARAISO, CHILE	P. KITTL	D. MOOK
III	1993	ESCOLA POLITÉCNICA DA UNIVERSIDADE de SÃO PAULO (EPUSP),	SÃO PAULO, SP, BRAZIL	C. MAZZILLI	M. CRESPO DA SILVA
IV	1995	UNIVERSIDAD DEL SALVADOR	BUENOS AIRES, ARGENTINA	P.A.A. LAURA	D. MOOK, VIRGINIA TECH.
V	1997	U. PUERTO RICO	SAN JUAN, PUERTO RICO	LUIS SUAREZ, U. PUERTO RICO	M. EISENBERG, UNIV. OF FLORIDA
VI	1999	PONTIFÍCIA UNIVERSIDADE CATÓLICA DO RIO de JANEIRO (PUC-Rio),	RIO de JANEIRO, RJ, BRAZIL	DJENANE PAMPLONA, PUC-Rio	CHARLES R.STEELE, STANFORD UNIVERSITY
VII	2002		TEMUCO, CHILE	GERARDO DIAZ, UNIVERSIDAD de CHILE	CHARLES R.STEELE, STANFORD UNIVERSITY
VIII	2004	PALÁCIO de LAS CONVENCIONES	HAVANA, CUBA	REINALDO RODRIGUEZ-RAMOS, UNIVERSIDAD de LA HABANA	MARTIN OSTOJA-STARZEWSKI, MCGILL UNIVERSITY
IX	2006	HOTEL FIESTA AMERICANA	MÉRIDA, YUCATÁN, MÉXICO	GUILLERMO MONSIVAIS GALINDO, UNAM	JEFFREY W. EISCHEN, NORTH CAROLINA STATE U.
X	2008	HOTEL GRAND OASIS CANCÚN	CANCÚN, QUINTANA ROO, MÉXICO		T.L. ATTARD, CALIFORNIA STATE UNIVERSITY, FRESNO

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Reviewers

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OPENING CERIMONY

THE UNIVERSITY IN TIMES OF CULTURAL SCHOCK

LUIZ BEVILACQUA

EMERITUS PROFESSOR

FEDERAL UNIVERSITY OF RIO de JANEIRO

Technological and scientific advances have overcome all predictions and scenarios proposed in the course of the last century. Among the most important driving forces that boosted up those extraordinary transformations, two are to be highlighted: the extraordinary capacity to scrutinize the microcosms and the macrocosms and the extraordinary calculating capacity provided by the successive families of super-computers.

The converging achievements obtained with the help of these tools gave rise to a new methodology to deal with science. Windows were opened up connecting several knowledge compartments that used to develop without any or with very few interactions. But the more astonishing event that we are living nowadays is not the knowledge accumulation properly but the speed in which it develops. The acceleration impelled by the successive jumps in science and technology surpassed our ability to control the path of the progress. Past seems to force the way through the present and mangle the future. We are simultaneously former users and observers of objects displayed in a Science and Technology Museum. When things try to accumulate without any possible control in time we are in the presence of a shock wave. We are in the middle of a cultural shock wave. Traveling along a shock wave takes a completely different strategy as that adopted to progress along calm waters. The impact of this new cultural environment on Universities requires substantial modifications; it is not only a question of reviewing the curriculum, introducing or suppressing a couple of disciplines.

The advancements in Information Technology promoted a great approximation between academic communities around the world. This outreaching instrument may be used for the good or bad. If the information avalanche reduces the time devoted to creative tasks and push people to be only information transmitters, our global society may be reduced to creation centers and application centers, a stratification that is most undesirable.

The academic community has nowadays an extraordinary chance to interact and promote an evenly exchange of ideas and cooperative contribution to the advancement of science and technology.

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PAC0223	NUMERICAL AND EXPERIMENTAL ANALYSIS OF INFLATED MEMBRANE OVER ELASTIC FOUNDATION	PAMPLONA, D. C.; MOTA,D.E.S.
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PAC0082	STOCHASTIC MODEL OF A CRAKED ROD	FABRO, A.T.; RITTO, T.G.; SAMPAIO, R.; ARRUDA, J.R.F.
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PAC0242	APPLICATION OF GALERKIN METHOD TO BENDING OF STOCHASTIC KIRCHHOFF PLATES	DA SILVA JR.,C.R.A.; BECK, A.T.
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PAC0322	STOCHASTIC DYNAMICS OF AN AIRFOIL FORCED TO OSCILLATE BY THE FLOW	SOUSA, F. O. S.; DINIZ, A. C. C. G.; MORAIS, M. V. G.; Brazil JR., A. C. P.
PAC0433	RELIABILITY BY MONTE CARLO SIMULATION STRUCTURAL WITH ADAPTIVE IMPORTANCE SAMPLING TECHNIQUE	OLIVEIRA, A.L.; FREITAS, M.S.R.; SOUSA JR, J.B.M.
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PAC0155	PHASE-LOCKED SOLUTIONS IN A HUB CONNECTED OSCILLATOR RING NETWORK	BRIDGE, J.
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PAC0488	A THEOTERICAL INVESTIGATION OF CONCENTRATION WAVES IN FLUIDIZED BEDS	RISPOLI,V.C.; SOBRAL,Y.D.; CUNHA, F.R.

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PAC0383	DEVELOPMENT OF FULLY-PLASTIC J SOLUTIONS FOR CIRCUMFERENTIALLY CRACKED PIPES UNDER COMBINED BENDING AND TENSION	RUGGIERI, C.; PARISE, L. F. S.; CHIODO, M. S. G.
PAC0403	2D EVALUATION OF CRACK OPENINGS USING SMEARED AND EMBEDDED CRACK MODELS	GAMINO, A.L.; SOUSA, J.L.A.O.; MANZOLI, O.L.; BITTENCOURT, T.N.
PAC0476	MICROMECHANICAL MODELING OF MECANICAL BEHAVIOR OF IMPACT MODIFIED PP	CHOI, B.-H.; CHUDNOVSKY, A.
PAC0487	INVESTIGATION OF THE DEPENDENCY OF THE STRESS CONCENTRATION FACTOR ON PLATE LENGTH IN NOTCHED PLATES UNDER BENDING	POL, M.H. ; BIDI, A.; AZIZI, S.; A. V. HOSEINI
PAC0498	MODELING OF CRACK INITIATION IN HIGH DENSITY POLYETHYLENE PIPE DUE TO OXIDATION INDUCED STRESSES	CHUDNOVSKY, A.; CHOI, B.H.

1. SOLID MECHANICS

Invited Lecture

COEXISTENT PHASES AND CRITICAL POINT BEHAVIOR IN THERMOELASTIC SOLIDS

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Abstract. *Materials are known to behave in strange and novel ways in the neighborhood of critical points. The softening of various material moduli is commonly reported, and the smooth change of homogeneous states into complex multiphase microstructures is possible. For solids, the analysis of this behavior is complicated by the fact that the full notion of stress and deformation gradient (as tensors), including shearing, must be considered, rather than simply the classical effects associated with pressure, specific volume, and temperature. In this work, I consider sequences of equilibrium coexistent phases, induced by thermal and mechanical loading, and the asymptotic limits and relations between the thermodynamic fields of deformation gradient, temperature and the specific heat at constant deformation for elastic solids in the neighborhood of critical points. A generalized form of the famous Rushbrooke inequality from physical chemistry is obtained. Also, a generalized Clausius-Clapeyron equation is obtained.*

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NOTES

PAC0070: REANALYSIS FOR STRUCTURAL DYNAMIC MODIFICATIONS

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Abstract. *Structural dynamic modification (SDM) techniques can be defined as the methods by which dynamic behaviour of a structure is improved by predicting the modified behaviour brought about by adding modifications like those of lumped masses, rigid links, dampers, beams etc. or by variations in the configuration parameters of the structure itself. Such methods, especially those with their roots in finite element models, have often been described as reanalysis. Most of the techniques imply a dynamic test at some stage of SDM and currently prefer implementation on a personal computer. The need for SDM arises because of the demands on higher performance capabilities of complex mechanical and structural systems, like machine tools, automobiles, rail vehicles, aerospace systems and high speed rotating systems, which require sound dynamic design, i.e. desired dynamic characteristics like vibration levels/response, resonances/eigenvalues, dynamic stability and mode shapes. This paper deals with improving of dynamic charasteristics some structures like tube collector or dredge. It is shown how change of conditions of support can improve dynamic characteristics of structure. Distribution of potential and kinetic energy in every finite element is used for analysis.*

Keywords: *Structural dynamic modification, reanalysis, eigenvalues, design variables*

PAC0076: NONLINEAR ELECTROMECHAwNICAL RESPONSE AND POLARIZATION SWITCHING OF 1-3 PIEZOCOMPOSITES

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Abstract. *This work deals with the nonlinear electromechanical response of 1-3 piezocomposites. The composites contain square or circular piezoelectric rods in an epoxy matrix. Experiments were performed to measure the displacement versus electric field curves. Three dimensional finite element analysis was also conducted to study the electromechanical fields in the 1-3 piezocomposites by introducing a model for polarization switching. Comparison was then made between numerical results and experimental data.*

Keywords: *Piezomechanics, Finite element method, Material testing, 1-3 piezoelectric/polymer composites, Electromechanical field concentrations*

PAC0088: NUMERICAL SOLUTION OF BOUNDARY INVERSE PROBLEMS FOR PLANE ORTHOTROPIC SOLIDS

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Abstract. *We deal with numerical analysis of inverse problems for plane orthotropic solids when measured data are given only on the boundary of the domain. For numerical analysis of such problems we apply discrete methods In this paper we have elaborated iterative procedure to the solution of inverse problems for plane orthotropic solids when input data measured from suitable states are sufficient for determination*

of unknown material parameters. We derive the number of measured input states and conditions for these measured input states which secure determinability of the numerical solution. We deal with numerical experiments. We also study influence of measured input data on stability of the numerical solutions.

Keywords: *Inverse Problem, Orthotropic Solid, Discrete Method*

PAC0096: THE FIVE-MOMENT EQUATION METHOD FOR CONTINUOUS BEAMS ON ELASTIC SUPPORTS

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Abstract. *The Three-Moment Equation, due to B.-P.-E. Clapeyron (1855), is a well known method used in the resolution of continuous beams on rigid supports in solid mechanics. It is proposed in this work a generalization of that classic method, here extended to beams on elastic supports. The analytic solution is obtained and the resultant system of linear equations contains five, instead of three, bending moments in each equation. It was produced a code, in FORTRAN, for the automatic resolution of the problem in that results a pentadiagonal system of linear equations.*

Keywords: *continuous beams, beams on elastic supports, statically indeterminate elastic systems*

PAC0097: A GEOMETRICALLY NONLINEAR MODEL OF CERAMIC CRYSTALS WITH DEFFECTS APPLIED TO SILICON CARBIDE

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Abstract. *A model is developed for anisotropic ceramic crystals undergoing potentially large deformations that can occur under significant pressures or high temperatures. The model is applied to enable an improved understanding of silicon carbide (SiC), with a focus on hexagonal polytype 6H of α-SiC. Incorporated in the model are the following features: nonlinear anisotropic thermoelasticity; piezoelectricity and electrostriction; nucleation and glide of Shockley partial dislocations on the basal plane; dilatation from point defects and elastic fields of dislocation lines; and cleavage fracture. Physical properties are obtained from experimental data and calculations reported in the literature.*

Keywords: *crystal plasticity, piezoelectricity, dislocations, ceramic, silicon carbide*

PAC0114: EXPERIMENTAL STUDY OF DAMAGE USING A TRUE TRIAXIAL TEST

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Abtract. *In this paper, we present an original experimental study of damage in a typical brittle rock, sandstone. In fact, a macroscopic approach is adopted. In this context, material damage is characterized by the determination of representative macroscopic quantities such as the effective elastic properties of damaged material. This approach can provide with useful information for engineering applications.A new methodology is proposed for the experimental quantification of anisotropic damage. The experimental test is composed of two steps, the*

development of a microcrack distribution in a large cubic sample by using a true triaxial press and quantification of mechanical behaviour on small samples drilled from the cubic sample in different orientations. In the first step, cubic samples of 40x40x40cm are submitted to a true triaxial compression state. The three principal stresses can be independently applied to desired value. By using various ratios between the three stresses, it is possible to induce different distributions of microcracks in cubic sample. In the second step, small cylinder samples (37.5x75mm) have been drilled from the cubic samples in different orientations. Due to the oriented distribution of microcracks in the cubic samples, each cylinder sample presents a different mechanical response. Conventional triaxial compression tests have been performed on these samples. Comparisons of the mechanical responses between cylinder samples drilled in different orientations allow evaluating damage states induced par applied stresses. The obtained results provide with interesting experimental data for the formulation of constitutive models for the description of brittle rocks

Keywords: *Damage, Experiment, sandstone, triaxial, microcracks, brittle*

PAC0158: STRESS CONCENTRATION FACTOR IN THE CASE OF AN ORTHOTROPIC PLATE WITH A SQUARE HOLE

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Abstract. *As it is known, laminates composite panels are increasingly required in modern technological applications and consequently modelling the structure as an orthotropic element is worthy of consideration. Certainly, fiber reinforced composite materials such as boron/apoxy, etc. are of interest in civil, mechanic, naval and aeronautic engineering. Also, the orthotropic characteristics are often caused by metallurgical processes. In some instances, cutouts must be made into laminated panels for practical reasons, changing the stress distribution. The present study deals with the determination of the stress concentration factor that holes of square shape with rounded corners cause in an orthotropic rectangular plate subjected to in-plane loading. The calculations are performed by means of a finite element code. Different combinations of axial and tangential forces applied to its middle plane at the outer edges are considered. The mutually perpendicular principal axes of orthotropy are assumed in many different directions with respect to the sides of the plate. The study evaluates the influence of the fiber orientation and the characteristics of the orthotropic materials since such structures do not exhibit easily predictable behavior.*

Keywords: *Stress concentration, orthotropy, plane stress*

PAC0165: SYNTHESIS OF MICROSTRUCTURES USING TOPOLOGICAL SENSITIVITY ANALISYS

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Abstract. *This work addresses the topological asymptotic analysis of the two-dimensional macroscopic elasticity tensor to topological microstructural changes of the underlying material. In particular, the microstucture is topologicaly perturbed by the nucleation of a small circular inclusion. Using the topological derivative concept, applied within a variational multi-scale constitutive framework, a simple analytical expression for the sensitivity is proposed. In the multi-scale modelling, the macroscopic strain and stress at each point of the macroscopic continuum are defined as volume averages of their microscopic counterparts over a Representative Volume Element (RVE) of material associated with that point. These mathematical concepts allow the closed form calculation of the sensitivity, whose value depends on the solution of a set of equations over the original (unperturbed) domain, of a given shape functional with respect to an infinitesimal domain perturbation. The main result -- a symmetric fourth order tensor field over the RVE domain -- measures how the macroscopic elasticity tensor estimated within the multi-scale framework change when a small circular inclusion is introduced at the micro-scale level. The final format of the proposed analytical formula is strikingly simple and can be used in applications such as the synthesis and optimal design of microstructures to meet a specified macroscopic behaviour. In order to show this feature we present several numerical examples using the obtained result together with a level-set based algorithm.*

Keywords: *Topological derivative, topological sensitivity analysis, multi-scale modeling, synthesis of microstructures.*

PAC0181: VIBRATION AND NOISE CONTROL OF CHIPPING HAMMERS

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Abstract. *Pneumatic percussive power tools are extensively used in construction, industrial, and mining sites. They are one of the noisiest machinery used in the construction industry, generating noise levels well above of 110 dB. Besides, the vibration from the hand held power tools lead to the hand-arm vibration (HAV) disorder such as pain, numbing, and blanching of the fingers known as the white finger disease. Techniques to reduce noise and vibration have been developed, however they are not sufficiently effective. The main goal of this effort is to reduce the noise and vibration levels of a chipping pneumatic hammer by using a single integrated device. A prototype was developed to control noise and vibration of a chipping hammer. The vibration control is based in the implementation of simultaneous Impact Vibration Absorbers (IVAs). The noise control is based on using compact silencers and re-directing the noise away from the tool operator. A prototype vibration/noise control device was fabricated and tested. The results indicate good reduction of the impulsive accelaration, e.g. peak reductions of 27%. Noise measurements show the effectiveness of the acoustic treatment implemented in the new device. Noise reduction is achieved over a wide frequency range, e.g. from 125 to 4000 Hz range. Maximum reduction occurs in the 1250 Hz band with an attenuation of 6 dB. It is important to remark that the noise reduction achieved in the low frequency range can complement the good noise reduction performance of other devices such as ear muffs.*

Keywords: *vibration control, noise control, impact vibration absorbers, chipping hammer*

PAC0200: BIRD STRIKE MODELING IN COMPOSITE STIFFENED PANELS

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Abstract. *This paper focuses on the development of a numerical methodology for bird strike modeling in composite stiffened panels. The proposed methodology incorporates an Equation of State (EOS) to predict behaviour of the bird, a Continuum Damage Mechanics (CDM) model to predict damage in the composite panel and a contact-logic to predict skin-stiffener debonding. The three constitutive models have been implemented into ABAQUS/Explicit finite element code as user-defined material models. A series of impact simulations for composite stiffened panels were carried out to validate the proposed modeling methodology.*

Keywords: *High velocity impact, composites, damage mechanics, finite elements*

PAC0231:REVISITING THE CATTANEO-MINDLIN CONCEPT OF INTERFACIAL SLIP IN TANGENTIALLY LOADED COMPLIANT BODIES

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Abstract. *The Cattaneo-Mindlin concept of interfacial slip in tangentially loaded compliant bodies is revisited and its basic simplifying assumptions are critically examined. It is shown that these assumptions, which, in the absence of modern numerical techniques, were essential in 1949 to enable an elegant quantitative solution of the basic problem of pre- sliding between contacting bodies, are actually non physical. An alternative approach to the same problem that is based on treating sliding inception as a failure mode involving material plastic yield is discussed. This alternative approach was suggested even before 1949 but for the same lack of modern numerical techniques could only be promoted qualitatively. Some recent theoretical models, that are based on this earlier alternative approach, and in which the simplifying assumptions of the Cattaneo-Mindlin concept were completely relaxed are described along with their experimental verification. It is shown that the pre-sliding problem between contacting bodies can be accurately solved by these models using realistic physical assumptions and failure criterion.*

Keywords: *spherical contact, pre-sliding, static friction, junction growth, contact condition*

PAC0233: ON THE APPLICABILITY OF NEW SYMPLECTIC APPROACH FOR EXACT BENDING SOLUTIONS OF MODERATELY THICK RECTANGULAR PLATES

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Abstract. *The exact bending solutions of moderately thick rectangular plates with two opposite sides simply supported are derived based on the symplectic geometry method. The basic equations for the plates are transferred into Hamilton canonical equations. Then the whole state variables are separated. According to the method of eigenfunction expansion in the symplectic geometry, the exact bending solutions of the plates are obtained. Since only the basic elasticity equations of the plates are used and there is no need to select the deformation functions arbitrarily, the approach utilized is completely reasonable.*

Keywords: *moderately thick plate, exact solution, symplectic approach*

PAC0240: THE DEFORMATION OF CYLINDRICAL SHELLS SUBJECTED TO RADIAL LOADS

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Abstract. *Cylindrical shells have a simple geometry and application in pressure vessels and piping engineering. Thedevelopment of calculation algorithms in structural project is impelled by a constant challenge in the search of moreaccurate and fast design tools in engineering. The objective of this work is to contribute with a simple and reliable numerical tool for the stress analysis of cylindrical vessels subjected to generalized forces. A hybrid formulation in the definition of forces and displacements is proposed for cylindrical shells subjected to radial loads. Variational techniques coupled with functional analysis are used to obtain an optimized solution for the shell displacement and further stress field evaluation. As it is not possible to obtain exact solutions for the displacements or deformation field whenever the external loads are either concentrate or locally distributed, the solution here proposed deals with the combination of unknown analytic functions combined with Fourier expansions, where the former depend on the axial shell coordinate and the trigonometric terms are dependent upon the cylinder circumferential polar angle. These functions are expanded in Fourier series where displacement amplitudes are combined with trigonometric terms. The result is a system of ordinary differential equations where the solution is analytic after evaluation of eigenvalues and eigenvectors. The boundary conditions are then used to reach the final solution. As an example a large cylindrical shell subjected to pinching loads is considered. The results for the radial displacement and section ovalization are analyzed where the solution was obtained with three terms (n_θ=6) for the accuracy is acceptable in this case. The transverse displacement presents important dependence on the shell thickness vs radius, as the shell can be a thin-walled one (this case is included in the presented example) up to a moderately thick one, where the surface displacement ranges until the extreme edges, which is not the case analyzed. The proposed method leads to accurate results with a relatively low complexity input data. For conclusions of this work it is remarked that the definitions of the load system and boundary conditions are easily processed as the method has pre-defined possibilities for each load case or edge boundary conditions. An analytic solution is obtained and a low number of terms in the Fourier series show good accuracy. A comparison with finite element methods is presented.*

Keywords: *piping engineering, Fourier series, system of differential equations, boundary conditions*

PAC0283: INTERNAL LOADING DISTRIBUTION IN STATICALLY LOADED BALL BEARINGS SUBJECTED TO A COMBINED RADIAL, THRUST, AND MOMENT LOAD, INCLUDING THE EFFECTS OF TEMPERATURE AND FIT

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Abstract. *A new, rapidly convergent, numerical procedure for internal loading distribution computation in statically loaded, single-row, angular-contact ball bearings, subjected to a known combined radial, thrust, and moment load, is used to find the load distribution differences between a loaded unfitted bearing at room temperature, and the same loaded bearing with interference fits which might experience radial temperature gradients between inner and outer rings. For each step of the procedure it is required the iterative solution of Z + 3 simultaneous nonlinear equations – where Z is the number of the balls – to yield exact solution for axial, radial, and angular deflections, and contact angles. Numerical results are shown for a 218 angular-contact ball bearing.*

Keywords: *ball, bearing, static, load, temperature, fit*

PAC0285: VIBRATION OF MULTILAYER FUNCTIONALLY GRADED THICK SHELLS OF REVOLUTION

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Abstract. *In the present work the three-dimensional linear theory of elasticity is used to develop equations that predict the natural frequencies of vibration of multi-layer functionally graded shells of revolution. A general semi-analytical approach is adopted, in which solutions are sought for specified circumferential harmonic modes of vibration. The theory is specifically applicable to multi-layer cylindrical, spherical, and toroidal shells of arbitrary constant thickness, having a radial variation in material properties. To obtain numerical results use is made of the differential quadrature method. The procedure is validated through comparison with results cited in the literature. Several different boundary conditions are covered. New results are given for a three-layer thick toroidal shell. The influence of several material and geometric parameters is noted. The data provided is intended to contribute to the understanding of complex multi-layer functionally graded structures.*

Keywords: *vibrations, shells of revolution, functional grading, multi-layer shells*

PAC0298: ELECTROMAGNETIC SOLIDS WITH LOCAL DISPLACEMENT OF MASS

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Abstract. *The non-local model of electro-magneto-thermo-mechanics for polarized non-ferromagnetic solids is proposed. It takes into account the process of local mass displacement due to structural changes of a physically small element of a body. Such changes can be observed in close vicinity of newly created surfaces, due to the body polarization, etc. To take into account the local mass displacement, the state parameter space is extended to contain two more pairs of new conjugate parameters: (i) the specific density of the induced mass and the reduced potential which measures the influence of mass displacement on the internal energy, and (ii) the specific vector of local mass disp¬lacement and the gradient of the reduced potential . An approach which takes into account possible irreversibi¬lity of the local mass displacement is also proposed. On this basis we obtained the reological constitutive relations for the specific vectors of the mass displacement and for the polarization. In the linear approximation, the proposed model takes into account the coupling between mechanical and electromagnetic processes for isotropic bodies, and allows one to study the surface charge kinetics and the formation of near-surface inhomogeneities of the stress-strained state as well as the electric polarization, surface tension and disjoining pressure. Quantitative investi¬gation of such effects for dielectric elastic layers with traction-free surfaces is carried out. For a layer of varying thickness the lateral force, which influences the stability and the strength of a thin film, is calculated. It is shown that the model describes correctly the anomalous behavior of the electric capacitance of a thin dielectric film and the non-linearity of electric field distribution inside the film (the so-called Mids anomaly). Our results agree well with the results of Mind¬lin's polarization-gradient model and Eringen's non-local model of piezoelectricity, as well as with the results of Kafa¬dar's multipoles theory.*

Keywords: *local mass displacements, irreversible thermodynamic processes, dielectric materials, non-local theory, interfacial phenomena*

PAC0299: NON-SATURATED SOIL CONSOLIDATION MODELLING IN PRESENCE OF IMMISCIBLE POLLUTANTS

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Abstract. *The main scope of this work is to carry out a mathematical framework and its corresponding finite element discretization for the partially saturated soil consolidation modelling in presence of an immiscible pollutant. A multiphase system with the interstitial voids in the grain matrix filled with water (liquid phase), water vapour and dry air (gas phase) and with pollutant substances, is assumed. The scopes of the mathematical model addressed in previous works of this author, were broaden regarding the presence of an additional phase and considering the pollutant saturation suction coupling effects. The ensuing mathematical model involves equations of momentum balance, energy balance and mass balance of the whole multiphase system. Encouraging outcomes were achieved in several different examples.*

Keywords: *Consolidation, immiscible pollutants, finite elements, multiphase porous media, geomechanics*

PAC0302: STRESSES FOR CRACK TIPS WITH ROUNDING

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Abstract. *In classical elasticity, when cracks are modeled with stress-free elliptical holes, stress singularities occur as crack-tip root radii go to zero. This raises the question of when do crack-tip stresses first start to depart from physical reality as radii go to zero. To address this question, here cohesive stress action is taken into account as radii go to zero. To obtain sufficient resolution of the key crack-tip fields, two highly-focused numerical approaches are employed: finite elements with successive submodeling concentrated on the crack tip, and numerical analysis of a companion integral equation with considerable discretization refinement at the crack tip. Both numerical approaches are verified with convergence checks and test problems. Results show that for visible cracks, classical elasticity analysis leads to physically sensible stresses provided crack-tip radii are accounted for properly. For microcracks with smaller crack-tip radii, however, cohesive stress action also needs to be included if accurate crack-tip stresses are to be obtained. For cracks with yet smaller crack-tip radii, cracks close and stresses throughout the crack plane become uniform.*

Keywords: *elasticity, crack-tip stresses, cohesive stresses, rounding crack tips*

PAC0309: FLEXURAL VIBRATIONS OF PLATES: THEORY AND EXPERIMENT

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Abstract. *Theoretical and experimental results for flexural waves of a rectangular plate with free ends are obtained. Both the frequency spectrum and the wave amplitudes are analyzed. The plane wave expansion method is applied to the Kirchhoff-Love equation to obtain theoretically the normal-mode frequencies and wave amplitudes of the rectangular plate. The method of measuring the flexural vibrations of the metallic plate is based on the use of electromagnetic-acoustic transducers (EMATs). The EMATs, that are non-contact devices, were also used to excite the out-of-plane waves. A point by point scanning to measure the wave amplitudes is performed. The theoretical predictions of the 2-D Kirchhoff-Love model agree with the experimental measurements for an aluminum rectangular plate at frequencies below 2 kHz..*

Keywords: *rectangular plates, vibrations, electromagnetic acoustic transducers, Kirchhoff-Love equation, out-of-plane waves*

PAC0319: MODELLING TRACTION AND TEAR OF A TEXTILE CONVEYOR BELT

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Abstract. *The present work is about results obtained through a mathematical modelling and simulation of a textile conveyor belt with the purpose of calculating its resistance to traction and resistance to tear propagation. Experimental tests were performed, according to ISO norms, in order to determine the above mentioned parameters and also for determining main characteristics of the band and its constituting parts. Obtained experimental results were compared with specifications from manufacturer's catalog and with results obtained through mathematical modeling and simulation procedures. Used mathematical models are based on material resistance principles, theory of elasticity and theory of composites. Simulation procedures are based on the finite element method using the multilayer element which allows geometric models be treated as composites. Obtained experimental results were similar to those described by manufacturer's catalog as well as to those obtained by simulation and mathematical modeling.*

Keywords: *finit element, hyperelasticity, traction, tears propagation, conveyor belt*

PAC0320: MODELING ADHESIVE STRENGTH OF A TEXTILE CONVEYOR BELT

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Abstract. *The present work is about simulation of a textile conveyor belt in order to calculate the adhesive strength between its constitutive parts. Some tests were performed, according to ISO-252/1-99 norm, with the purpose of determining the adhesive strength by experimental way. Some measurements were also made in order to be used in the mathematical modeling process of the belt's geometry. Used mathematical models are based on material resistance principles and numerical mathematic. Simulation process is based on finite element method. Obtained through simulation results were similar to tabulated limit values for peel stress.*

Keywords: *finit element, hyperelasticity, adhesive strength, conveyor belt*

PAC0325: A CONSISTENT GRADIENT-PLASTICITY FORMULATION FOR POROUS MEDIA BIFURCATION ANALYSIS

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Abstract. *The strain localization problem of frictional cohesive materials is strongly related to the softening mechanical behavior and the instability phenomena in structural materials. In this situation a pathological dependences of the FE numerical solution is observed with respect to the size and orientation of the considered special discretization. This difficulty is mostly related to the strong dependence of the softening behavior in the post-peak regime on the boundary conditions in terms of the govern stress and hydraulic conditions. Thereby, the mathematical modeling of deformation behavior of porous media requires appropriate constitutive models in order to objectively describe their complex strength degradation processes under monotonic type of loading. In fact, these enhanced constitutive theories should be able to describe non local strain behaviors. In this work, a thermodynamically consistent gradient plasticity formulation is proposed in order to objectively model the deformation behavior and strain localization of frictional cohesive porous media, like soil or concrete. The non-local softening formulation of the proposed constitutive model incorporates the dependence of the gradient characteristic length on the governing stress and hydraulic conditions to realistically predict the size of the maximum energy dissipation zone. Firstly the basis of the thermodynamically consistent gradient plasticity theory is discussed. Then this theory is extended for the case of porous media like soils and particularly for the formulation of the non-local softening law. The localization tensor of the proposed non-local theory for porous media is obtained and the conditions for localized type of failure in uniaxial and triaxial compression tests are numerically evaluated.*

Keywords: *Gradient-plasticity, localized failure, softening, porous media, Finite Elements*

PAC0349: MECHANICS OF PEELING FOR EXTENSIBLE ELASTIC ADHESIVE TAPES

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Abstract. *The measurement of interface mechanical properties between an adhesive layer and a substrate is significant for optimization of a high-quality interface and is of significance to numerous applications including peeling and electronic packaging. A common method for measuring these properties is the peel test. Although analytical models exist for peeling of elastic tapes from smooth surfaces, there is a need for rigorous experiments in this area. Furthermore, several assumptions are made in the existing models regarding the mechanical and material properties of the tape and the testing conditions. These include inextensibility of the tape and negligible pre-strain prior to detachment. The assumptions require that the elastic energy term in the energy balance of the peel process be neglected. However, this term can become significant for elastomers at small peel angles, in which case the tape is considered to be an extensible linear elastic medium. The peel force at varying angles is determined for various commercial tapes. Tests are conducted using a newly-developed peel arrangement capable of peeel angles from 0 to 180 degrees. The peel zone and the tape are imaged in great detail using optical techniques. The influence of extensibility and pre-strain on adhesion is examined, and results are compared to a newly developed model of the peeling process accounting for these parameters. The dependency of adhesion energy on the peel angle is also investigated, and an attempt is made at modeling the peeling process as a mixed-mode fracture problem.*

Keywords: *Peeling, Adhesion, Mixed-mode fracture*

PAC0350: EFFECT OF SEISMIC ANALYSIS ON THE DESIGN OF REINFORCED CONCRETE LINING OF CUT AND COVER TUNNELS (CASE STUDY: CUT AND COVER TUNNEL OF LINE 1 OF TABRIZ URBAN RAILWAY TUNNEL)

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Abstract. *Although the vast application of the cut and cover tunnels in urban underground space developments and establishment of these tunnels in the shallow ground, where the ground strongly vibrated during an earthquake, seismic analysis and design of this kind of tunnel linings may be unavoidable. Up to now, several analytical methods are offered to analysis and design underground spaces seismically. In this paper the potent and weak points of analytical solutions have been explained and then numerical seismic analysis of, the cut and cover tunnel of the Tabriz urban railway (line 1), as a case study for high seismicity region, has been carried out under Maximum Credible Level (MCL) earthquake using FLAC2D. Also the results of this analysis have been compared with ground-structure interaction seismic analysis by SAP2000. At last, the executive reinforced concrete, the rectangular lining frame of the studied tunnel, estimated under the static and seismic loads.*

Keywords: *seismic analysis and design cut and cover tunnel, reinforced concrete rectangular lining*

PAC0354: EXPERIMENTAL FAULT DETECTION IN ROTATION SYSTEM USING STATE OBSERVERS BY LMIS

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Abstract. *Rotating systems have many applications in wide-ranging industrial contexts. The breakdown of this equipment results in economic wastes or leads to dangerous situations. To avoid such problems is very important, and it can be done through tools that inform about the inform about the existence of faults, as well as, about their progress in time. A review of the modeling process used for rotor-support-structure shows that the finite element method is the major method employed. In this paper, with the aid of well defined theoretical models, obtained using the finite element technique, and the state observer method for the identification and location of faults it is possible to monitor the parameters of a rotor-support-structure system, including the foundation effects. In order to improve safety, these parameters must be supervised that the occurrence of failures or faults can. The state observers were designed using Linear Matrix Inequalities (LMIs). Finally, experimental results (using for this a rotation system in the mechanical vibrations laboratory at Ilha Solteira's Mechanical Engineering Department) demonstrate the effectiveness of the methodology developed.*

Keywords: *Rotation System, Fault Detection, State Observers, Linear Matrix Inequalities (LMIs)*

PAC0360: FUZZY CLUSTERING TO DISTINGUISH STRUCTURAL DAMAGE FROM TEMPERATURE EFFECT

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Abstract. *Structural Health Monitoring (SHM) denotes a system with the ability to detect and interpret adverse changes in a structure. Many companies invest large amount of money in SHM applications, since damage can lead to catastrophic and expensive failures. This paper is addressed to apply impedance technique for structural health monitoring. This technique is based on high frequency to monitor changes in the impedance signals. This can be done by using piezoelectric sensor/actuator that get measurements directly related with the mechanical impedance of the structure. When this approach is used for practical applications, it is very important to stand out the environmental influences, since it can interfere in the signal and could indicate a false damage diagnosis. In this work the influence of the temperature is evaluated to classify the impedance signals in clusters. A fuzzy clustering algorithm is used to organize the data in clusters with the aim of distinguish damage situation from structural changes caused by temperature variations. In the experimental application, an aluminum beam with one coupled piezoelectric ceramic was analyzed. A commercial system from National Instruments controlled by LabVIEW® software was used for input excitation and data acquisition. In all tests the beam was suspended horizontally to simulate a free-free boundary condition.*

Keywords: Impedance Technique, Temperature Variation Effect, Fuzzy Clustering

PAC0374: EULERIAN ELASTOPLASTICITY: A PARAMETRIC DESCRIPTION

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Abstract. *Eulerian elastoplasticity based on the additive decomposition of the deformation rate is presented in a phenomenological description. Complex material behavior may be represented in a natural way, if one uses a parametric representation of fundamental constitutive quantities. Then, flag-like loops observed in the uniaxial deformation of materials with strain recovery effects can be represented by the general elastoplasticity theory of three-dimensional continua.*

Keywords: *Elastoplasticity, Eulerian description, parametric description*

PAC0390: ON INCREMENTAL THERMOELECTROELASTICITY THEORY

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Abstract. *The generalized Hamilton principle and the theorems of uniqueness of solution and of reciprocity of work, that have been written by Nowacki for linear thermopiezoelectricity in the absence of initial fields, are extended here to incremental thermoelectroelasticity with initial fields. For the uniqueness theorem we assume that in the initial state entropy does not depend on time and temperature is uniform, whereas for the theorem of reciprocity of work we assume that in the initial state both the entropy and temperature fields do not depend on time.*

Keywords: *Incremental thermoelectroelasticity, Hamilton principle, Reciprocity of work theorem, Thermopiezoelectricity, Uniqueness theorem.*

PAC0391: A VARIATIONAL VISCOELASTIC FRAMEWORK FOR FIBER REINFORCED SOFT TISSUES

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Abstract. *This paper presents a constitutive model that is appropriate to the simulation of fiber-reinforced materials, in particular biological tissues. Many biological soft tissues are constituted by a net of collagen and elastin fibers embedded in a compliant solid cellular matrix. Classical examples are ligaments, tendons, arteries, etc. The distribution of these fibers as well as the mechanical interaction among them and that of fibers and cellular matrix provide the anisotropic rate dependent (viscous) behavior of these materials. The model proposed here follows a variational framework in which the behavior of standard inelastic materials is described by a free energy incremental potential whose local minimization provides the constraints for the internal variables updates at each load increment. This potential is additively decomposed in two contributions. The first one is related to the assumed isotropic behavior of the cellular matrix, while the second one takes into account the fiber induced anisotropy by means of the structural tensors given by the fiber directions. Different material models can be represented depending of the choice of suitable potential functions. The material model is implemented in the academic large-strain Finite-Element METAFOR and some numerical tests are performed showing the adequation of the proposed model to the simulation of soft fiber-reinforced tissues.*

Keywords: *Biomechanics, anisotropy, nonlinear viscoelasticity*

PAC0414: OPTIMISATION OF A BEAM IN BENDING SUBJECTED TO A SEVERE INERTIA IMPACT LOAD

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Abstract. *This paper summarises an optimal analytical study of a bar when it is subjected to shock inertia loading such that the severe bending causes permanent yielding. The findings are related to a practical case study application and help explain the necessary actions that have to be taken to minimise the impact damage. The analysis relates the sudden strain energy which the bar gains following an impact (when either the moving bar is suddenly brought to a halt or alternatively when the stationary bar is collected by a body moving with substantial momentum) and establishes the bending strength as a function of mass, stiffness and other kinematic conditions. The optimal analysis results in a surprising paradox which is borne out in the actual detail design solution to a critical component which had caused major maintenance problems in the braking system of railed vehicle braking system. The system, which uses heavy duty elastic cords that are anchored at one end and are securely attached to a catch bar, the beam under consideration, at the other. The study reveals some interesting findings relating to the best bar configuration in terms of geometrical design, support locations and material choice.*

Keywords: *impact failure, inertia loading, beam bending energy*

PAC0420: PORTEVIN-LE CHATELIER EFFECT: FORMULATION, ANALISIS AND NUMERICAL SIMULATION

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Abstract. *This work deals with the formulation, analysis and numerical simulation of the Portevin-Le Chatelier (PLC) effect, within a one-dimensional context. We start with the formulation of the problem within the scheme of modern continuum mechanics, where the plastic deformation is considered as an additional degree of freedom. A thermodynamically consistent constitutive theory is developed in which non-local and rate effects are considered by the introduction of the gradient and rate of plastic deformation. The governing equations are obtained after combining the basic balances with the constitutive theory. The qualitative analysis of the stationary homogeneous solution shows that the Portevin-Le Chatelier effect is associated with a negative strain- rate dependence of the flow stress. Also, with the help of Hopf bifurcation' theorem, we obtain sufficient conditions for the existence of solutions of the traveling wave type. A computer simulation based on the finite element method and a Euler implicit scheme and staggered algorithm is briefly presented. The numerical results illustrate the localization of plastic deformation in narrow bands.*

Keywords: *Portevin-Le Chatelier, non-local plasticity, rate dependent plasticity, continuum mechanics, instability plastic*

PAC0425: SCALING OF A DOUBLE PLATE STRUCTURE UNDER AXIAL IMPACT

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Abstract. *A technique for scaling structures under dynamic load is suggested in the present work. In order to take strain rate effects into account, the initial impact velocity is properly changed such that model and prototype exhibit the same behavior, i.e. perfect similarity is achieved. A double plate structure under in plane axial impact is studied to infer the performance of the correction methodology. It is indeed shown here that, when the correction is employed, all the structures analyzed have their model behaving exactly as expected, regardless of the magnitude of the scaling factor.*

Keywords: *scaling, structural impact*

PAC0457: A VARIATIONAL FORMULATION FOR A SET OF HYPERELASTIC-VISCOPLASTIC MATERIAL MODELS IN A FULLY COUPLED THERMO-MECHANICAL PROBLEM

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Abstract. *Many different contexts in solid mechanics demand the consideration of thermal effects during deformation. Be it intrinsic material properties (e.g. glass transition temperatures of rubber-like polymers) or specific deformation regimes (large strain and strain rates), there is plenty of motivation for the study of thermo-mechanical coupling. In this paper, an adiabatic problem is considered. A fully coupled thermo-mechanical problem is formulated. Isotropic hyperelastic-viscoplastic materials are considered in a variational structure. The classical multiplicative decomposition of deformation in elastic and inelastic (plastic) parts is used in the construction of the incremental pseudo-potential, together with the hypothesis of isochoric inelastic deformation. This leads to the use of separate potentials associated with volumetric, isochoric elastic and plastic deformations, purely thermal accumulation and dissipated energy. The use of different potentials commonly found in literature is explored. Temperature dependence for all the potentials, the essence of the fully coupled thermo-mechanical problem, is briefly discussed. It is important to note that assuming no local heat generation or heat flux allows for temperature to be considered as an additional internal variable. A radial-return mapping scheme and elastic predictor states are used in the solution of the resulting non-linear problem with respect to temperature and cumulated plastic strain. Temperature increase, heat dissipation and entropy change are examples of what can be predicted by the model. Applications to selected materials are presented.*

Keywords: *Thermo-mechanical coupling, Variational formulation, Constitutive updates*

PAC0509: MECHANICAL AND TRIBOLOGICAL CHARACTERISATION OF FUNCTIONALLY GRADED COATINGS WITH COMPLICATED STRUCTURE

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Abstract. *. In the paper authors developed of accurate and efficient analytical and numerical simulation tools for simulation of functionally graded coatings with alternating gradient in material properties. The method was used in recent works by Aizikovich et al. for solution of the raw of applied contact problems for graded materials in case of more simpler inhomogeneity laws. The given work shows in examples the possibility of analytical solutions by the earlier developed method for the quite complicated base models like graded-layered.*

Keywords: *Graded Coatings, Contact Problems, Analytical and Asymptotic methods*

PAC0516: THE INFLUENCE OF THE VARIABLE THERMAL CONDUCTIVITY OF A PERFORATED PLATE ON A HEAT CONDUCTION PROCESS

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Abstract. *In this paper, the effect of a circular perforation on the heat conduction in a plate with variable thermal conductivity is studied. The corresponding heat equation is written in non-dimensional form, depending on three non-dimensional parameters: the aspect ratio of the plate; the radius of perforation related to the width of the plate and the non-dimensional thermal conductivity parameter , which measures the variation of the thermal conductivity with temperature. This equation is solved by two different approaches. The first one is numerical, using a coordinate fitted grid generator, and the second one is analytical, by developing an asymptotic solution for small values of the radius of perforation related to the width of the plate and the non-dimensional thermal conductivity parameter assumed to be very small compared with unity. The non-dimensional heat flux given by the Nusselt number has been obtained and the numerical results have been compared with the analytical solution. Excellent agreement is achieved even for values of the radius of perforation related to the width of the plate up to values close to 0.4.*

Keywords: *Thermal conductivity, heat conduction, Nusselt number, perforated plate*

PAC0540: A PLANE BOUNDARY-VALUE PROBLEM OF THERMO-MAGNETOELASTICITY FOR TWO PARALLEL DC- BUSBARS BY A BOUNDARY INTEGRAL METHOD

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Abstract. *A boundary integral method previously introduced by two of the authors is properly extended to investigate the plane problem of linear, uncoupled thermo-magnetoelasticity for two parallel DC-busbars placed a distance apartin free space kept at a constant temperature. The basic equations and boundary conditions are briefly mentioned and the solution of the problem is obtained for all quantities of physical interest. Numerical results are given for the "magnetic displacements" occurring in the representation of the mechanical displacements and a detailed discussion of these results is provided.*

Keywords: *DC busbars, thermo-magnetoelasticity, boundary integral method*

PAC0541: PLASTIC STRAIN LOCALIZATION PROMOTED BY THERMOMECHANICAL COUPLING IN METALLIC MATERIALS

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Abstract. *Thermomechanical coupling is an important phenomenon in different engineering problems. Inelastic cyclic strain promotes heating of metallic structural elements, and a considerable amount of heat can be generated in situations where high loading rates and/or high amplitudes of inelastic strain are of concern. The temperature rise of mechanical component depends on the loading amplitude, frequency and temperature boundary conditions. Nevertheless, traditional low-cycle fatigue models neglect the material temperature variation due to thermomechanical coupling and unreal life predictions may be obtained. Indeed, there are situations where such couplings cannot be neglected and a physically more realistic model must take it into account. In this paper, a continuum mechanics model with internal variables is proposed to study the thermomechanical coupling effects of metallic components subjected to inelastic loadings. A thermodynamic approach allows a proper identification of the thermomechanical coupling in the mechanical and thermal equations. A numerical procedure is developed based on an operator split technique associated with an iterative numerical scheme in order to deal with the non-linearities in the formulation. With this assumption, coupled governing equations are solved involving three uncoupled problems: thermal, thermoelastic and elastoplastic behaviors. Numerical simulations of steel plates with a stress concentrator subjected to inelastic loadings are presented and analyzed. Results suggest that the proposed model is capable of capturing important localization phenomena related to plastic strain localization due thermomechanical coupling*

Keywords: *Thermomechanical Coupling, Modeling, Numerical Simulation, Elastoplasticity*

PAC0549: FRACTURE OF RUBBERS UNDER MULTIAXIAL CYCLIC LOADING

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Abstract. *The purpose of this study is to propose a fatigue criterion based on the continuum damage mechanics (CDM) theory to predict the fatigue life of rubber-like materials. The fatigue life of a styrene-butadiene rubber (SBR) under different loading paths was investigated. A CDM model was adapted to a generalized Ogden constitutive law and applied to fatigue tests achieved on the SBR material. It was shown a quite good agreement between experimental data of uniaxial tension and pure shear fatigue tests and predicted values given by the model.*

Keywords: *rubber, fatigue life, multiaxial loading, large strains, continuum damage mechanics*

PAC0551: EFFECTS OF MULTIAXIAL STATE OF STRESS IN THE BANDS CHARACTERISTICS DUE TO DYNAMIC STRAIN AGEING FOR AA5083-H116 ALUMINIUM ALLOY

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Abstract: *Digital Image Correlation (DIC) and Digital Infrared Thermography (DIT) are employed to capture and characterize the spatio-temporal aspects of Portevin-LeChâtelier effect due to dynamic strain ageing in a notched specimen. Deformation bands are visualized and it is observed that these bands are generally trapped around stress concentrators in contrast to the smooth specimens where they are seen to propagate along the whole specimen.*

Keywords: *Portevin-LeChâtelier effect; Digital image correlation; Digital infrared thermography; Dynamic strain ageing*

2. FLUID MECHANICS

NOTES

PAC 0065: A COMPLETE, NONLINEAR INDUCED FLOW THEORY FOR ROTORS IN INCOMPRESSIBLE FLOW

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Abstract. *Although the rotor blade may be moving at transonic speeds near the tip, the rotor wake is generally determined by incompressible potential flow theory. The solution of the potential flow equations (and of their derivative, the vorticity transport equations) has generally been deemed sufficient to define the wake geometry and induced flow of rotors. Thus, most models are based on these equations. Over the past 25 years, one genre of these models has been the group of finite-state inflow equations in which the inflow is expanded in terms of shape functions, resulting in a matrix set of ordinary differential equations that describe the flow (See Pitt (1980), He (1989), Morillo (2001) and Hsieh (2006)). These have now culminated with the most general form of the equations, with previous versions being special cases of the general one. The purpose of this paper is to outline the features of this general set of inflow equations, including their derivation and special cases. Thus, this paper can form the basis for any version of the model for anyone interested in using it. The present paper also provides insights into the limitations and accuracy both of the most general case and of the special cases.*

Keywords: *Induced Flow, Inflow, Rotor, Incompressible, Finite-state, Potential flow*

PAC0069: MECHATRONICAL PRESSURE CONTROLLER FOR FUEL INJECTION SYSTEMS IN CNG POWERED COMBUSTION ENGINES

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Abstract. *One of the essential parts of Compressed Natural Gas (CNG) powered engines is the pressure regulator which reduces the storage pressure (up to 250 bar) from the tank system to a near constant outlet pressure of approximately 2 up to 10 bars within the fuel injection system. To generate fundamental data for the scientific project described in this paper a standard mechanical pressure regulator for CNG-powered engines was investigated theoretically and practically. Thereto the particular components of such a system were modeled, simulated and verified by comparison of measured and simulated results. In the next step the modeled state of the art mechanical pressure regulator was substituted by new developed mechatronical devices and the space of improvement for different versions of those pointed out based on simulation. Subsequently the realized mechatronical pressure regulators with the major potential for further development were practically investigated on a test rig at Trier University of Applied Sciences. Experiments and Simulations are aligned here to validate a new device. The main advantages that accrue by using a mechatronical pressure regulator instead of an ordinary mechanical one are demonstrated.*

Keywords: *Compressed Natural Gas, Fuel System, Mechatronical Pressure Regulator, Modelling, Simulation*

PAC0089: REDUCED ORDER POD/KRIGING MODELING FOR REAL-TIME 3D CFD

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Abstract. *Reduced order models based on the Proper Orthogonal Decomposition and Kriging methods are presented in the context of in-flight icing simulation via CFD. They predict a wide swath of flow fields and ice shapes based on a limited number of "snapshots" obtained from complete high-fidelity (3D viscous, compressible, turbulent) CFD computations. Modes are extracted from these snapshots and used to reconstruct the CFD field, and/or the aerodynamic coefficients, and/or the ice shapes, for other conditions within the range. This reduces calculation times by orders of magnitude from the full 3D ones, enabling a more complete map of the performance of an iced aircraft over a wide range of flight and weather conditions to be used in its certification and in pilot training.*

Keywords: *Real-time CFD, In-flight icing, Flight simulators, Reduced order models, Proper orthogonal decomposition, Kriging*

PAC0129: EXPERIMENTAL STUDY AND MATHEMATICAL MODELING OF AIRFLOW IN GRAIN BULKS UNDER ANISOTROPIC CONDITIONS

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Abstract. *A mathematical model, algorithm, and software were developed to calculate the static pressure, streamlines, and airflow velocity distribution in grain bulks for two- and three-dimensions under anisotropic conditions. The empirical relationships between permeability factors in horizontal and vertical directions (anisotropy factors) were analysed for soybean, wheat, maize, oats, rice, peas, flax seed and lentils mass. It was showed that anisotropy factor depends on the grain form and increases significantly with a deviation of this form from spherical. Anisotropy factor is rising with increase in air velocity, and the velocity influence rate varies from very weak for seeds with the form close to spherical (peas, soybean), up to essential, for grains with a greater deviation of the form from spherical (lentils, rice). In this work the relationship between the maximal area of grain contour projection on a horizontal plane (midsection for vertical flow) and the most probable value of the area of grain contour projection on a vertical plane (midsection for horizontal flow) was used as the principal parameter to specify the anisotropy factor of an anisotropy granular medium. As simulations show, there is difference between airflows through isotropic and anisotropic medium. This difference depends on grain type (value of anisotropy factor), area cross-section variation of storage bin (expansion ratio) and air inlet location. It was carried out numerical simulations of real and hypothetical aerated grain stores to detect the anisotropy influence on operational risk areas.*

Keywords: *Aeration, Anisotropy medium, 3-D airflow simulation, Aerated grain storage bins, Finite-element method*

PAC0134: TWO-DIMENSIONAL INSTABILITIES IN FLUIDISED BEDS

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Abstract. *The formation of bubbles in fluidised beds is a subject that still intrigues many scientists in the field. The one-dimensional limit, in which concentration waves driven by particle inertia propagate upwards, seems to be well understood. However, the connection between the instability of the one-dimensional waves to transverse disturbances and the formation of bubbles is still unclear. Moreover, recent theoretical and experimental studies have observed the formation of bubbles in gas-fluidised beds, but not in liquid-fluidised beds and, despite a detailed characterisation of the structures of the bubbles is already available, the physical mechanism leading to this differentiation is still unknown. In this work, we focus on the study of the instability of the one-dimensional concentration waves to transverse disturbances, leading to gravitational overturning. We propose an extension of models available in the literature to describe the gravitational instability of unbounded stratified particulate flows. The rheology of the particulate phase is simplified to retain only the relevant mechanisms in the model. This approach brings significant improvements to the numerical solution of the problem. A linear stability analysis is performed in order to determine the dispersion relation of the transverse modes. In addition, a numerical simulation of the full governing equations is carried out and is checked against the theoretical results of the linear stability. The influence of the physical parameters in the stability of the waves is evaluated. It is found that stratified particulate flows are unstable to transverse disturbances and that the instability is driven by a tilt-and-slide mechanism that creates ascending regions of low concentration of particles and descending regions of high concentration of particles. Nevertheless, we did not observe structures in this flow resembling bubbles in fluidised beds.*

Keywords: *fluidised beds, gravitational instability, bubble formation, stability analysis*

PAC0180: A UNIFIED NUMERICAL SIMULATION FOR POLYMERIC LIQUIDS

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Abstract. *Numerical simulation results for viscoelastic liquids are presented whereby modified Tait equation is used to describe the liquid compressibility. An original non-dimensionalization procedure is presented to avoid the failure of the standard formulation in the incompressible limit. The Least-Squares finite element method (LSFEM), coupled with the Newton-Raphson's method, is used to solve the resulting system of equations. The method is used to predict the velocity and stress fields in a channel with a bump. Viscoelastic flow computations are presented for different Weissenberg numbers. The method is also used to simulate the flow in a multi-pass rheometer (MPR). Although using a one-mode Giesekus model, the predicted shear-rate dependent viscosity curve is in good agreement with the experimental results.*

Keywords: *Finite Element, Least-Squares, Multi-pass Rheometer, Viscoelastic Liquids, Giesekus Model*

PAC0186: MAGNETIC CONTROL OF INSTABILITIES IN A THERMOCAPILLARY DRIVEN LIQUID BRIDGE

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Abstract. *The magnetic stabilization of an axisymmetric flow in an electrically conducting liquid bridge in micro-gravity is investigated. The base state is driven by thermocapillary (Marangoni) forces on the free surface, due to an applied heat flux. The resulting toroidal flow is susceptible to three-dimensional perturbations, with transitions to both steady and unsteady non-axisymmetric flow, varying with the Prandtl number of the fluid and strength of the applied magnetic field. The base state can be damped and stabilized by applying a steady magnetic field, aligned with the axis of the liquid bridge. Low Prandtl number cases, typical of molten metals or semiconductors, are treated here. To study a wide range of field strengths, numerical and asymptotic analyses, as well as novel combinations of these computa¬tional and analytical techniques are employed. In the low magnetic field case, spectral numerical methods are used to solve the base flow and perform the linear stability analysis. The ratio of the magnetic damping to viscous effects is measured by the Hartmann number. The base state is strongly stabilized in going from Hartmann numbers of zero (no magnetic field) to order 100. Depending on the Prandtl number, this corresponds to a two order of magnitude or more increase in the critical thermocapillary Reynolds number. As the Hartmann number is increased, the flow is confined to thin boundary layers near the free surface and end walls. The resolution of these layers requires taking full advan¬tage of every symmetry in the base state and perturbations and, careful treatment of the singularity in the cylindrical coordinate system. Near Hartmann numbers of order 100, the base state suggests an asymptotic pattern, which is investigated in the high Hartmann number limit. For infinite Hartmann number, an analytical base flow solution is found. The linear stability of this flow is also investigated and clearly highlights the dominant transition mechanism. To match the two solutions at intermediate Hartmann numbers, a multiscale solution is developed. This combines the numerical and analytical techniques, eliminating computational difficulties without sacrificing the dominate physics.*

Keywords: *magnetic damping, thermocapillary flow, spectral methods, linear stability*

PAC0205: FLUID MECHANICS ASPECTS OF A BURIED NATURAL GAS PIPELINE AT A RIVER CROSSING

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Abstract. *Design of a buried pipeline river crossing is a case of soil/fluid/structure interaction, and fluid mechanics plays an important role therein. Specifically, sediment-transport, buoyancy, hydrodynamic drag and lift, and flow induced vibration influence the stability of a pipeline buried beneath a river bed. Further, it may be noted that a river crossing of a high pressure buried natural gas pipeline has important health and safety concerns, since natural gas is odourless, colourless, tasteless, flammable, and less dense than air at atmospheric pressure, and exposure and rupture of a buried pipeline can send a catastrophic buoyant gas plume into the surrounding populated areas. This paper presents a brief account of the design of river crossing of a 1.52 m diameter buried natural gas pipeline in the Caribbean island of Trinidad (100N, 610W), and points out the shortcomings of the current design methodology which – due to the inherent complexity of soil/fluid/structure interaction – is essentially empirical. The paper concludes by highlighting areas for further research on the fluid mechanics aspects of a buried pipeline at river crossings.*

Keywords: *Caribbean, Pipeline, River, Scour*

PAC0303: SWIRL NUMBER INFLUENCE ON COMBUSTION INSTABILITIES IN DOUBLE-STAGE SWIRL CHAMBE

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Abstract. *This work presents a new Low-NOx combustor configuration to especial application in gas turbine. In this new concept, the combustion happens in two phases, being the first one rich in fuel (primary chamber) and the second with deficiency (secondary chamber with bigger diameter). Therefore, the occurrence of the unfavorable conditions for NOx formation is obtained through the dynamic control of the reactants flow. Three control combustion process parameters are analyzed: equivalence ratio, primary chamber length/diameter ratio (L/D), fuel jet Reynolds number and air flow swirl number. However, for some parameter combinations, it's observed the combustion acoustic instabilities phenomena. The results show that for high swirl numbers, the instability was attenuated, being too this behavior observed for smaller Reynolds numbers and L/D = 3 (the biggest ratio). This work present some suggestions in order to attenuate the oscillations in this kind of combustor, in the spite of the difficult understanding of the studied phenomena.*

Keywords: *Combustion, Gas Turbine, Combustion Instability*

PAC0306: NUMERICAL SIMULATIONS OF THE AERODYNAMIC BEHAVIOR OF LARGE HORIZONTAL-AXIS WIND TURBINES

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Abstract. *In the present work, the non-linear and unsteady aerodynamic behavior of large horizontal axis-wind turbines is analyzed. The flowfield around the wind turbine is simulated with the general nonlinear unsteady vortex-lattice method, widely used in aerodynamics. By using this technique, it is possible to compute the aerodynamic loads and their evolution in the time domain. The results presented in this paper help to understand how the existence of the land-surface boundary layer and the presence of the turbine support tower, affect its aerodynamic efficiency. The capability to capture these phenomena is a novel aspect of the computational tool developed in the present effort.*

Keywords: *Large horizontal-axis wind turbines, Unsteady aerodynamics, Vortex-lattice method*

PAC0333: TRANSIENT LAMINAR OPPOSING MIXED CONVECTION IN A DIFFERENTIALLY AND SYMMETRICALLY HEATED VERTICAL CHANNEL OF FINITE LENGTH

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Abstract. *A detailed numerical simulation for transient laminar opposing mixed convection in a downward vertical channel flow with both walls suddenly subjected to isothermal heat sources over a finite portion of the channel walls has been investigated by solving the unsteady two-dimensional Navier-Stokes and energy equations. Computations were carried out for values of the Reynolds number ranging from 100 to 500 and the buoyancy parameter, Ri=Gr/Re2, ranging from 1 to 10. The effect of the buoyancy parameter on the nondimensional heat flux (Nusselt number) from the heated surfaces is presented and discussed in detail..*

Keywords: *mixed convection, opposed flows, unsteady convective flows, symmetrical heating*

PAC0367: INSTABILITY OF FLOW IN A CHANNEL WITH DISTRIBUTED HEATING

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Abstract. *The linear stability of channel flow between two horizontal parallel walls in the presence of distributed heating has been investigated. The case of periodic heating applied at the bottom wall has been considered in details. This heating results in the creation of zones of fluid with alternatively increased and decreased temperature. The mean flow and the linear stability equations have been solved using spectral methods. Two types of instability, i.e., vortex instability and traveling wave instability, have been examined. For the traveling wave instability, two and three dimensional oblique waves have been considered. It has been found that from among various possible forms of disturbances the streamwise vortices appear at the lowest value of the Rayleigh number if the flow Reynolds number is sufficiently small, and two-dimensional travelling-waves appear first if the flow Reynolds number is sufficiently large. The conditions when the two-dimensional waves dominate are similar to those found in the case of an isothermal flow.*

Keywords: *natural convection, buoyancy effects, flow control.*

PAC0388: TRACKING BIRTH OF VORTICES IN TWO-DIMENSIONAL FLOW

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Abstract. *In order to avoid undesired effects from vortices in many industrial processes, it is important to know the set of operating parameters at which the flow does not have recirculation. The map of these conditions in the parameter space is called vortex-free operating window. Here, we propose an efficient way to construct such*

window automatically without expensively checking every possible flow states. The proposed technique is based on tracking a path in the parameter space at which the local kinematic condition at a stagnation point for vortex birth is satisfied. This multiparameter continuation is performed by solving an augmented Navier--Stokes system. In the augmented system, the birth condition and the governing equations were represented in Galerkin's finite element context. We used the proposed method in two important coating flows with free surfaces: single-layer slot coating and forward roll coating.

Keywords: *birth of vortex, flow topology, Galerkin finite element method*

PAC0503: A MASS CONSERVATIVE APPROACH FOR A COUPLED FLOW SHALLOW WATER SYSTEM

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Abstract. *A better comprehension of coupled flows had been targeted for (1st) precisely evaluate and manage the pollution or contaminant environmental damage impacts from human discharges in fresh water disposability, (2nd) to adequately deals with the season behavior of environmental flows, and/or the invertible changing in the direction of flows, and (3rd) satisfy the required continuity between the hydraulic head and the liquid total pressure at the interface of the coupled systems of flow. The main purpose of this paper is to derive an efficient and robust computational model that answer the above objectives, leading to accurate solutions in an acceptable finite time and in an economically way. In this work a mass conservative formulation is employed to guarantee the satisfaction of incompressibility condition associated with the fluid motion. The model is full transient, considering the interactions between water free motion and porous media flows, which are not yet well understood. A stabilized Petrov-Galerkin procedure, the CAU method, is presented to accurately approximate the full transient coupled problem, when high velocity free water flows occurs. Stabilization of the pressure spurious modes is also employed. In this sense, for the water free flow, a non-hydrostatic shallow water like approach is proposed. Coupling of the free flow with porous medium flow is done by an iterative solution process, based on a Conjugate Gradient method. With this procedure we can by-pass the LBB condition using low order finite elements. Some numerical experiments are performed, to highlight the main features of the proposed model.*

Keywords: *Mass Conservation, Surface and Subsurface Flows, Finite Element, Stabilization Method*

PAC0537: MODELING OF THE STOCKPILES' FREE-SURFACE DEFORMATION DUE TO WIND EROSION

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Abstract. *Aeolian erosion of particles is very common in nature, mainly in areas where a granular loose material is exposed to the wind. Some of these occurrences take place in desert regions, but also in the vicinity of villages, as well as in stockyards, causing environmental problems and, depending on the type of the granular material released, pollution is also a concern. Among those situations, the problem of airborne particles eroded from stockpiles also gives rise to economic losses, as valuable material might be removed and transported away from the piles. For the prediction of the erosion potential, the procedure suggested by EPA is normally adopted. Its derivation was based on velocity measurements performed in the vicinity of rigid models. In this work, experimental*

results, obtained in a wind tunnel, using a sand pile, are shown, revealing that the areas where the erosion is more intense are different from those suggested in the common literature references. The deformation of the sand pile was continuously measured, using a novel experimental technique, giving more reality to the simulations. The wind flow around the conical pile is also computationally modeled, establishing a comparison between experimental and numerical results for the cases of the pile exposed or sheltered by a porous fence.

Keywords: *aeolian erosion, wind erosion, free-surface deformation, stockpiles, shelter barrier*

PAC0558: CHANGES IN COUPLED VIBRATION FREQUENCIES AND MODES OF THE WALL-CAVITY INDUCED BY STIFFNESS VARIATION IN THE STRUCTURE

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Abstract: *The problems of fluid-structure interaction are quite sensitive to certain changes in important parameters of the coupled system. This work aims at showing through a simple example the changes in natural vibration frequencies and modes for wall-cavity system, when the structural rigidity is modified by the consideration of different modules of elasticity. The numerical results are obtained using the Finite Element Method, with the help of the program ANSYS for simple triangular finite element for both the fluid (2D acoustic fluid finite element) and the solid (plane stress element). These results are compared with analytical expressions specially built for this, showing an excellent agreement between them. High values of wall elasticity modules (E), imply in coupled frequencies reproducing almost the same values of the uncoupled cavity case, but with slightly smaller magnitudes. The wall behaves as if it were rigid in this range of frequencies and modes of the system are similar to the uncoupled reservoir. However, the one-dimensional coupled modes (plane waves in y - piston mode) reproduce those which appear in the uncoupled case, but with lower frequencies.*

Keywords: *fluid-structure, finite element, vibration modes, acoustic cavities*

3. DYNAMICS

Invited Lecture

A CONTINUUM MECHANIST'S REVISIT OF MOLECULAR DYNAMICS

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Abstract. *When seen from the viewpoint of continuum physics, the intriguing novelty of the Andersen-Parrinello-Rahman MD method to simulate solid/solid phase transitions is that it mixes macroscopic information - the MD-cell deformation descriptor - with the microscopic information about the motion of the molecules within the cell, while letting the thermal fluctuations of both molecules and cell be driven by a macroscopic control, the applied stress. The success of the method depends crucially on a shrewd specification of the total kinetic energy. One purpose of my talk is to discuss a set of assumptions under which the kinetic energy takes exactly the form postulated in A-P-R MD. Another purpose is to show how one of those assumptions - namely, irrotationality of cell motion - should be incorporated in whatever metadynamics one proposes to explore the energy landscape along paths connecting local minima. A third and last purpose is to point out a connection between zero-temperature A-P-R MD and the search via the Cauchy-Born Rule for an elastic stored energy mapping consistent with a given intermolecular potential.*

Acknowledgement. This lecture was made possible through financial support from Pró-Reitoria de Pós-Graduação (PRPG/USP).

NOTES

PAC0081: TWO-STEP GENETIC ALGORITHM METHODOLOGY FOR STRUCTURAL DAMAGE DETECTION BY USING DYNAMIC PARAMETERS

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Abstract. *This paper proposes a real-coded genetic algorithm to solve the structural damage detection problem in terms of a two-step process. First, the number of probably damaged elements is reduced by using an improved energy-based damage localization methodology. Next, the damage extension in these elements is quantified by using a genetic algorithm. The objective function is formulated using natural frequencies and mode shapes changes between damaged and undamaged conditions of the structure. The advantage of this function is that it does not employ complete mode shapes avoiding the errors introduced by mode shapes expansion techniques. Some examples illustrate the good performance of the proposed methodology, considering incomplete and noisy measurements. A comparison with the application of the real-coded genetic algorithm performing damage detection in one-step process is presented.*

Keywords: *Damage detection, genetic algorithms, dynamic parameters*

PAC0085: CO-SIMULATION PROCEDURE FOR THE FINITE ELEMENT AND FLEXIBLE MULTIBODY DYNAMIC ANALYSIS

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Abstract. *The structural flexibility of the mechanical components of the pantograph constitutes an issue seldom taken into account when evaluating the quality of the pantograph-catenary contact. A flexible multibody formulation in which the elastodynamics of each body is described with respect to a floating frame of reference is used. The mean axis conditions describe the reference conditions that ensure the uniqueness of the displacement field of each flexible body. In the applications foreseen for this methodology only linear elastic deformations of the bodies take place and, consequently, the deformation field of each flexible body can be described by a summation of deformation modes. Free-free vibration modes are used in all models presented in this work. Instead of involving the modal coordinates directly in the definition of any kinematic constraint, a virtual body is rigidly attached to the node, or nodes, of the flexible body in which a joint is to be defined. Then, the kinematic constraint equations are formulated using the virtual body, which for the purpose is defined as a rigid body with a null mass, instead of the flexible coordinates. The virtual bodies are also used to apply concentrated forces on the flexible body components. In this work several pantograph system models are built and demonstrated. The flexible pantograph models are used for the study of the contact of pantograph-catenary of an high-speed train moving at its nominal exploration velocity, of approximately 300 km/h. The catenary is modeled and simulated in a linear finite element code. By using a co-simulation procedure the dynamics of the pantograph, simulated in a multibody code, is effectively coupled with that of the catenary, described in a linear finite element code. The mean contact force, its standard deviation and the number of losses of contact serves as criteria to evaluate the contact quality..*

Keywords: *Integration time step, Flexible multibody dynamics, Contact mechanics, Pantograph-catenary contact*

PAC0086: CONTACT MECHANICS IN A ROLLER CHAIN DRIVE USING A MULTIBODY APPROACH

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Abstract. *In this work, a novel multibody methodology to address the kinematic and dynamic effects of roller chain drives is presented. The chain itself is modeled as a collection of rigid bodies, connected to each other by revolute clearance joints. Each clearance revolute joint, representing the connection between pair of links, is made up of the pin link/bushing link plus the bushing link/roller pairs, if the chain is a roller chain. The clearance joint approach is further extended to the roller/sprocket teeth surface contact pairs. The internal conformal contact and the external contact between these cylindrical geometries is described using a new analytical model that puts together the precision of the contact force evaluation with the numerical efficiency required. To start the dynamic simulation and to ensure the accuracy prediction outcomes of the dynamical behavior of these nonlinear mechanical systems, a proper set of initial conditions on the positions and velocities of the chain drive components is required. Furthermore, the problem of contact initialization and its coordination with the numerical integration procedures is taken into account by controlling the time step size of the numerical integration algorithm in the vicinity of the impact. The methodologies adopted results in a computer program general enough to analyze very different chain drive systems, e.g. chain drives in industrial machines, marine engines, car engines or motorbikes. This methodology is demonstrated through its application to the study of a bicycle roller-chain drive being the methodological assumptions discussed in the process.*

Keywords: *Cylindrical contact, Hertzian contact, Polygonal effect, Time step control*

PAC0090: STABILITY ANALYSIS OF FLEXIBLE ROTORS SUPPORTED BY HYBRID PERMANENT MAGNET – GAS BEARINGS

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Abstract. *Modern turbomachinery applications require nowadays ever-growing rotational speeds and high degree of reliability. It then becomes natural to focus the attention of the research to contact-free bearings elements. Common alternatives focus on gas lubricated journal bearings or magnetic bearings. In the present paper both the technologies are combined with the aim of developing a new kind of hybrid permanent magnetic - gas bearing. This new kind of machine element is intended to exploit the benefits of the two technologies while minimizing their drawbacks. The poor start-up and low speed operation performance of the gas bearing is balanced by the properties of the passive magnetic one. At high speeds the dynamic characteristics of the gas bearing are improved by offsetting the stator ring of the permanent magnetic bearing. Furthermore this design shows a kind of redundancy, which offers soft failure properties. In the present paper, a detailed mathematical modeling of the gas bearing based on the compressible form of the Reynolds equation is presented. Perturbation theory is applied in order to identify the dynamic characteristic of the bearing. Due to the simple design of the magnetic bearings elements - being concentric rings with radial magnetic orientation - analytical expressions for the calculation of the magnetic flux density and forces are employed, opposed to the main literature trend where finite element software*

is utilized at least for the calculation of the B-field. Numerical analysis shows how the rotor equilibrium position can be made independent on the rotational speed and applied load; it becomes function of the passive magnetic bearing offset. By adjusting the offset it is possible to significantly influence the dynamic coefficients of the hybrid bearing. A multibody dynamics model of a global system comprised of rotor, two passive magnetic bearings and a gas bearing is built in order to study the lateral and axial dynamics. Campbell diagrams and stability maps are presented, showing the main advantages and drawbacks of this special kind of hybrid fluid film bearing.

Keywords: Rotodynamics, Magnetism, Reynolds Equations, Fluid Film Bearings

PAC0135: DYNAMICS OF A GUYED TOWER THROUGH A SIMPLIFIED APPROACH

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Abstract. *Guyed towers are one of the most usual structural systems employed in the wireless, microwave communication industry. In particular, lattice towers are extensively used to support antennas of different sizes, shapes, and locations. These towers are an example of structures with nonlinear behavior even under service conditions. This paper deals with the dynamic problem of cable supported structures, in particular a guyed tower. A analytical solution is proposed. The structure is composed of two main structural elements: the guys (cables) and the tower (mast). At this stage a simplified plane model of a tower and two cables is tackled. When dealing with towers, the cables are often highly pretensioned, which causes the cable sag to be small. It is quite usual to use a parabola to model this type of cables. However, it is known that this approximation could not be appropriate when the cables are inclined. On the other hand, the extensibility of the cables should be taken into account when cables are taut. In this work the equations governing the dynamics of extensible cables (both slack and taut) are stated without approximation. Then, the static problem of the extensible cable is derived from them. The constitutive equation used for the cables is consistent with the Mechanics of Continuum laws and comprises the well-known Strength of Materials relationship but, at the same time, it is capable of capturing the high sensibility of the non-linear problem. An equivalent beam-column represents the latticed tower introducing the shear to consider the truss flexibility. Additionally, the second order effect of the vertical loads on the mast is accounted for. Due to the interaction between the mast and the cables, axial and transverse displacements are coupled. A simplified approach is explored, which consists of the dynamics of the system with the quasi-static behavior of the cables. The system is finally solved with a finite element modeling. Future work regarding the construction of a reduced model employing Karhunen-Loeve bases is also briefly described.*

Keywords: *guyed, tower, beam-column, cables*

PAC0136: PROPAGATION OF MAGNETOELASTIC WAVES IN A VORTEX FIELD IN SUPERCONDUCTING STRUCTURES

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Abstract. *Magnetic field enters the type - II superconducting body along a discrete arrangement of magnetic vortex lines. In the dynamic case when the magnetic field vary in time, around each such a line a supercurrent flows. So, the vortices interact one to another with the help of the Lorentz force forming this way a new mechanical field of elastic properties. Moreover, those lines arrange themselves in a triangular or quadratic lattice. Such a set is observed if the intensity of the applied to the material magnetic field is close to its lower limiting value.The paper aims at investigating the dispersion and amplitude distributions of magnetoelastic waves propagating solely in the vortex field of the superconducting structures: halfspace, layer on halfspace and layer. Our attention have been focused on the surface waves and an influence of the layer thickness on the dispersion features and amplitudes for various wave velocities. The vortex field consists only of soft vortices (the superconducting crystal is free of lattice defects). Some anomalous properties of the vortex dynamics have been discussed..*

Keywords: *mechanics of superconductors, magnetic vortices, magnetoelastic waves*

PAC0147: DYNAMICS OF THE WHEELCHAIR AND WHEEL CONTACT

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Abstract. *Nowadays on the one hand the requirements and prospects of wheelchair users in reference to comfort, usability, security and new possibilities of assistance are increasing. On the other hands, the economical general framework generates the need to reduce the development and production costs of wheelchairs. One resolution to this conflicting demands the usage of state of the art simulation tools in the area of dynamic co-simulation for vehicles. In this paper the modeling aspects and the results of the wheelchair dynamic behavior are presented. One important part for the dynamic behavior of wheelchairs is the tires and the road surface and the correct physical modeling of their parameters, consequently different tire models are used and discussed in this paper. The inputs of these models are normally the normal load, the sideslip angle and the longitudinal slip, and the outputs are shear force, aligning moment, and overturning moment. These models are implemented in simulation programs for multi body systems and the effect of the contact between the tires and the road were analyzed and compared for different combinations of these parts. With the proved models of the dynamical behavior in the next step it is possible to simulate different control systems to use in automatic or semi-automatic wheelchair. Also the influence of the wheelchair movements on the user and the implemented sensors can be analyzed in a more realistic way by using co-simulation possibilities. So the use of combined simulation models offer a effective tool for shorter design and testing time periods for new developments in the wheelchair area. The result of this work has extreme importance to the development of the new designs and parts for wheelchairs and for control system implemented in wheelchair.*

Keywords: *Wheelchair, dynamic, tire, behavior, simulation*

PAC0163: TRANSVERSE VIBRATIONS OF RECTANGULAR PLATES WITH ELASTICALLY ATTACHED MASSES AT AN ARBITRARY POSITION

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Abstract. *The present study is concerned with the determination of the natural frequencies and mode shapes of rectangular plates carrying an elastically attached mass (three-degree-of-freedom spring-mass system) under the variation of its parameters (stiffness, mass, moment of inertia, location). An analytical approach based on Lagrange multipliers as well as a finite element formulation are employed and compared. Numerically reliable results are presented for the first time illustrating the convenience of using the present analytical method which requires only the solution of a linear eigenvalue problem. The results obtained through the variation of the mass, stiffness and moment of inertia of the three-degree-of-freedom spring-mass system (subsystem) can be understood under Rayleigh's statement. The analysis of the influence of different locations demonstrates that the increase or decrease of the frequency values as we approach or move the subsystem away from the center of the plate depends on mode number. When the subsystem is located at the center of the plate, the ``new'' modes result in a combination of the subsystem's modes (rotation about x-axis, y-axis, translation) and the bare plate's modes that posses the same symmetry. This situation no longer exists as we moved the subsystem away from the center of the plate since different bare plate's modes enable distinct motions of the subsystem contributing differently to the ``new'' modes as its location is modified.*

Keywords: *three-degree-of-freedom spring-mass system, plate, natural frequencies and mode shapes, linear eigenvalue problem*

PAC0173: NUMERICAL AND EXPERIMENTAL STUDY OF POWERTRAINS SUBJECTED TO HIGH TORQUE FLUCTUATION

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Abstract. *. The powertrain of vehicles is a quite complex system and it requires special attention of the engineers during its design. One of the reasons for this complexity is that this system is supposed to operate in a wide range of conditions, from idle to transient conditions in which there is high torque fluctuation in a short period of time. This torque fluctuation, which may be considered a critical situation, happens when the driver requires the engine to deliver high torque, and suddenly ceases the engine charge. This sequence of events, when applied to mistuned*

systems, may lead to low frequency longitudinal vibrations in the vehicle frame, and possibly clank noise, which causes uncomfortable behavior to the driver and passengers. According to the literature and previous studies, this phenomenon is not directly related to a vibration mode of the system. Instead, the behavior of the system during this transient condition is mainly affected by the nonlinear characteristics of the clutch and the clearances in the transmission's gears. Such phenomenon is known as Surging. In order to study this phenomenon, a nonlinear mathematical model for the system is proposed in this paper. The results of several numerical simulations are shown. Frequency and order analysis are also provided, leading to a better understanding of the system dynamic behavior. Finally, experimental data are analyzed and the results are compared with the simulated ones. Based on the experimental and numerical results, some conclusions are made about the characteristics of the surging phenomenon and about the main parameters that affect its appearance

Keywords: *Surging phenomenon, tip-in/tip-out, drive train vibration, numerical simulation*

PAC0182: ASYMPTOTIC METHODS IN SINGULARLY PERTURBED MECHANICAL SYSTEMS DYNAMICS

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Abstract. *One of the central problems in solving of concrete engineering tasks is a problem of modelling. The description of complex engineering objects dynamics on the language of the mathematical model is inevitably accompanied be series of additional questions of methodological and methodical nature (with using both formalized procedures and non-formalized ones of heuristic character). Therefore it is necessary the careful development of such model, that will be corresponding both to our knowledge level and to available computing possibilities. Here the main aim is to work out the general approach applicable to different mechanical systems for solving problems of modelling. Herewith it is necessary the generalizations, that will be reflecting the most important general lines of the examined object or phenomena and – will be helping for constructing the adequate mathematical model, correct in dynamics problems. The developed approach is based on the combination of the asymptotic methods with methods of the stability theory of A.M.Lyapunov-N.G.Chetayev, and with extension of classical statements (including A.M.Lyapunov's reduction principle, N. G. Chetayev's stability postulate, N.N.Moiseev's minimal models, …) for important applications to problems of engineering practice. In this research the effective approach is established, that is considering the problem of modelling in Mechanics from united point (as s-stability problem). Besides the different mechanical systems are considered with unified view as objects of singularly perturbed class; the procedures of division of the motion of such systems on different-frequency components are worked out. And the approximate models of lower order are constructed on regular scheme as simplified systems, that are describing the motions of selected class (slow s-motion). The methodology of stability theory in combination with asymptotic approach is very perspective, both for applied problems and in general gnosiological aspect. The developed method, based on Lyapunov's theory, allows to consider the various mechanical systems with the unified positions; to come up to the idealization problem in mechanics (with the designing of idealized models by strict mathematical way; with the substantiation of validity of these models; with the receiving of correctness conditions in dynamics). This technique gives the regular manners for the decomposition of system. It allows to investigate the complex systems by analytical (and computer-analytical) methods in problems of analysis and synthesis.*

Keywords: *asymptotic models, mechanics, stability, singularity*

PAC0203: ANALYSIS OF IN-PLANE WAVE PROPAGATION IN THIN PLATES BY ENERGY SPECTRAL ELEMENT METHOD

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Abstract. *The propagative approach proposed in this study is a simple modeling of energy vibrational model of plate. Mechanical energy equations analogous to the thermal energy equations are derived to examine the propagation of longitudinal waves and in-plane shear waves in thin plates. The derived energy equations are expressed with the time- and space-averaged energy density, and can be used for the prediction of in-plane structural vibration energy at middle- and high-frequency ranges. The formulation is based on the Energy Spectral Element Method (ESEM) which is a matricial methodology to solve the approximated analytical energy equation of Energy Flow Analysis (EFA). Simulated examples are performed and compared with other energy solutions from the Energy Finite Element Method (EFEM) and Modal Superposition Method (MSM) .*

Keywords: *wave propagation, energy flow analysis, energy spectral element method, energy finite element method, plate*

PAC0210: ENERGY SPECTRAL ELEMENT METHOD FOR ACOUSTIC WAVEGUIDES

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Abstract. *Sound field behavior in an acoustic enclosure is an important part of the design of transportation vehicle passenger cabin, concert halls, conference rooms, and etc. Different analysis methods are available to design engineers, which presents its strengths and weaknesses. Enclosures at low frequency band and negligible absorption at the walls, may be modeled by Modal Analysis or Finite Element Method. However, as the frequency band increases, both methods becomes computationally intensive and SEA or Sabine model can be an efficient approach. Nevertheless, these methods do not account for any spatial variation within the enclosure. The solution of approximate Energy Flow Analysis (EFA) for acoustic enclosure can be done analytically. In this paper an alternative approach, called the Energy Spectral Element Method (ESEM), is formulated and applied to predict the spatial distribution of the energy flow and density of acoustic waveguides at high frequencies. ESEM is a matrix metodology based on the EFA to solve acoustic and structural vibration problems. In this work, numerical models involving simple and coupled one-dimensional acoustic waveguides are generated by ESEM, and the results are compared with energy densities computed from the pressure fields predicted by the Spectral Element Method (SEM).*

Keywords: *Energy Flow Analysis, Waveguides, Energy Spectral Element Method, Acoustic Enclosure*

PAC0297: COROTATIONAL NONLINEAR DYNAMIC ANALYSIS OF LAMINATED COMPOSITE SHELL STRUCTURES

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Abstract. *The dynamic analysis of laminated composite shell structures is performed using a simple displacementbased. 18-degree-of-freedom triangular flat shell element, obtained by the superposition of a membrane element and a plate element. The membrane element is based on the assumed natural deviatoric strain formulation (ANDES), having corner drilling degrees of freedom and optimal in-plane bending response. The plate element employs the Timoshenko's laminated composite beam function to define the deflections and rotations on the element boundaries. This formulation provides first-order shear flexibility to the element and naturally avoids shear-locking problems as thin shells are analyzed. The geometrically nonlinear behavior of the structures is achieved by the element independent corotational formulation (EICR) together with a consistent treatment of finite rotations. An energy conserving procedure for the time-integration of the nonlinear dynamic equations is also included. Finally, two examples are presented to show that the algorithm is able to solve highly nonlinear dynamic problems.*

Keywords: *Laminated composite materials, Shell structures, Nonlinear dynamics*

PAC0307: AEROSERVOELASTIC ANALYSIS OF LARGE HORIZONTAL-AXIS WIND TURBINES: A NEW METHODOLOGY

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Abstract. *The current trend in wind turbine development shows a vast increase in turbine dimensions. Rotor blade manufacturers are aware of the fact that scaling-up can introduce aeroservoelastic stability problems. The present effort is directed towards better understanding of the unsteady and nonlinear aeroservoelastic characteristics of large-scale horizontal-axis wind turbines. This understanding is to be realized by developing comprehensive computational tools, and the understanding gained is to be used for predicting the uncontrolled and controlled responses of large horizontal-axis wind turbines. The primary components of the computational analysis are the following: a model of the flow field; a model of the structure; a model of the control system; a scheme for inter-model communication; and a method to numerically integrate all of the governing equations simultaneously and interactively in the time domain. Since the aim is to study general unsteady motions and also explore nonlinear phenomena, it is proposed to carry out the simulations in the time-domain. The simulation framework is highly modular, so that individual components can be changed/replaced without modifying the overall organization.*

Keywords: *Horizontal-axis wind turbines, Nonlinear aeroservoelasticity, Dynamical systems*

PAC0312: PROPAGATION OF LASER EXCITED ELASTIC WAVE IN A COATED CYLINDER

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Abstract. *The study of the elastic wave propagation in a coated cylinder is important for the non-destructive evaluation of the coating properties for surface treatment engineering. In this work, a physical model and corresponding theoretical solution are proposed to describe the circumferential propagation of elastic waves, which are excited in a homogeneous, isotropic, and coated cylinder by a laser line source. The modeling is compared to author's previous model on the cylinder without coating. The agreement in dispersion spectrum and transient displacement indicates the effectiveness of the modeling. Numerical results are further obtained for aluminum rod coated with copper and vise versa. The dispersions of surface waves are different. The high frequency component travels faster for hard coatings with velocities faster than that of the substrate, and it is vise versa for soft coatings with velocities slower than that of the substrate.*

Keywords: *Coated cylinder, Elastic wave, Laser ultrasonic technique, Cylindrical surface wave*

PAC0328: DYNAMICS OF A ROLLING TIRE

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Abstract. *The dynamics of a rolling tire are studied in order to estimate the vibration transmitted to the structure of the vehicle, and the noise produced. The conventional model of a tire, adopted in previous studies, considered the tire a ring or shell rotating about a fixed center. In the present model, the tire is also modeled as a ring, but one whose center is not fixed and is free to move. Also it is assumed that there is one point on the tire that is always in contact with the ground. These assumptions make it possible to consider the influence of the inertia of translational motion of the tire body. In the present study, the large deformations due to the stationary loads such as the weight of the car or the passengers are neglected in order to highlight the effect of rotational speed and tire-road interaction on the tire vibrations. Equations of motion, written in polar coordinates system, are obtained by using Hamilton's principle. Numerical results are obtained by the application of the Galerkin Method. The results show that the natural frequencies of the tire obtained by the proposed method are significantly different from those obtained by the conventional method. Also it is observed that the so-called veering in the conventional model does not occur in the proposed model. Moreover, the differences between the lower natural frequencies obtained by using the proposed method and those obtained by using the conventional method are significant. By contrast, the effect of the translational motion of the tire on higher frequencies is negligible.*

Keywords: *Tire, Ring, In-plane Vibration, Galerkin Method*

PAC0366: REVISED ASSUMPTIONS FOR MONITORING AND CONTROL OF 3D LATTICE STRUCTURES

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Abstract. *A successful structural monitoring and control systems should be able to discern critical events, scan frequencies and dynamic ranges. This, in turn, requires that models, applied in these systems, are as close as possible to real structural behavior. Many structures, among them, electricity transmission towers, windmills, radio and TV masts, bridges and parabolic dishes, concentrating solar energy, are build as trusses. All of them are subjected dynamic loadings coming, mostly from wind gusts, water waves and thermal activity of sun. The paper is revising assumptions, commonly made for trusses. The main assumption made is that systems of rods are pin joint. Such structures don't exist, in real engineering design. All, above, mentioned structures are made with rigid or flexible joints. The "pin joint" assumption was made for static analyses. It stated that if joint displacements caused by rod bending can be neglected, comparing with displacements caused by rod elongations, the structural system can be considered as pin joint. As it is commonly known, such cases occur when some necessary conditions joining number of joints and hinges are fulfilled. The "pin joint", static assumptions has been, without any formal justification, taken for granted in dynamics. Simple examples presented in the paper show that "pin joint" assumption can lead to considerable errors. The paper is illustrated with two numerical examples (simple 2 bar structure and 25 bar transmission tower). Presented examples allowing to compare results of different assumptions applied for structural elements connections.*

Keywords: *lattice structures, monitoring, control, structural dynamics*

PAC0372: APPLIED STATIC CONVERTER TO SYSTEMS PIEZOELECTRIC ACTUATORS FOR NEUTRALIZATION OF MECHANICAL VIBRATIONS

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Abstract. *Piezoelectric actuators are widely used in smart structural systems to actively vibration control and noise, and to enhance performance. Because of the highly capacitive nature of these actuators, special power amplifiers, capable of delivering large currents, are required to drive these systems. In this paper, a study to reducing the reactive energy that happen in the system. This is accomplished by incorporating the actuator with its capacitive characteristic circuit. Non-ideal circuit performance is addressed, along with theoretical limits to possible power savings and practical difficulties in achieving them. The proposed converter introduces a energy to correct the different phase between current and voltage that is given to PZT actuator. This proposed process is optimized because with the introduction of the reactives energies to the process the characteristic of the circuit which PZT this inserted raisin to have a characteristic resistive. This way the change of energies had not existed reactivate among elements that would be changing energy with the actuator that possesses characteristic electric capacitive.*

Keywords: *PZT actuator, actively vibration control*

PAC0386: DYNAMICAL ANALYSIS OF LANDING GEAR FOR CRITICAL WORK CONDITIONS

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Abstract. *The research on the most effective methods of aircrafts' landing gears design as well as the evaluation of the gear's condition during utilization period and possibilities of extending its durability are the subject of numerous studies, including the ones by leading worldwide aviation companies and national scientific centers. It is indicated in these studies that numerical analysis of the strength of the construction elements of the examined aircraft's part (beside experimental research) is a necessary stage of proper methodology of aviation research, in particular in programming and reliability evaluation and development of methods of increasing durability in case of solutions already used in practice. Majority of the fatigue numerical analysis and prediction of the landing gear's lifetime is limited to the linear analysis and the local phenomena appearing around a failure. Such approach was developed at the first stage of the work. The influence of a failure on the complete landing gear system is subject of our consideration. Chosen experimental tests were performed at the drop stand. Appearing forces in the landing gear parts, accelerations and displacements were recorded during stand tests. Service fracture in the top leg of landing gear was appeared in the fatigue tests and is the main aim of this study. This fracture was caused by technological factors (disturbances). In the numerical part of these investigations various 3D models of the complex landing gear with different cracks lengths were developed and computed for the dynamic FE analysis using explicit integration scheme. Achieved experimental and numerical results of transport airplane's landing gear with existing cracks are discussed in this paper.*

Keywords: *landing gear, crack, experimental and numerical studies*

PAC0399: ATYPICAL MODES OF PERIODIC RETICULATED BEAMS

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Abstract. *This paper focuses on the dynamic behaviour of periodic reticulated beams. The homogenization method of periodic discrete media is applied to identify the macro-behaviour at the leading order. With a systematic use of scaling, the analysis is performed on the archetypical case of symmetric unbraced framed cells. Such cells can present a high contrast between shear and compression deformability, conversely to "massive" media. This opens the possibility of enriched local kinematics involving phenomena of global rotation, inner deformation or inner resonance, according to studied configuration and frequency range.As for transverse vibrations, the possible beam-like behaviors are established by varying the properties of the basic frame elements. The study emphases the existence of two frequencies ranges. The lower frequency range is reached when horizontal elastic forces balance the inertia induced by the lateral translation. A Generic atypical beam, governed by a differential equation of sixth degree includes the mechanisms of shear, global and inner bending. Three intrinsic cell parameters are sufficient to define the macro behavior and provide simple criteria to identify the relevant model for real structures. The higher frequency range is reached when momentum elastic forces balance the inertia induced by the rotation. In this case the translational motion vanishes and specific unusual gyration mode appears. According to the cell properties internal resonance may also be involved and leads to abnormal dynamics. As for longitudinal vibrations, the usual compression beam behaviour is recovered after up-scaling, except when the eigenfrequencies of the structure in compression and of the elements in bending are of the same order. This internal resonance effect leads to an effective mass function of frequency and to memory effect at the scale of the structure. In addition, cut-off frequencies related to the local bending modes are obtained.*

Keywords: *generalized beams, reticulated beams, inner resonance , gyration modes, homogenization*

PAC0409: DYNAMIC MODELING OF A FOUR ROTOR FLYING VEHICLE

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Abstract. *The use of unmanned vehicles is an area of interest for researchers due to the broad number of applications and tasks they can perform. These vehicles may be classified depending on the medium for which they were fabricated, i.e. aquatic, terrestrial or aerial vehicles. This work shows the dynamic study and modeling of one type of aerial unmanned vehicle which has proven to be very useful within academic and industrially controlled envioremnets. The vehicle which will be studied is the quad-rotor helicopter, which broadly consists of a central body formed by a box with the batteries and on-board computers for control and avionic functions. The body is joined by four beams which have a motor with two rotating wings at the far extreme of each of them. This gives sustentation to the vehicle and gives the possibility of controlling the orientation and translation of the system. By controlling the relative velocities of the four motors it is possible to obtain distintct operation states of the vehicle. (i) It is possible to maintain the vehicle suspended on the air at a constant or variable height over the floor., (ii) Using differential velocities on the rotors, the vehicle can displace itself in both directions on a horizontal plane, making it feasible to move the vehicle with a controlled behavior in the three directions, x-y-z .that lie within the vehicle´s flight envelope. Although several theroretical papers can give account of the quad-rotor´s dynamic model, many of these attmetps make several assumptions that are only true for small indoor type vehicles. For this reason, the first stage of this work is to model physically the dynamics of the vehicle as a totally non-linear system, where the complex dynamics of the rotating wings are taken into account. This is followed by a linearization and and comparison between the "real" and linear systems.*

Keywords: *quadrotor, model, lineal system, non linear system*

PAC0412: PREDICTED SEISMIC RESPONSE, BASED ON MEASUREMENTS, OF A BUILDING EQUIPPED WITH A BASE CONTROL SYSTEM

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Abstract. *Two instrumented buildings, which are practically identical 3-story reinforced concrete structures, are studied. One building is constructed with a traditional fixed-base foundation and the other with a Base Control System (BCS). The BCS consists of a combination of helicoidal springs and viscous dampers. On August 5, 2006, the accelerometers recorded the response due a 5.7 magnitude earthquake that shook the buildings. Finite element (FE) models were developed, calibrated and used to carry out a comprehensive comparison of the seismic response of the two buildings and to evaluate the performance of the isolation system. In the analysis, the stiffness and damping coefficient of the devices are regarded as constants, although the dynamic properties of the protection devices weakly depend on the displacements and frequencies. These approximations allow using commercial finite element software to calculate the response due to the recorded seismic excitation, which was numerically obtained integrating in time domain. The response time histories provided by the calibrated FE models of both buildings were compared. They included the acceleration at different levels, the base displacements, the axial forces and*

bending moments on different columns, the base shear and the dissipated energy. The results showed that the BCS was able to reduce the accelerations and internal forces in the isolated building to less than one third of the values corresponding to the rigid base structure. The strategy of including some vertical flexibility and vertical damping in the protection devices and admitting some small rocking motion of the building was also validated, based on the fact that the vertical movements contributed to dissipate 20% of the total seismic energy.

Keywords: *Base isolation, Base Control System, helical springs, instrumented structures, viscous dampers*

PAC0421: PROGRESSIVE DYNAMIC ANALYSIS OF SERIAL ROBOTS BASED ON SCREW THEORY: AN EXTENSION TO THE THEORY

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Abstract. *Theory of screws applications are based on the combined representation of angular and linear velocity or, similarly, force and moment, as one element of a six-dimensional projective vector space. In a variety of areas of robotics, methods and formalisms based on screw theory have shown advantages over other techniques and have led to significant advances. These methods include the development of fast and efficient dynamics algorithms, discoveries in the nature of robot compliance and mechanism singularity, and the invention of numerous parallel mechanisms. One significant advantage of using screw theory is the possibility to reuse the partial model of the robot. It is possible to model two or more pieces of the robot independently and then combining these pieces forming a complete model. The standard approach (D-H) requires remodeling the whole manipulator. This paper presents the development of theory based on Lagrangian formalism and screw theory. This new method is very interesting in cases when the payload is not completely rigid and has some DoF by itself. So, the dynamic model of the whole system changes during the task execution. Examples of this kind of application are found in liquid transportation tasks where it is possible to find a payload with passive joints used to allow the correct orientation of the recipient. In these cases,when the manipulator is attached to the payload a least one new link is added to the kinematic chain. Details of the impact in the dynamic model produced by the new link are presented with emphasis on the fact that the dynamic model doesn't need to be rebuilt from scratch. The authors believe this approach consists a major advance with important applications in reconfigurable robots.*

Keywords: *dynamics; robotics, screw theory, robot manipulator dynamics*

PAC0444: A STUDY OF SELF-HEATING EFFECTS IN VISCOELASTIC DAMPING DEVICES

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Abstract. *It is well-known that applying cyclic loading on a structure results in vibrations whose level depends both on the excitation and the structure's mechanical properties. In this context, passive structural damping using viscoelastic polymers and elastomers has lead to various studies and practical applications over the last decades. The energy dissipated by the viscoelastic dampers is converted into a small amount of heat. When subjected to cyclic loading, this heat may cause significant temperature rise. Taking into account the fact that the components of the complex modulus (respectively known as storage and loss moduli) are highly temperature-dependent, the evolution of the temperature field can result in two distinct phenomena, namely: a) the thermal equilibrium, which occurs after a large number of cycles if the influence of the reached temperature field on the mechanical properties is small enough. In this configuration, since the pseudo-equilibrium is reached, the temperature gradually increases at a very small rate until the load is removed b) the "thermal runaway" described by Lesieutre and Govindswamy happens when the heat generation is large enough to cause chemical reactions which makes the material less rigid and may result into irreversible degradation of the structure. The main objective of this paper is to present the results obtained with a finite-element tool based on a commercial software in order to calculate the transient temperature distribution into a tridimensionnal viscoelastic structure subjected to a harmonic loading. This procedure involves a coupling between thermal and structural fields since the heat generation calculations at every time step is based on the strain energy values in the viscoelastic parts, determined by harmonic damped structural analyses. Moreover, since the temperature distribution is non-uniform and time-dependent, it is necessary to update the structural stiffness and damping matrices and thus perform a new harmonic analysis. This step is repeated at various stages of the global analysis. After giving a general overview of the theoretical aspects, the detailed procedure is discussed in terms of physical and computational aspects. Afterwards, the FE modelling strategy applied to a 3D structure is presented. Finally, the results are discussed and compared to those obtained from previous simulations.*

Keywords: *dynamics, viscoelastic damping, finite element, thermoviscoelasticity*

PAC0455: DYNAMIC BEHAVIOUR OF HYDROGENERATORS DURING MECHANICAL TRANSIENTS

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Abstract. *This work presents the first results of dynamic behaviour analyses of large hydrogenerators undergoing mechanical transients. It is focused, in this specific case, on dynamic forces acting upon the guide bearings during machine startups. The analysis of this behaviour was based on processing the dynamic vibration and pressure signals recorded during the commissioning of unit 18A of the Itaipu Hydroelectric Power Plant. It was also founded upon numerical simulations made with simplified mathematical analytical models, using scientific free software. The work demonstrated that an adequate knowledge of the dynamic behaviour of the hydrogenerator under transient regime is of significant importance to the evaluation of the condition of the machine being monitored.*

Keywords: *Hydrogenerators, Dynamic Behaviour, Transients, Vibrations, Pressure Fluctuations*

PAC0466: OPTIMAL CONCEPTION OF THE ISOLATORS SYSTEM FOR A POWER GENERATOR

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Abstract. *The design of the supporting structure for a power generator group, under predefined data relative to loadings and frequency of operation of the group to be protected, involves the definition of a specific system of vibration isolators for the supporting structure. The objective of this work is the computational development of an optimal system of vibration isolators for the group constituted by the motor, the generator and the supporting structure. The methodology of the work involves the modeling of the group as a rigid body and placed over isolators, which are selected with an objective function oriented to minimize the maximum natural frequency of the group in order to be far away from the excitement frequency. Some results of this development include the optimal definition of the stiffness and damping parameters of the vibration isolators for safe operation of the group.*

Keywords: *vibration isolator, motor generator, nonlinear optimization*

PAC0468: VEHICLE DYNAMICS APPLIED IN FREIGHT CARS

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Abstract. *This study presents an analysis of impact between two railway cars. The dynamic analysis considers a constant force type, dissipative, shock absorber which correlates the effect of the coupling force, lading force, cushion travel, closure time, impact speed, and friction. In this work the maximum end-wall force on lading can be determined which is very usefull to prevent the damage in the products transportation. The relation of the end-wall force on lading and the cushion travel is an important subject of study for companies interested in better characteristics of the coupler, wall vagon and the velocity of operation in yards and railroads.*

Keywords: *Freight car, impact, end-wall force, coupler*

PAC0495: PASSIVE VIBRATION CONTROL USING OPTIMAL DISTRIBUTED TUNED MASS DAMPERS

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Abstract. *The Distributed Tuned Mass Damper (DTMD) technology, which is one of the modifications of the classical Tuned Mass Damper (TMD) technique, is defined as the multiple TMD design based on one mode of the primary structures. The modeling procedure for this kind of problem is similar to that for TMD design, especially for discrete*

(or modeled as discrete) primary structures, such as the building-type structures. Therefore, the challenge work in this area is to attain the best vibration suppression performance through an optimally designed DTMD system. From the point of optimization, basically, two typical approaches have been utilized to design the DTMD system. The first one is to directly obtain the transfer function and then define the variance or the Dynamic Magnification Factors (DMF) as objective functions, which was utilized by many researchers. In the other methodology, the transfer function is expressed as a dynamic model with an optimal H2 controller under predefined form. Different kinds of optimization techniques, such as the Min-Max method, Steepest Decent Algorithm method, Sequential Quadratic Programming (SQP), and also the global optimization methods, have been adopted by researchers to find the optimum parameters of the DTMD system. In this study, a new optimal DTMD design method will be presented, in which the optimization objective function and method will be established based on the Linear Quadratic Controller design method. The presented method provides a simple and straight-forward way to design the DTMD system. The numerical example will be presented to illustrate the vibration suppression performance of the optimally designed DTMD system.

Keywords: *TMD, DTMD, Passive Vibration Control, Optimization, Linear Quadratic Controller*

PAC0512: THEORETICAL AND EXPERIMENTAL INVESTIGATIONS OF OSCILLATORY ROLLING MOTION OF A ROD BUNDLE INSIDE A TUBE

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Abstract. *This paper presents a study of the fundamental mode of the a rod bundle structure confined in a tube through a comprehensive numerical model and a experimental setup. The fundamental mode is found to be a rolling mode that has a relatively low frequency.The floating frame formulation is used to model the elasto-rigid body motion of the bundle and the results show that the rigid body motion, the nonlinear constraints and the gravity have a significant influence on the fundamental rolling frequency.*

Keywords: *rod bundle, rolling motion, floating frame, finite element*

PAC0513: THE CLOSE APPROACH BETWEEN A PLANET AND A CLOUD OF PARTICLES

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Abstract. *The idea of the present paper is to study the swing-by maneuver between one of the planets of the Solar System and a cloud of particles. This is what happens when a fragmented comet crosses the orbit of a planet like Jupiter, Saturn, etc. We used the dynamical system that is formed by two main bodies (the Sun and one of the planets of the Solar System) and we assumed that they are in circular orbits around their center of mass and a cloud of particles is moving under the gravitational attraction of these two primaries. The motion is assumed to be planar for all the particles and the dynamics given by the "patched-conic" approximation is used, which means that a series of two-body problems are used to generate analytical equations that describe the problem. The main obejctive is to understand the change of the orbit of this cloud of particles after the close approach with the planet. It is assumed that all the particles that belong to the cloud have semi-major axis a ± da and eccentricity e ± de before the close approach with the planet. It is desired to known those values after the close approach. In particular, we will study the effects of the periapsis distance in this maneuver.*

Keywords: *Astrodynamics, Orbital maneuvers, Swing-By, Gravity assisted maneuvers, Orbital motion*

PAC0547: SIMPLIFIED APPROACH FOR THE ANALYSIS OF A VISCOELASTIC PLATE IMPACT RESPONSE USING FRACTIONAL DERIVATIVE CONSTITUTIVE EQUATIONS

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Abstract. The impact of a rigid body upon an infinite isotropic plate is investigated for the case when the viscoelastic features of the plate represent themselves only in the place of contact and are governed by the standard linear solid model with fractional derivatives. Thus, the problem concerns the shock interaction of the dropping mass and the target, wherein instead of the Hertz contact law the generalized fractional-derivative standard linear solid law is employed as a law of interaction. The part of the plate beyond the contact domain is assumed to be elastic, and its behavior is described by the equations of motion which take rotary inertia and shear deformations into account. It is assumed that transient waves generate in the plate at the moment of impact, the influence of which on the contact domain is considered using the theory of discontinuities. To determine the desired values behind the transverse shear wave front, one-term ray expansions are used, as well as the equations of motion of the falling mass and the contact region. As a result, we are led to a set of two linear differential equations, the solution of which is found analytically by the Euler substitution method, what allows us to obtain the time-dependence of the contact force. Numerical analysis shows that maximum of the contact force increases tending to the maximal contact force at the fractional parameter equal to unity.

Keywords: *impact, shock interaction, fractional derivative viscoelasticity, ray method*

PAC0548: THE RAY METHOD FOR ANALYZING THE NORMAL IMPACT OF AN ELASTIC ROD UPON THE LATERAL SURFACE OF AN ELASTIC THIN-WALLED BEAM OF OPEN SECTION

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Abstract. *The problem on the normal impact of an elastic rod with a rounded end upon an elastic Timoshenko arbitrary cross section thin-walled beam of open section is considered. The process of impact is accompanied by the dynamic flexure and torsion of the beam, resulting in the propagation of plane flexural-warping and torsional-shear waves of strong discontinuity along the beam axis. Behind the wave fronts upto the boundaries of the contact region (the beam part with the contact spot), the solution is constructed in terms of one-term ray expansions. During the impact the rod moves under the action of the contact force which is determined due to the Hertz's theory, while the contact region moves under the attraction of the contact force, as well as the twisting and bending-torsional moments and transverse forces, which are applied to the lateral surfaces of the contact region. The procedure proposed allows one to obtain rather simple relationship for estimating the maximal magnitude of the contact force, which can be very useful in engineering applications.*

Keywords: *ray method, thin-walled beam of open section, transient waves, normal impact*

PAC0553: INFLUENCE OF IMPERFECT BONDING ON INTERFACE OF MAGNETO-ELECTRO-ELASTIC HETEROSTRUCTURES: SH WAVES DISPERSION RELATIONS

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Abstract. *In the present work the dispersion relations of stationary SH waves in a heterostructure with magneto-electro-elastic properties under imperfect mechanical bonding on the interface have been obtained. The calculations of the dispersion relations were based on the consideration of a symmetric system and results are presented by considering only the symmetric modes of the dispersion curves. Different limit cases are presented. The first dispersion branch for the symmetric modes is presented for five different values of a parameter used in the modeling of the imperfect bonding.*

Keywords: *Piezoelectricity, Piezomagnetism, Magneto-electro-elasticity, Dispersion curve, Wave propagation*

PAC0557: ANALYTICAL PROCEDURE FOR FREE VIBRATION ANALYSIS OF BEAM-CAVITY SYSTEMS

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Abstract. *This paper presents an analytical procedure for solution of the dynamic interaction problem between a simple beam and a rectangular cavity containing an acoustic fluid. Initially an analytical expression for the fluid domain with a harmonic vibrating boundary is established, based on the separation of variables technique. This solution provides the dynamic pressure field, which is dependent of two unknowns: the coupled system frequency and the vibrating boundary deformed shape. The dynamic equilibrium equation of the coupled structure is defined using the virtual work principle, with the dynamic pressures acting as external forces. Solution of this expression is achieved upon the definition of an imposed deformation function for the structure, providing the coupled frequencies for a given mode shape. These results can be readily applied in the analytical expression for the fluid domain, providing the correspondent cavity modes. Comparisons of this procedure with Finite Element Method models indicate a good agreement between both solutions. Some advantages of this technique include the possibility of parametric analysis and the validation of numerical solutions.*

Keywords: *analytical methods, fluid-structure, structural dynamics, free vibration, acoustic cavities*

4. CONTROLS

NOTES

PAC0078: DIGITAL CONTROL TEMPERATURE OF A HEATING DEVICE - CONSTRUCTION OF A KIT DIDACTIC OF LOW COST FOR THE TEACHING OF DIGITAL CONTROL IN COURSES OF MECHANICAL ENGINEERING

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Abstract. *The heating devices are of great applicability in industrial processes such as chemical and metallurgical types and also in systems for thermal treatment of metal and ceramic materials. In these processes the accurate control of periodic temperature patterns is crucial. Nowadays there are several techniques of control, among them the digital control. Digital controllers are used in several applications in order to maximize performance, or minimizing energy consumption. When they are implemented by computer, great versatility and flexibility are shown as their parameters can be adjusted according to the changes in the processes. The main goal of this work is the design of a digital system to control the temperature of a heating device that follows temperature references of step or ramp type. The constructive aspects of the heating device prototype, developed specifically for this study, the modeling of the system, the electronic system for monitoring temperature and the power circuit, to supply the heating device, are shown. The experimental results are compared with numerical simulations.*

Keywords: *Digital control, Automation and control, Heating systems*

PAC0149: SEMI-AUTOMATED OBSERVER-BASED CONTROLLER DESIGN

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Abstract. *Controller synthesis for aerospace applications is typically complex, also said multi-objective. It is not unusual to combine different design techniques, where each one must be tuned appropriately in order to comply with the required specifications. Furthermore, if one considers gain scheduling, then the same set of procedures must be repeated for each single operating point, with additional constraints on controller interpolation. The resulting complexity can even increase once that robustness and fault tolerance are mostly necessary, which confirms the challenging nature of the entire conception and development of such systems. By the other side, the combination of observer-based approaches with intelligent computation provides some answers to this difficult task, as it will be shown in this work. Firstly, a robust controller is automatically designed by computational intelligence, with a genetic algorithm that searches a parameter space of considerable dimensions, according to the ratings given by a fuzzy system, where the specifications are stored. Subsequently, the controller found undergoes an internal reorganization following its observer-based form, where the state variables are meaningful (= physical) estimates. A faulty operation in a launcher attitude control system demonstrates the appeal of the proposed techniques.*

Keywords: *Observer-based, controller, computational intelligence, design*

PAC0336: VIBRATION CONTROL OF STRUCTURES USING MAGNETORHEOLOGICAL DAMPERS

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Abstract. *Civil engineering structures used to be designed as structures incapable of adapting to the dynamics of an environment under constant change. However, recently, a number of factors emerged that show the need of considering them with some degree of adaptability. These factors include the increasing structural flexibility due to the tendency of building taller and longer structures which need to be protected against environmental loads. In this context, passive and active control systems and combinations of them like hybrid and semi-active devices have received considerable attention over the last years as a way of structural protection. Particularly, semi-active control devices do not add mechanical energy to the structure directly therefore stability is guaranteed. They can be viewed as controllable passive devices because their damping and/or stiffness properties can be controlled. Moreover, they offer the adaptability of active control devices without demanding large power sources. In fact, many of them can operate on battery power which is crucial during seismic events when the main power source of energy can fail. Thus, semi-active control devices combine the best characteristics of both active and passive control systems. Magnetorheological (MR) dampers are a type of semi-active device that use controllable fluids whose properties can change when exposed to a magnetic field. In the present work, MR dampers are used to control the response of a two-storey three-dimensional building model subjected to seismic load. A type of clipped-optimal control algorithm based on the Linear Quadratic Regulator (LQR) is used to the semi-active control design. A parametric study is conducted to evaluate the influence of the weighting matrices on the semi-active control performance. MR dampers are employed under semi-active and passive control configurations. In most real problems, all the state variables are not available for measurement which leads to the necessity of estimating those that are not obtained by sensors. An algorithm based on the Linear Quadratic Gaussian (LQG) technique is proposed to the semi-active control. Time delay is also investigated. The results show that MR dampers are efficient for structural response reduction. The semi-active control algorithm used can improve the dampers efficiency. It is demonstrated that a proper choice of the weighting matrices is crucial to the semi-active control performance and that time delay can interfere on response reduction.*

Keywords: *Structural dynamics; vibration control; semi-active; magnetorheological damper*

PAC0375: AEROELASTIC GUST-RESPONSE ANALYSIS FOR A TYPICAL AIRFOIL SECTION WITH MAGNETORHEOLOGICAL DAMPER

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Abstract. *The aeroelastic response to time-dependent external gust load excitation of a two degree of freedom typical airfoil section using a Magnetorheological damper (MRD) to increase the structural damping is presented. The expressions of the unsteady aerodynamic lift and moment in the time domain are given in terms of the*

Wagner's function and the gust load is a sinusoidal signal. In the present research, the MRD is connected to the plunge degree of freedom of the airfoil. The modeling of the MRD is based on the Bingham model which describes the viscous-plastic behavior of the device. The effects of the different gust excitations frequecies and the control parameter variations of the MRD on the aeroelastic response are discussed. The numerical results show that the presence of this damper can used as a semi-active control device to alleviate the pitch-plunge dynamic response to a periodic gust excitation.

Keywords: *Aeroelasticity, Magnetorheological Damper, Gust Load, Aeroelastic Response*

PAC0377: AN ALGORITHM TO OPTIMIZE THE POSITION OF ACOUSTIC SENSORS IN ACTIVE SYSTEMS OF NOISE CONTROL IN DUCTS

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Abstract. *Acoustical noises are known as pollution sources that might cause adverse effects in human life. In order to address these problems, considerable interest has been shown to develop new technologies in Active Noise Control. This work is aimed at developing an algorithm to optimize the best position of the acoustical sensor so as to guarantee a better performance of the Active Control of Noises in ducts. A short introduction to basic acoustics in ducts is presented and several effects that the acoustical noise might cause in human's life quality are discussed as well. One presents algorithms of Active Noise Control in Ducts, including Feedforward algorithms, Feedback algorithms, as well as a hybrid system that uses both concepts. A discussion is made over the algorithms LMS, FXLMS and some particularities found during the development of this work. In order to validate the performance of the methodology, one developed a theoretical model in ANSYS and built an experimental bench made of a PVC duct with loudspeakers (actuators) and microphones (sensors). One used amplifiers and sign conditioners to accomplish the interface among the transductors and the respective control platform dSPACE. Results and discussions are presented regarding the performance of the control systems.*

Keywords: *Noise Active Control, LMS, FXLMS*

PAC0411: EVALUATION OF A COMMUTED CONTROL SYSTEM IMPLEMENTED TROUGH A NEURAL NETWORK

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Abstract. *Switched control systems with proportional-integral-derivative (PID) logic, exhibit excellent behaviour and are highly reliable. They have proved to be an advantageous option for tuning control variables independently, despite the skepticism found in specialized literature. In fact, this solution is especially appropriate for problems characterized by: i) state vectors of relatively small dimension, ii) large mechanical inertias, iii) high accelerations,*

iv) high stability requirements with small error bounds and v) quick response. All these are typical conditions when controlling the testing of internal combustion engines, which is studied in this paper. A control system of variable structure is produced by incorporating a switching unit. This unit governs the behavior of the system through strategies which anticipate the limitations of the PID logics involved and allows the commutation between them. The availability of independent and simultaneous feedback loops forces a synchronization process of the orders on the electromechanical actuators. In such a process the switching unit behaves as a state machine, such as a sequential Moore machine. As one could guess, the good performance of these types of control systems depends heavily on the correct definition of the commutation conditions, which become production rules. This definition involves a very laborious process, and poses a limitation. In order to overcome this difficulty, it was decided to integrate computational intelligence to the selection of the best control structure for each case. For this purpose, a multilayer perceptron neural network was used. Therefore, a neural adaptive control which replaces the commutation unit was implemented. Details of the proposed solution and the criteria used for the definition of the neural network are presented in this work for the case of controlling the testing of internal combustion engines. Numerical simulations were carried out to evaluate the performance of the neural control unit prior to its implementation in a real installation.

Keywords: *Switched control, Adaptive control, Artificial Neural Networks, Computational Intelligence*

PAC0430: APPLIED STATIC CONVERTER TO SYSTEMS PIEZOELECTRIC ACTUATORS FOR NEUTRALIZATION OF MECHANICAL VIBRATIONS

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Abstract. *Piezoelectric actuators are widely used in smart structural systems to actively vibration control and noise, and to enhance performance. Because of the highly capacitive nature of these actuators, special power amplifiers, capable of delivering large currents, are required to drive these systems. In this paper, a study to reducing the reactive energy that happen in the system. This is accomplished by incorporating the actuator with its capacitive characteristic circuit. Non-ideal circuit performance is addressed, along with theoretical limits to possible power savings and practical difficulties in achieving them. The proposed converter introduces a energy to correct the different phase between current and voltage that is given to PZT actuator. This proposed process is optimized because with the introduction of the reactives energies to the process the characteristic of the circuit which PZT this inserted raisin to have a characteristic resistive. This way the change of energies had not existed reactivate among elements that would be changing energy with the actuator that possesses characteristic electric capacitive.*

Keywords: *PZT actuator, actively vibration control*

PAC0450: ROBUST H_∞ CONTROL FOR UNCERTAIN LINEAR SYSTEMS USING THE LINEAR MATRIX INEQUALITY APPROACH

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Abstract. *This paper presents the H_∞ control strategy formulated by means of the Linear Matrix Inequality (LMI)*

approach to control a uncertain linear system. The system considered is manufactured by Quanser Consulting Inc., and represents a building controlled by an active mass driver (AMD). The performance of the robust H_∞ control strategy is analyzed based on a numerical optimization technique, using an efficient convex optimization software. Experiments are conducted to evaluate the performance of the proposed robust controller for the uncertain system.

Keywords: *uncertain linear system, robust H_∞ control, linear matrix inequality (LMI)*

PAC0490: A DEADBEAT CONTROL ALGORITHM FOR NOISE AND VIBRATION CONTROL

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Abstract. *As a consequence of the steadily improvement of digital computers speed performance in the last decades, several new digital control strategies have been proposed by the scientific community, among them, the deadbeat control strategy, successfully proposed for regulation type problems. This paper presents a further application of the deadbeat control technique applied to the noise and vibration control problem. It is shown that for a fast enough sampling rate, the deadbeat control algorithm delivers a very fast and accurate controller response. The design procedure of the proposed deadbeat control algorithm is also presented and discussed. Finally, simulation results are included to verify the feasibility of the proposed technique and to assess the controller performance.*

Keywords: *Noise control, Vibration Control, Deadbeat Control*

PAC0561: ANALYSIS OF SMART STRUCTURES INCLUDING STRUCTURAL HEALTH MONITORING

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Abstract. *The paper presents an overall modelling approach for piezoelectric smart leight-weight structures to actively reduce vibration and noise.This approach includes the coupled mechanical, electric and acoustic field equations, which are numerically solved by a combined FEM-BEM approach. Control can also be integrated into the final modelling approach. The paper shows that the already attached piezoelectric patches can additionally be used to monitor the health of the structure. For this purpose, a piezoelectric patch is excited with high frequency Lamb waves, which interact very sensitive with structural damages. The changes in the signals received at piezoelectric patches can be used to identify the size and the position of structural damages.*

Keywords: *Piezoelectric smart structure, active noise and vibration control, FEM, BEM, structural health monitoring (SHM), Lamb waves.*

NOTES

5. COMPUTATIONAL MECHANICS

NOTES

PAC0084: PERTURBATION/GALERKIN FINITE DIFFERENCE APPROACH TO LAPLACE AND POISSON EQUATIONS

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Abstract. *While steady state solutions can be generated from time-dependent equations, there are important physical problems governed by steady state equations. A modified two-step hybrid method has been developed which combines perturbation methods based on the steady state parameter, D = Dx (or Dy) with the Galerkin method, providing a systematic way to develop new higher order finite difference equations to Poisson and Laplace's equations. We refer to these as steady-state hybrid equations. The usual five-point difference formulas for both the Laplace and Poisson equations are recovered from the perturbation solutions where the truncation error for Laplace's equation is of order two. The finite difference formulas based on the hybrid solutions are nine-point formulas for both the Laplace and Poisson equations. Both equations are found to have truncation error of order four.*

Keywords*: finite difference equations, Laplace equation, Poisson equation, perturbation methods, truncation errors*

PAC0099: ACOUSTIC WAVEGUIDE PROFILE FOR WANNIER-STARK Ladder GENERATION

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Abstract. *We present a mathematical formulation that permits to calculate the appropriate profile of an acoustic waveguide of variable cross section in order to have resonances of the Wannier-Stark Ladder type. The formulation starts from the equation governing the propagation of acoustic waves - the Webster equation- and it is applied for the case when the profile of the waveguide permits the existence of such resonances as predicted in a previous paper. The numerical calculations of the transport properties for such waveguide gives rise, in fact, to the presence of the Wannier-Stark Ladder resonances.*

Keywords*: waveguide, Stark Ladder, acoustics, Webster*

PAC0116: FAST SOLUTION OF FLUID STRUCTURE INTERACTION PROBLEMS IN THE FREQUENCY DOMAIN - WITH AN APPLICATION

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Abstract. *Fluid structure interaction problems are common in the field of engineering. They are a prime example of coupled multi physical problems, where no single physical phenomenon can be said to be dominant. Even when the individual systems are linear, often the coupling results in nonlinearities. This happens when the state of one system affects the parameters of the other. In the particular case of interaction between fluid films and solid structures, the fluid film thickness depends on structural deformation. These types of problems arise in the area of tribology. Solving such a system in the time domain is conceptually straight forward, but computationally heavy, since the ratio between the lowest and highest eigenfrequency can be large. Furthermore, the amount of information*

gained by time domain analysis alone is limited. Frequency domain analysis can be performed, but presents certain challenges. If the problem is discretized with finite elements, it is easily seen that the computational work is one order of magnitude greater than that of the corresponding solid-only problem. This means that analysis of finely discretized systems will challenge the patience of any analyst. The solution time can however be reduced if certain prudent approximations are made. This is the focus of this presentation. A method is introduced, which solves the equations as decoupled, as a series expansion. This reduces the memory requirements and the solution time. If the solid forces dominate the problem, the series expansion converges to the exact result. The method is tested on a generic problem, which highligts its strengths and limitations.

***Keywords**: Reynolds Equation, Tribology, Fluid Structure Interaction, Frequency Domain, Harmonic Response*

PAC0142: DAMAGE AND FRACTURE OF DUCTILE MATERIALS SUBMITTED TO HIGH STRAIN RATES. AN IMPLICIT THERMOMECHANICALLY COUPLED APPROACH WITH ELEMENT EROSION

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***Abstract.** In this paper, we present a general consistent numerical formulation able to take into account strain rate, thermal and damage effects of the material behavior. A thermomechanical implicit approach for element erosion to model material failure is also presented. The numerical model will be illustrated by an application from the impact domain. All these physical phenomena have been included in an implicit dynamic oriented object finite element code (implemented at LTAS-MN²L, University of Liège, Belgium) named Metafor.*

***Keywords**: Finite elements, large strains and strain rates, implicit time integration algorithms, damage and fracture*

PAC0145: Two-Dimensional Simulation of ablation due to aerodynamic heating in the sara sub-orbital platform

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***Abstract.** Space and sub-orbital vehicles reach high velocities within atmosphere, about 100 km over Earth's surface. Such high velocities result in aerodynamic heating and air temperature surpasses 2000o C at the stagnation point. Besides the effects of high temperatures on the mechanical behavior of the structure and on-board devices, it is mandatory to preserve the payload, by using an efficient TPS (Thermal Protection System). Along the year,s ablative materials have been effectively used as TPS of space vehicles. In order to obtain the temperature profile and the heat load, the energy conservation equation has to be solved togetherwith the moving boundary problem concerned to the ablation process. The coupling between the heat transfer processes in the surface and within the layers represent an additional difficulty. A common approach is to consider the heat conduction as one-dimensional, in the normal direction relative to the local surface. However, such hypothesis becomes inaccurate as temperature gradients in the tangential direction, change of material or a great thickness variation occur. In this work, the computational simulation of the ablative process in the vicinity of the stagnation point during the flight of SARA Sub-orbital Platform via an interface tracking method is presented, taking into account the effects of the two-dimensional conduction in the wall layers. Such procedure will allow a more accurate dimensioning of the TPS,*

contributing for project optimization.

***Keywords**: Simulation, Ablation, TPS, Aerodynamic heating*

PAC0151: OPTIMAL DESIGN OF FERROELECTRIC CERAMICS MICROSTRUCTURE

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***Abstract.** Piezoelectricity (or electric-field-induced strain) in ferroelectrics has found extensive applications in sensors and actuators and offers great potential for next generation high density storage devices such as NvRAM. Ceramic ferroelectrics which can be manufactured at a fraction of the cost of single crystals, which are prone to deficiencies such as depolarization and chemical inhomogeneity, are attracting keen interest lately. Recent reports on ceramic BaTiO3 suggest that grain-orientation in a flux of random grain boundaries could greatly enhance the piezoelectricity. These findings underscore previous notion of the role of grain boundaries in the control and design of ceramic FE materials. Piezoelectric properties in ceramics can be optimized by a proper choice of the parameters which control the distribution of grain orientations although this choice is complicated and it is impossible to analyze all possible combinations. In this work we have implemented a finite element based computational homogenization model, characterizing ferroelectric properties, together with a stochastic optimization technique of simulated annealing to solve the optimization problem. We show that there could be an optimum choice of distribution parameters available at which the ceramic material shows better piezoelectric performance than its oriented single crystal counterpart.*

***Keywords**: Ferroelectrics, Ceramics, Optimization, Computational*

PAC0156: WINKLER PLATES BY BOUNDARY KNOT METHOD

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***Abstract.** This paper describes the implementation of the Boundary Knot Method (BKM) in the resolution of plates on winkler foundation. This is the first time the BKM is applied in this kind of problem. The BKM is a boundary collocation, meshless and integration-free method. To solve the problem of plates on winkler foundations, the inhomogeneous term is determinated through known particular solutions. Kelvin and modified Kelvin nonsingular functions are employed to approximate the homogenous solution. Even though the approach of the problem is similar to the fundamental solution method, the BKM uses only nonsingular general solutions, therefore, the artificial boundary used in MFS is not required. The BKM application is validated through its application on various problems of different boundary conditions: combination of clamped, simply supported and free edges. Several cases are discussed and compared with solutions obtained by FEM. The obtained results are generally good when applied to thin plates in which shear and direct stresses can be overlooked.*

***Keywords**: Winkler plate, Boundary Knot Method*

PAC0194: NUMERICAL SIMULATION OF CONTACT PROBLEMS UNDER LARGE 3D ELASTOPLASTIC DEFORMATION

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Abstract. *In this work news simulations of 3D contact problems with friction in solid mechanics are presented. The bodies in contact undergo finite deformation within an elastoplastic range. A brick element based on a compressible elastoplastic material is applied in the numerical examples. The augmented Lagrangian method is used to solve the contact problems. For the contact formulation within the finite element method, the matrix formulation for a node-to-surface element consisting of a master surface with four nodes and a contacting node is derived. Here, the discretised contact surfaces are not smooth, i.e. there is no continuity of the normal vector between the adjacent surfaces. At the edge between the surfaces the normal is not uniquely defined. That needs a special algorithmic treatment. When one slave node is sliding from one surface to the adjacent one, the node-to-surface contact formulation is not sufficient to solve the contact problems. Then, for the special cases the node-to-edge and node-to-node contact formulations are employed, see Bandeira et al. (2005). The purpose of this paper is to present numerical examples using the formulation of contact mechanics and the elastoplasticity algorithm for large 3D deformation, considering the possible sliding of slave node from one surface to the adjacent one. The formulation is derived based on exact linearization. Several numerical examples for contact problems in elastoplastic range are presented.*

Keywords: *Finite element, plasticity, contact mechanics, computational mechanics, non-linear analysis, numerical simulation*

PAC0227: MINDLIN'S PROBLEM FOR A HALFSPACE INDENTED BY A FLEXIBLE CIRCULAR PLATE

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Abstract. *The paper deals with a contact problem of an isotropic elastic halfspace indented by a flexible circular plate and simultaneously subjected to a Mindlin-type axial force. The approach adopted is to solve the contact problem for the flexible circular plate and the elastic halfspace; this serves as the auxiliary solution to examine,*

via the Maxwell-Betti's reciprocal theorem, the influence of the internal Mindlin force. The contact between the flexible plate and the elastic halfspace is solved using a variational approach. The net displacement of the flexible circular plate and the internal Mindlin force can be evaluated in analytical form. The result has applications to the in situ evaluation of the deformability characteristics of geologic media.

***Keywords**: Contact mechanics, anchor-flexible plate interaction, Mindlin force problem, variational solution*

PAC0253: HYBRID-TREFFTZ ELEMENTS APPLIED TO THE STRESS CONCENTRATION PROBLEMS IN LINEAR ELASTICITY

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***Abstract.** The Hybrid-Trefftz Finite Element (HTS) has been applied with success in the analysis of linear and non-linear problems in structural mechanics. The HTS is based on the approximation of two independent fields: stresses within the element and displacements on its boundary. The stress fields should satisfy the Trefftz´s constraint, i.e., should satisfy, a priori, the Navier equation. In this work, a three-dimensional HTS element is applied to structural analysis of stress concentration problems. Stress concentration factors (Ktn) and Stress intensity factors (K) are computed and compared with the results presented in the literature. The p-hierarchical nature of this element is fully exploited, so both mesh discretization (h-refinement) and increase of the polynomial degree used as approximation for stress and displacements fields (p-refinement) are applied in the examples..*

***Keywords**: Trefftz finite elements, Stress concentration, Numerical simulation*

PAC0327: A MIXED STABILIZED FINITE ELEMENT FORMULATION FOR STRAIN LOCALIZATION ANALYSIS

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***Abstract.** This work exploits the concept of stabilization techniques to improve the behavior of either mixed u/p or mixed u/σ linear/linear simplicial elements (triangles and tetrahedra) when strain localization analysis is required. Different stabilization methods are proposed and compared to check the global stability of the corresponding discrete finite element formulation. Both elasto-J2-plastic constitutive behavior and isotropic damage behavior have been considered with an exponential softening. Implementation and computational aspects are also discussed showing the robustness of the proposed formulations. It will be also pointed out how the results obtained do not suffer from spurious mesh-size or mesh-bias dependence, comparing very favorably with those obtained with standard, non-stabilized, approaches.*

***Keywords**: Strain localization, Finite Element Technology, Mixed Stabilized Formulation.*

PAC0379: NUMERICAL ANALISYS OF LID-DRIVEN CAVITY FLOWS BY THE IMMERSED BOUNDARY METHOD USING THE VIRTUAL PHYSICAL MODEL

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***Abstract.** The study of flows over complex geometries represents a great challenge due to the difficulyt in representing the geometry. The body fitted mesh methods, like non-orthogonal and unstructured grids, are efficient to represent complex geometries and provide consistent results. Nevertheless, the complex calculations to build the mesh make these methods computationally expensive when the problem involves moving boundaries due to the re-meshing process. Another approach to solve this class of problems is the Immersed Boundary Method developed by Peskin (1977). This method is based on two distinct meshes: a fix eulerian mesh used to solve the fluid governing equations, and a lagrangian mesh used to represent the immersed body. The coupling between the two meshes is made by adding a force term in the momentum equations. Using this approach the no-slip condition is imposed virtually by the force term, which makes the numerical simulation with moving boundaries less expensive. The objective of the present paper is to show results obtained from a computational code based on the Finite Volume Method developed to solve incompressible, bi-dimensional and transient flows using the Immersed Boundary Method. The Physical Virtual Model proposed by Lima e Silva et al. (2003) was chosen to calculate the force term. In order to validate the code, the lid-driven cavity was simulated for low Reynolds numbers, Re = 100 and Re = 400. The results were analyzed using dimensionless velocity profiles, maps of velocity vectors, vorticity and force field showing good agreement with literature data.*

***Keywords**: Immersed Boundary Method, Virtual Physical Model, Finite Volume, Lid-driven cavity*

PAC0381: DYNAMIC ANALYSIS BY OPTIMIZED FEM-BEM COUPLING PROCEDURES

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***Abstract.** In this work, time-domain dynamic analyses of nonlinear models considering coupled finite element and boundary element techniques are discussed. In the present formulation, the domain of the original problem is divided into different sub-domains, which are separately discretized by the Finite Element Method (FEM) or by the Boundary Element Method (BEM), according to the special features and advantages of the two methodologies. Each sub-domain is analyzed separately and a successive renewal of the variables at the interfaces between the sub-domains is performed through an iterative procedure, until final convergence is achieved. An expression for an optimal relaxation parameter is presented in order to ensure and/or speed up the convergence of the iterative coupling algorithm. In the case of local nonlinearities within the finite element sub-domains, it is straightforward to perform the iterative coupling together with the iterations needed to solve the nonlinear system. The procedure turns out to be very efficient. Moreover, different durations of time-steps in each sub-domain are easily introduced taking into account the present FEM-BEM coupling formulation, enabling more accurate and stable analyses (as is well known, optimal FEM and BEM time discretiztions are usually quite different). Numerical results are presented,*

illustrating the potentialities of the proposed methodology.

***Keywords**: Dynamics, Finite Elements, Boundary Elements, Iterative Coupling, Optimal Relaxation Parameter*

PAC0385: EXPERIMENTAL AND NUMERICAL STUDIES OF THE SCISSORS-AVLB TYPE BRIDGE

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***Abstract.** Scissor bridges are characterized by high mobility and modular structure. Single module-span consists of two spanning parts of the bridge; two main trucks and support structure. Pin joints are used between modules of the single bridge span. Some aspects of this experimental test and numerical analysis of the scissor-AVLB type bridge operation are presented in this paper. Numerical analyses here presented were carried out for a scissors-type BLG bridge with treadways extended as compared to the classical bridge operated up to the present in the Armed Forces of the Republic of Poland. A structural modification of this kind considerably affects any changes in the effort of the force transmitting structure of the bridge. These changes may prove disadvantageous to the whole structure because of torsional moments that additionally load the treadways. Giving careful consideration to such operational instances has been highly appreciated because of the possibility of using this kind of bridges while organising the crossing for vehicles featured with various wheel/track spaces (different from those used previously). The BLG bridge was numerically analysed to assess displacements and distributions of stresses throughout the bridge structure in different loading modes. Because of the complexity of the structure in question and simplifications assumed at the stage of constructing geometric and discrete models, the deformable 3D model of the scissors-type bridge needs verification. Verification of the reliabiliy of models was performed by comparing deflections obtained in the different load modes that corresponded with tests performed on the test stand. It has been shown that the examined changes in conditions of loading the treadways of the bridge are of the greatest effect to the effort of the area of the joint which is attached to the girder bottom. Stress concentrations determined in the analysis are not hazardous to safe operation of the structure.*

***Keywords**: scissor-AVLB type bridge, experimental test, numerical FE analysis*

PAC0394: PARAMETER SPACE FOR STONELEY WAVES IN SOME ELASTIC AND VISCOELASTIC MATERIALS

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***Abstract.** In this work we show that basic procedures such as the Newton-Raphson method makes the calculation of dispersion relation of surface waves in elastic and viscoelastic more efficient and free of ambiguities such as the appearance of spurious roots. The calculation of the dispersion relation and range of existence of Stoneley waves in elastic and viscoelastic media is presented using symbolic computation programs such as Maple or Mathematica.*

***Keywords**: Stoneley, Rayleigh, dispersion, surface wave*

PAC0395: BUCKLING OF EULER-BERNOULLI BEAMS WITH GENERAL BOUNDARY CONDITIONS

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Abstract. *A simple and concise approach is presented for the buckling analysis of a generally supported Euler-Bernoulli beam. In the application of Galerkin method, the flexural displacement is sought as the linear combination of a trigonometric series and an auxiliary polynomial function. The polynomial function enriches the trigonometric series in the sense of: (a) satisfying general boundary conditions; (b) improving the convergence by catching all the relevant discontinuities at the boundaries of the original displacement and some of their derivatives. The reliability and robustness of the proposed approach are demonstrated with emphasis on convergence.*

Keywords*: Buckling, Galerkin, Fourier series*

PAC0418: Simultaneous topology optimization and optimal control for vibration suppression in structural design

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Abstract. *This work presents a structural topology optimization methodology, which includes an optimal control design for reducing vibrations. Continuum finite elements modeling is applied to simulate the dynamic characteristics of the structure. The modal basis is used to derive an optimal control. The cost functional is the strain energy of the structure and the control energy. Results of numerical simulations for a beam model are presented and discussed.*

Keywords*: Topologic optimization, optimal control, vibrations, dynamics*

PAC0419: PARALLEL COMPUTATIONAL PERFORMANCE OF A NUMERICAL ALGORITHM TO SIMULATE 3-D TRANSONIC AND SUPERSONIC FLOWS USING FINITE ELEMENTS

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Abstract. *Numerical simulation of 3-D problems in Fluid Dynamics requires a large amount of computational resources in terms of computational power and main memory. Clusters of personal computers have been used as a mid range solution due to their low cost, easy maintenance and upgrade flexibility. The performance of an algorithm to simulate 3-D high compressible transonic and supersonic flows using the Finite Element Method, which was implemented for distributed memory and hybrid shared / distributed memory parallel configurations, is presented in this work. An explicit one-step Taylor-Galerkin scheme is used for time integration and both tetrahedral and hexahedral meshes are employed in the spatial discretization. Clusters formed by nodes with homogeneous or heterogeneous computational power are employed. The task division is achieved through two different techniques based on nodal ordering in order to minimize the bandwidth of the system of equations: the first one minimizes the number of neighbor sub-domains in the partitioned mesh, minimizing the number of communication operations among the cluster nodes, and the second one minimizes the number of common elements among sub-domains, minimizing the amount of data exchanged by the cluster nodes through the network. The influence of the meshes size and type (structured or unstructured), the task division and load balancing employed as well as of the number of cores or processors of each cluster node is analyzed through two examples in terms of speed-up. The results obtainedfrom these examples show the importance of task division and load balancing in the efficiency of parallel solutions in distributed memory configurations, and the viability of using personal computers in clusters as an alternative to reach relatively high performance computing with cheap resources.*

Keywords*: Parallel Computing, Computational Fluid Dynamics, Finite Element Method, High Performance Computing, Compressible Flow.*

PAC0519: ESTIMATION OF NATURAL FREQUENCY OF THE BEARING SYSTEM UNDER PERIODIC FORCE BASED ON PRINCIPAL OF HYDRODYNAMIC MASS OF FLUID

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Abstract. *Estimation of natural frequency of structures is very important and isn't usually calculated simply and sometimes complicated. Lack of knowledge about that caused hard damage and hazardous effects. In this paper, with using from two different models in FEM method and based on hydrodynamic mass of fluids, natural frequency of an especial bearing (fig.1) in an electric field (or, a periodic force) is calculated in different stiffness and different geometric. In final, the results of two models and analytical solution are compared.*

Keywords*: Natural frequency of the bearing, Hydrodynamic mass of fluid method*

PAC0530: NUMERICAL ANALYSIS OF THE EFFECT OF TORISPHERICAL HEAD ON THE BUCKLING OF PRESSURE VESSEL

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Abstract. *Effect of torispherical head on the buckling of pressure vessels was investigated by finite element (FE) method.The FE method with use of nonlinear buckling analysis was applied to predict the critical buckling load. The influences of geometrical parameter such as thickness, knuckle radius and diameter of cylindrical part, on the buckling of heads have been studied. The Arc Length method which can control the load level, the length of the displacement increment and the maximum displacement was been used. By verification performed with the European Convention for Constructional Steelwork (ECCS) code, it was confirmed that the nonlinear buckling analysis could assure accurate results for buckling strength. It was shown that geometrical imperfections had little effect on buckling strength.*

Keywords*: pressure vessel, torispherical head, finite element, nonlinear buckling*

6. COMPOSITE MATERIALS

NOTES

PAC0132: GLOBAL APPROACH FOR THE DESIGN OF SUSTAINABLE POROUS CONCRETE

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Abstract. *This paper deals with hemp-lime concrete made up with hemp particles (wasted vegetable particles called shivs) mixed with lime binder. The hemp concrete is well adapted as sustainable powerful modern building material: it is characterized by low environmental impact and high level technical properties. It is use to built new houses or to refurbish old constructions in order to reach hight performances in particular for thermal insulation. In this paper, various examples of hemp concrete applications are shown and the main advantages of this building material are presented. This composite material is porous (80% in volume) with different characteristic sizes (from µm to cm). It is used as filling insulating material of a load-bearing structure for interior and exterior walls, ceiling and roof, and for thick insulating coats. Due to its porous microstructure, this sustainable concrete offers the opportunity of a lightweight ductile material, convenient to use, with an excellent thermal insulation coefficient (weak thermal conductivity 80mW/mK), a high capacity of sound absorption. Finally, the specific hygro-thermal behaviour of this material leads to very comfortable ambiance what ever are the variable conditions of temperature and relative humidity in an habitation. The paper shows that the transfers of vapour through the material and the phase changes result in better thermal insulation properties. A comparison of performances for various building materials (cellular concrete, baked clay) is presented.*

Keywords*: Building material, hygro-thermal transfer, mechanical, acoustical, thermal performance*

PAC0146: REPRESENTATIVITY OF 2D NUMERICAL MODELS NEAR BIMATERIAL CORNERS IN ADHESIVE CFRP-AL LAP JOINT

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Abstract. *The representativity of the asymptotic linear elastic solution at corners in CFRP-Al adhesive double-lap joints using 2D numerical models has been compared with results using 3D models. In most cases, a two-dimensional stress state (generalized plane strain) can be assumed, for the sake of simplicity, in adhesively bonded double-lap joints configurations. Anyway, it is well known that edge effects appear at the free lateral faces of the joint where the stress state is purely 3D. The magnitude of this effect has been quantified by performing a 3D numerical model of a carbon fiber reinforced plastic and Aluminium (CFRP-Al) double-lap joint and comparing the results with the ones given by the 2D representation. The size of the adhesive thickness (0.1 mm in this kind of joints) makes the 3D model computationally expensive (a large area with a very low thickness and stresses varying in the thickness direction need a very fine mesh). The edge effect was shown to affect at a distance of the order of the adherent thickness and with stresses less severe than those found in the 2D model, in this particular case. Stress comparisons between numerical 2D and 3D solutions were carried out at a distance of few fiber diameters from the corner tip were failure is expected to initiate.The results showed that edgde effects are significant only near the free-edge of the sample.*

Keywords*: adhesive joints, edge effect, bimaterial corner, stress singularities, composites*

PAC0148: PLASTICITY EFFECTS IN CFRP-AL ADHESIVE JOINTS

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Abstract. *In this work, an adhesive double- lap joint between unidirectional carbon-epoxy composite and aluminium plates has been analyzed. An elastic-plastic numerical simulation (using finite elements) was carried out to check the extent of the yielded zone at the neighbourhood of the bimaterial corner appearing at the end of the overlap and to compare with the purely elastic solution. The results have shown that the yielding zone that appears around the corner can have a significant influence with the yielding criteria being used. Three yielding criteria were considered, taking or not into account, the influence of the mean stress (Raghava, Drucker Prager and von Mises). It was observed that at a distance of 30 micron (1/3 of the adhesive layer thickness), which is representative to analyze failure initiation, plasticity partially affects the linear elastic solution. For the particular geometry under study (double-lap joint between 1.6 mm thickness of 0º CFRP and 3.2 mm thickness Al, bonded with a FM73 adhesive) the elastic solution of plane strain numerical models can be considered to be representative of the 3D behaviour at the neighbourhood of these cross-points including plasticity effects. The results with the different yielding criteria were compared with the analytical (elastic) and numerical elastic (boundary element) solutions. The comparison with experimental evidences suggests that the most suitable criterion has to be dependent of the mean stress. A brief review about yielding criteria in polymers and their implementation in commercial FEM softwares is discussed.*

Keywords*: plasticity, adhesive joints, polymer, corner, composite materials*

PAC0199: DEVELOPMENT OF A COMPUTATIONAL TOOL FOR BONDED JOINT ANALYSIS

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Abstract. *The use of bonded joints is one of the most efficient ways of transmitting loads between the parts of a structure. Showing some different advantages when compared to fastener joints, it also allows the bonding of dissimilar materials, as metals and composites. For structural design these joints, it is necessary to know the forces, moments, displacements and stress acting in the joint after load application. In order to help the design process of bonded joints, a computer program which is capable to evaluate single and double lap bonded joint is proposed. The set of differential equations for each part (adherents and adhesive) of the problem geometry are obtained from the constitutive and equilibrium equations. To solve the set of equations of this boundary value problem, a computational tool in MatlabTM program is used. Two commercial programs are used to validate the program por computational tool implemented. One is the finite element program ABAQUSTM, and the other one is ESACompTM. The comparison between these programs showed a good curve fit for joint displacement field and adhesive stresses for composite joints, as well as for hybrid joints (metal-composite).*

Keywords*: bonded joints, hybrid joints, composite materials, boundary value problem, analytical methods*

PAC0256: INVESTIGATION OF THE COMPOSITE PROGRESSIVE FAILURE MODEL PARAMETERS

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Abstract. *The objective of the present survey is to investigate the intra-laminar progressive failure process of composite material under 3-point bending varying material degradation parameters. The mechanical material behavior is simulated using a phenomenological model that considers five failure modes: two for fiber-failure (FF) and three for inter-fiber-failure (IFF). In FF modes, the lamina failures under longitudinal tension or compression. In IFF modes, the lamina failures under transverse tension (Mode A), or transverse compression (Mode B or C). Each failure mode has a failure criteria and an associated degradation function that decreases de engineering material properties, turning the process of analysis iterative. The material model is implemented in a sub-routine written in Fortran and used together the finite element package Abaqus® in order to study the 3-point bending problem for [0°]10 and [0° /90° /0° /90° /0°]S stacking sequences. The finite element analyses are performed for a set of parameters through a Matlab® program that controls the parameters variability and generate the results of interest which are then evaluated. The forces vs. displacement curves from analyses are compared with computational results and experimental results obtained by Tita (2003).*

Keywords*: progressive failure, composite materials, failure criteria, finite element*

PAC0259: IDENTIFICATION OF THE ELASTIC PROPERTIES ON COMPOSITE MATERIALS AS A FUNCTION OF TEMPERATURE

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Abstract.*This paper presents an inverse method for the identification of the orthotropic engineering constants of composite materials. The vibration behaviour of a freely suspended test plate is used as information source. The material parameters in a finite element model of the test plate are tuned to match the measured resonance frequencies. The automated procedure is simple, accurate and fast and can be executed with temperature control.*

Keywords*: composite material, vibration, inverse method*

PAC0260: THE STUDY OF RESONANCE FATIGUE TESTING OF TEST BEAMS MADE OF COMPOSITE MATERIAL

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Abstract. *Increasing oil prices have intensified the trend to use composite materials in so-call primary components of cars and in aerospace applications. As a consequence, the fatigus behaviour of composites has became an important issue. This paper describeds accelerated fatigue tests on composite material beam specimens clamped in their middle part and fixed on an electromechanic shaker. Many loading cycles can be imposed on a specimen in a controlled way by inducing resonance vibrations. The bending mode shape that is associated to the fundamental resonance frequency causes a stress state in the specimen that is maximal at the clamping pont in the middle and zero at both free ends. The stress state and hence the fatigue behavior varies from point to point. By interrupting the fatigue test at well-chosen moments in time and measuring the amplitude distribution of the vibration mode, it is possible to calculate the evolutio of the beam stiffness as a function of the number of applied loading cycles. This evolution can be registered from oint to point in the beam. The paper will present the inverse method that is used to compute the stiffness distribution using the measured amplitude distribution of the vibration mode. The amplitude distribution is measured with a laser velocity scanner. The principle of the stiffness identification method is to compare the measured mode shape amplitude with numerically computed values. The paper will conclude with results obtained from tested composite material beam.*

Keywords*: Resonance, fatigue, composites ,inverse methods*

PAC0292: ANALYSIS OF A CRACKED FUNCTIONALLY GRADED STRIP WITH ARBITRARY DISTRIBUTED ELASTIC MODULUS

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Abstract. *The plane strain deformation for a crack in a functionally graded strip with arbitrary variations of material properties is studied by a newly formulated multi-layered model. The governing equation in terms of Airy stress function is solved by means of Fourier transformation. The mixed boundary problem is reduced to a system of singular integral equations that are solved numerically to obtain the stress intensity factors at crack tips. The strain energy density criterion is employed to predict the direction of crack initiation. A numerical example is given to investigate the influence of crack sizes and graded material properties on the fracture behavior of functionally graded materials.*

Keywords*: functionally graded materials, crack, plane deformation, stress intensity factor, Fourier transformation*

PAC0389: COMPUTATIONAL ANALYSUS OF CHOSEN MICROSTRUCTURE SAMPLE

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Abstract. *One of the possible options as a material for protective layers are aluminium foams which become also very popular due to their lightweight and excellent plastic energy absorbing properties. Such characteristics have been appreciated by the automotive industry with continued research to further understand foam properties. Compressed foaming materials exhibit extensive plastic response, while the initial elastic region is limited in tension by a tensile brittle-failure stress. Aluminium foams have become an attractive material as blast protective layers due to their desirable compressive properties. With different material engineering techniques (as, for example double-layer foam cladding) they can be customized to achieve the most desirable properties. Energy absorption capacity of foams under blast load was analytically confirmed based on a rigid-perfectly plastic-locking foam model. Initial research indicates that energy absorbed by the cladding is much larger than that under quasistatic conditions due to shock wave effect. In this paper the creation process of a real foam microstructure model and its*

numerical analysis for uniaxial test is presented. Energy absorption of foams strictly depends on the microstructure geometry. From the numerical point of view, the analysed structural domain was described with Lagrangean formulation. Calculations were carried out using the so-called directintegration procedure, colloquially called the 'explicit integration'. Performed research shows that the process selection of the FE model should be based on real foam geometry measurements. In the final part of these investigations the comparison process between numerical and experimental test was performed and presented results shows a good convergence.

***Keywords**: Foam, aluminum, microstructure modeling, experimental and numerical studies*

PAC0392: FATIGUE UNDER SHEAR STRESS BY USING THE IOSIPESCU METHOD

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***Abstract.** Composite materials have been used on several segments of the industry and are prominent for aeronautical and aerospace applications. Their increasing demand for primary structural components in small and large airplanes makes the research on long term durability, i.e. fatigue, a key factor for the structural reliability. Fatigue of composites under tensile stresses is well documented in literature. Few researches are devoted to fatigue under shear stresses mainly because pure shear load is not particularly easy to apply in composite materials. However, new testing standards can help the study of fatigue under shear loading, such as the Arcan test, the V-notch test and the Iosipescu test. These tests have in common the "scissor type" deformation in the test gage area. This work presents for the first time results on fatigue under shear stress by using the Iosipescu method. An epoxy resin and a glass fiber/epoxy composite were tested by using the Iosipescu coupon. Initially the specimens were submitted to static tests in order to obtain the ultimate shear strength (τ_{12}) and the in-plane shear modulus (G_{12}). The shear strength obtained was 41.6 MPa and 96.3 MPa, and the modulus were 1,4 GPa and 4,2 GPa, respectively for the epoxy resin and the glass fiber/epoxy composite. The specimens were tested under definite levels of stress ratio as a function of number of cycles. So, the SN curve was obtained. The maximum number of cycles was set at 120,000 cycles, which corresponds approximately to two times the life of a civilian airplane. The stress ratio used were R=0.1 and R=0.5. For the limit of 120,000 cycles the epoxy resin and the glass fiber/epoxy composite showed a shear strength of ~20 MPa and ~60 MPa respectively for a stress ratio of R=0.1 and ~50 Mpa and ~85 MPa respectively for a stress ratio of R=0.5.*

***Keywords:** Composite, fatigue, shear stress, epoxy resin, glass fiber*

PAC0508: MODELING OF CONSTRUCTIONAL FEATURES OF TIMING BELTS MADE OF MATERIALS WITH MACROMOLECULAR STRUCTURES

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Abstract. *The work presents constructional features of transmission timing belts depending on materials used for their production. Design of composites and usage of new polymer materials allows for improvement of constructional properties of belts.*

Keywords*: power transmissions belts, timing belts*

7. BIOMECHANICS

NOTES

PAC0104: FORCE ANALYSES IN HIP JOINT USING SIMULATION AND MEASURING

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Abstract. *The aim of this contribution is to compare numerical simulations and experimental measurements of forces in a hip joint. Both methods have been applied to obtaining information about forces affected in the hip joint during different physical activities. This information can be used for an optimal design of hip joint endoprothesis, ways to approach hip surgery, reconstruction, etc. The numerical simulations of all activities such as free walking, staircase walking etc. have been done in the computer program Anybody. A simple dummy muscle model was used in this study to simulate hip joint loading. This study was concerned with the development of a powerful and versatile human model capable of simulating with real results of human free and upstairs walking. Experimental measuring has been done on a real human body, which corresponded with the dummy model - weight, height, etc. The hip joint loading has been measured indirectly using acceleration measurements outside of the joint. The obtained results have been compared to obtain the relationship between them.*

Keywords*: Hip joint, Simulation, Measuring, Force analysis*

PAC0246: UNIFIED MODELING OF PASSIVE, ACTIVE AND DAMAGE BEHAVIOR OF SOFT BIOLOGICAL TISSUES

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Abstract. *In the present paper a thermodynamically consistent anisotropic constitutive model for soft biological tissues is proposed. The model takes into account preconditioning, softening, active contractility and force production in a unified manner. These phenomena are described by an alteration of so-called generalized structural tensors which define the material symmetry. Consequently, the model is able to predict large elastic, inelastic and active deformations. Its basis is provided by a generalized polyconvex and coercive strain energy function for fiber reinforced materials (Itskov et al., 2006; Ehret and Itskov, 2007). This guarantees material stability and the existence of a global minimizer of the total elastic energy in the elastic domain. The evolution of the generalized structural tensors is described by internal variables governing both the anisotropic properties and the stress-free configuration of the material. In order to describe active materials such as muscle tissue the internal variables are associated with muscle activation. Due to the generalized series form the model is applicable to a wide variety of anisotropic materials at large strains and demonstrates excellent agreement with experimental data on the passive and active response of soft biological tissues.*

Keywords*: soft tissues, polyconvex strain energy, anisotropy, softening, active response*

PAC0248: FINITE ELEMENT STATIC AND MODAL ANALYSIS APPROACH TO SIMULATE AND MEASURE THE TEETH STRESSING BY HARD CANDY MASTICATION

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Abstract. *The aim of this study was to use the Finite Element Method (FEM) to model the dental hard tissue (both enamel and dentin) in order to understand how the mastication of a hard candy could stress (or damage) the dental structure. The numerical models have been constructed trying to reproduce the dimensions and physical conditions of typical human molar sound teeth. The present analysis simulated the effect of mastication by numerically applying a corresponding force to the model and calculating the resulting stress through the tooth in three dimensions. The forces, capable to crack candies of different hardness, were experimentally determined using some common commercial caramels. The numerical essay has been made considering a range of force values around these measured results.*

Keywords*: Finite Elements, Numerical Simulation, Modal Analysis*

PAC0286: FINITE ELEMENT MODELING OF BIOMECHANICAL BEHAVIOUR IN A MOLAR, PERIODONTAL LIGAMENT AND MANDIBLE SYSTEM

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Abstract. *This paper presents a three-dimensional coupled structure-structure finite element model of a double rooted Molar attached to the mandible section by a thin Periodontal Ligament (PDL) soft tissue interface, the Molar is submitted to different load levels equivalent to those generated by orthodontic appliances in order to analize the effect in the sourrounding tissues and implement a computational medical tool. Viscoelastic behaviour of PDL is also considered. The results were compared with others specialized literature results.*

Keywords*: Finite Elements, viscoelasticity, Periodontal Ligament (PDL), Mandibular Right First Molar (MRFM)*

PAC0318: MIDDLE EAR MODEL

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Abstract*. An ear model under headphone load is presented in this effort with focus in the middle ear. The main function of the middle ear is to compensate the impedance from a system of low impedance, such as the external ear, to another of high impedance, such as the cochlear fluid in the internal ear. The ossicles system works amplifying the pressures due to the surface size differences between tympanic membrane and oval window. The pressure amplification is in the order of 27 dB. Experimental data from the middle ear has shown that the pressure amplification decreases above 1000 Hz. The decrease does not depend of the cochlear load for every frequency. The tympanic membrane (TM) and stapes footplate (FP) displacements were measured using double laser interferometers in human ears. The measurements supported by previous experimental studies indicate that there is slippage in the ossicles lever system above 1000 Hz. The reduction thought to be caused by the translational motion of the ossicles rotation axis. The full model is a structure-acoustic cavity coupled system.*

Keywords: *middle ear model, numerical simulation, acoustic- structure coupling*

PAC0424: EXPERIMENTAL IDENTIFICATION OF ELASTOMERIC MICROVALVE MODEL PNEUMATICALLY ACTUATED

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Abstract. *Microvalves and micropumps are employed in chemical and biochemical analysis systems (Lab-on-a-chip) to control fluids transportation. This work presents an experimental identification of lumped model parameters for an elastomeric microvalve pneumatically actuated. The model, developed with bond graph technique, represents the relationship between efforts (pressures) and flows (liquid flow) of the device. This microvalve is constituted of a working and actuation channels in crossed-channel architecture separated by a thin and flexible membrane. Applying pressure in actuated channel greater than pressure inside of the working channel causes membrane deflection. Its deflection restricts the transversal section of the working channel, and therefore controlling the liquid flow. The main model parameters are: pressures inside the working and actuation channels, liquid flow rate and membrane mechanical properties (Young's modulus and Poisson ratio). Integrated pressure sensors were attached on working and actuation channels to measure pressure variations on membrane. Average liquid flow rate was verified with an electronic balance. Curves of pressure and liquid flow rate were traced from experimental data. The identified parameters were inserted into the model and its curves of pressure and liquid flow were compared with the experimental ones.*

Keywords*: Microfluidics, microchannels, microvalves, micropumps, bond graphs*

PAC0469: ABOUT THE FEASIBILITY OF HURST COEFFICIENT IN THERMAL IMAGEM FOR EARLY DIAGNOSIS OF BREAST DISEASES

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Abstract. *This paper presents a study for diagnosis of breast diseases in early stages (cysts, fibroadenomas, tumors, etc.). This work is based on analysis of asymmetry between the patient's breasts using thermal images and considering that above certain values this is an indication of some abnormalities. Initially, for each thermal image, each patient's breast is segmented using a square window of the same size. The Hurst coefficient is used to characterize the breast's texture. For each computation, a movable (pixel by pixel for each row and column of the image) window computes the values that will result in the Hurst coefficient. Square windows of sides w equal to 5, 7, 9 ,11, 13 and 15 were used. Consequently, each image of NxN pixels has the values of the Hurst coefficient calculated* $\sum (N - (2i + 3))^2$ *times with i ranging from 1 to 6. Then, the average and standard deviation of Hurst coefficient for each window are used to form a feature vector. This is done in two ways. First, using the image of each breast. Second, using a new image obtained by the difference of temperature at vertically symmetric positions of each breast. This methodology is applied considering groups of patients who have confirmed diseases and healthy patients. Then, the possibility of obtaining a correct breast diagnose through the thermal images using combinations of this features are evaluated using machine learning techniques. The rate of correct diagnosis achieve 95% when Classification Via Regression is used.*

Keywords: *Processing of medical images, Thermography, Hurst coefficient*

8. FATIGUE AND FRACTURE MECHANICS

NOTES

PAC0188: NEW EXPLANATION OF DYNAMIC YIELDING PHENOMENON

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Abstract. *The influence of temperature and loading time on yield limit of solids is analyzed on the base of Einstein-Debye fluctuation theory. The probability of non-occurrence of plastic deformation is estimated. For explanation of anomalous behavior of yield stress the simple phenomenological model is proposed.*

Keywords*: dynamic loading, influence of temperature on yielding, dislocation movement, stress fluctuation, Einstein– Debye fluctuation theory*

PAC0209: A 3D X-FEM TWO SCALES MODEL DEDICATED TO CRACK GROWTH SIMULATIONS WITH CONTACT AND FRICTION

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Abstract. *The fracture and fatigue behaviour of structural components play a key role in repair decisions and life-extension programs for in-service structures. In particular, accurate computational modelling of fracture and fatigue with contact and friction along the crack faces is of great interest for instance for fretting or rolling contact fatigue. In this respect, a tri-dimensional eXtended Finite Element Method (X-FEM) two scale model dedicated to crack growth simulations with contact and friction is proposed. The first attempt to couple X-FEM and contact with friction along crack faces was proposed by Dolbow and Moës in the 2D case.. It was emphasized that imposing strong conditions at the interface with Lagrange multipliers can involve numerical instabilities related to the LBB inf-sup condition. Another limitation was also pointed out by Ribeaucourt et al. . Indeed, in the linear case, X-FEM allows the use of rather coarse meshes due to the asymptotic enrichment on the crack front; however, in the nonlinear case (contact and friction along the crack faces), a fine discretization of the interface is required due to possible complex contact conditions (rolling contact fatigue,…). As a consequence, it involves a fine discretization not only in the interface, but also in the bulk in the cracked area (an interface element is introduced for each finite element cut by the crack). The new proposed 2 scales X-FEM strategy is a first attempt to avoid the 2 previous limitations in the 3D case within a single formalism. In the proposed approach, the interface discretization (fine scale) can be adapted to the contact problem independently of the bulk discretization (coarse scale). Accuracy and numerical convergence rate of the 2 scales X-FEM model are studied and 3D numerical examples are proposed with 3D crack propagation in order to show the robustness and the efficiency of the method.*

Keywords*: X-FEM, 3D crack growth, unilateral contact, 3 fields weak formulation*

PAC0229: ON THE CRACK PROPAGATION MECHANISM OF BRITTLE ROCKS UNDER VARIOUS LOADING CONDITIONS

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Abstract. *The crack propagation mechanism of rocks under tensile and compressive loading conditions has been investigated. It is concluded that the brittle rocks fail due to the mixed mode fracture propagation under both tensile and compressive loading conditions. The micro-cracks are initiated due to tensile or tensile and shear under tensile loadings and due to tensile and shear under compressive loadings. The final crack propagation is duo to tensile or induced tensile for both loading conditions. Several example problems solved numerically and the results are compared with both analytical and experimental results. A higher order indirect boundary element method using special crack tip elements has been used to solve the various example problems in rock fracture mechanics. The results are compared with the corresponding results given in the literature and show good agreements with the analytical or observed experimental results.*

Keywords*: Crack Propagation, Mixed Mode Fracture, Tensile and Compressive loadings, Brittle Rocks, Indirect Boundary Element Method, Special Crack Tip Elements*

PAC0342: COHESIVE ZONE DESCRIPTION AND ANALYSIS OF SLOW CRACK GROWTH IN CERAMICS

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Abstract. *Ceramic polycrystals are prone to Slow Crack Growth (SCG) that is also environmentally assisted, similarly to what is observed for glasses. The kinetics of fracture are dependent on the load level, the temperature and also on the Relative Humidity (RH). However, evidences are available of the influence of the microstructure on SCG with an increase in the crack velocity with decreasing the grain size. This latter observation motivates a description that accounts explicitly for the microstructure. A physically motivated cohesive zone is proposed to describe the intergranular failure process. The methodology accounts for an intrinsic opening that provides an intrinsic length scale thus allowing the investigation of grain size effects. A rate and temperature dependent cohesive formulation is proposed to mimic the reaction-rupture mechanism that is thermally activated. We indicate how the parameters involved in the cohesive zone description can be determined from available data borrowed to the literature on ceramics single crystal for instance. We then analyse SCG in a 2D, plane strain, polycrystal, with a natural crack and subjected to a mode I, constant load. The simulations show that the crack growth is discontinuous in time and the related local velocity depends on the orientation of the grain facets and in particular of the local stress distribution.*

We show that the presence of defects like porosity at the grains triple junction is beneficial in terms of slow crack growth whereas it is usually thought detrimental in terms of microscopic fracture stress. Moreover, we show that it is necessary to account for initial thermal stresses related to the processing from the sintering temperature to the ambient to capture the influence of the grain size on SCG.

***Keywords**: Cohesive zone model, ceramics, polycrystals, slow crack growth*

PAC0361: THE ADHESIVE CONTACT ON THE THIN FILM WITH LIQUID-BRIDGE EFFECT AND SURFACE ENERGY

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***Abstract.** Micro-nano indentation technologies have become a commonplace tool for the measurement of mechanical properties at small scales. The indentation test technique has been widely used to quantitatively assess the adhesion strength of thin soft film-substrate systems. Some important factors which have been neglected in the macroscopic scale, such as the liquid-bridge force and the surface energy, are examined in this paper. It is found that the relative humidity and the amount of liquid-bridge have important effects on the force acting on the rigid punch, and hence the micro-contact behaviors of adhesive thin films. The theoretical results show that the influences of surface energy are of significance and need to be taken into account in some cases.*

***Keywords:** adhesion force, liquid-bridge effect, contact behavior, surface energy*

PAC0441: FATIGUE NOTCH SENSITIVITY OF ELONGATED SLITS

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***Abstract.** The fatigue notch sensitivity factor q can be associated with tiny non-propagating cracks at the notch root, thus it can be calculated if their propagation behavior is known. A generalized version of El Haddad-Topper-Smith's equation, used to reproduce the behavior of the Kitagawa-Takahashi plot, is adapted to evaluate the behavior of cracks emanating from circular holes and semi-elliptical notches. The q estimates obtained from this generalization, besides providing a sound physical basis for the notch sensitivity concept, show that the classical textbook q plots are only applicable to semicircular notches, since the elongated semi-elliptical slits can have very different q values. These predictions are supported by experimentally measuring the fatigue crack re-initiation lives after drilling a hole centred at the tip of deep pre-cracks, at a load-ratio R = 0.57, to avoid crack closure effects.*

***Keywords**: Notch sensitivity, short cracks, fatigue life prediction, non-propagating cracks*

PAC0483: FATIGUE CRACK GROWTH OF BIFURCATED CRACKS

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Abstract. *Crack bifurcation is a mechanism that can quantitatively explain fatigue crack growth (FCG) retardation effects even in the absence of plasticity induced crack closure. Empirical equations are proposed to calculate the process zone size and stress intensity factors (SIF) along the curved crack branches, based on extensive FE calculations. The equations are a function of the bifurcation angle 2 θ, ratio between the branch sizes c_0/b_0, and material crack growth exponent m. In this work, the increase in fatigue life associated with bifurcated cracks under near-threshold conditions is studied. The Levenberg-Marquardt algorithm is used to best fit non-linear equations to the FE results. The results show a competition between the effects of bifurcation and other retardation mechanisms under near-threshold conditions. The presented fatigue life calculation methodology can be used to predict the propagation behavior of bifurcated cracks in an arbitrary structure.*

Keywords*: Fatigue life prediction, bifurcated cracks, crack retardation, mixed mode modeling, finite elements*

PAC0521: MODEL *III* STRESS INTENSITY FACTORS FOR BENT CRACKS EMANATING FROM A CIRCULAR HOLE

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Abstract*. This paper provides a semi-analytic solution in antiplane elasticity for multiple bent cracks emanating from a circular hole with the traction free condition. The original filed is decomposed into a basic field and a perturbation field. In the perturbation field, the remote stresses are vanishing and the hole is of traction free. The complex potential for the perturbation field is composed of a principal part and a complementary part. The principal part can be obtained by some distribution dislocations at place of bent cracks and a concentrated dislocation at proper place. By using the traction free condition along the circular boundary, the complementary part can be derived from the principal part. Therefore, a system of singular integral equations is formulated, in which the dislocation distribution functions are unknowns. A semi-open quadrature rule is used to solve the integral equations numerically, and the stress intensity factors (SIFs) at the crack tips can also be evaluated. The present method belongs to the meshless method, which is more effective than boundary element method. Secondly, the configurations for the bent cracks are arbitrary. Two numerical examples are presented. The results from some special cases agree with those obtained by the conformal mapping method or those by stress function method.*

Keywords*: bent edge crack, antiplane elasticity, singular integral equation, stress intensity factor.*

PAC0535: THREE-DIMENSIONAL STRESS STATE AND ELASTIC-PLASTIC CONSTRAINT ANALYSIS OF THE CRACK FRONT FOR SIDE CRACK TENSION SPECIMEN

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Abstract. *A in-plane stress constraint factor C_i and a out-of-plane stress constraint factor C_o are introduced to study the three-dimensional stress state and the elastic-plastic constraint effect of the crack tip. The deep crack specimens(a/W=0.5) and the shallow crack specimens(a/W=0.1) with different thicknesses are performed in the present study. By using the finite element analysis, the result shows that the thickness effect of the deep crack specimens is more obvious than that of the shallow crack specimens. For the deep crack specimens, the crack constraint enhances with the specimen thickness increase. When the specimen thickness is equal to the specimen width, the constraint levels in the middle 2/3 thickness of the specimen approach to those from the plane strain analyse. For the shallow crack specimens, the crack constraint is almost fixedness when the specimen thickness changes from three times of a crack length to a specimen ligament length. Namely, increased thickness is helpless to enhance the crack constraint effect. Therefore, a shallow crack specimen may be designed by the lesser thickness than the standard specimen.*

Keywords: *side edge crack tension specimen, thickness effect, three-dimensional FEA, crack tip field, stress constraint*

PAC0543: MULTIPLE SURFACE CRACK GROWTH SIMULATION USING S-FEM

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Abstract. *Fatigue crack growth under mixed mode loading conditions is simulated using S-version FEM. By using S-FEM technique, only local mesh should be re-meshed for new crack configuration, and it becomes easy to simulate crack growth. By combining with auto-meshing technique, local mesh is easily re-meshed and curved crack path is modeled easily. Fully automatic crack growth simulation system in 3-dimensional problem is developed. Using this system, several kinds of plural surface cracks problems are simulated. It is shown that intereaction effect between two surface cracks appear in complicated manner depending on intial distances between two cracks.*

Keywords: *S-version FEM, Fatigue, Surface Crack Interaction Effect, Mixed Mode Loading*

PAC0545: A BI-FAILURE SPECIMEN FOR ACCESSING THE PERFORMANCE OF FAILURE CRITERIA

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Abstract. *This paper presents the design of a new tensile specimen to be used to access the performance of failure criteria. The specimen geometry is such that failure occurs in two distinct regions . In these two regions, failure is dominated by a near pure shear stress state and by a high triaxiality field. Hence, it is believed that these two extreme values occurring nearly at the same time during a test offer a chalenge for any failure criterion to predict material rupture. The paper also presents the material curves, some experimental tests and numerical simulation.*

Keywords*: failure, high and low triaxiliaty*

PAC0559: PUSH-OVER ANALYSIS OF 3D MASONRY BUILDINGS BY THE NT APPROACH

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Abstract. *In the paper the problem of static analysis of 3D masonry buildings is approached, based on the No Tension (NT) assumption of its wall elements. The method performs a full holonomic plastic analysis of the structure, starting from the treatment of the single structural panel by the NT theory. The proposed approach allows a more exahustive representation of its behaviour with respect to the classical POR approach, as well as the inclusion of architraves and tendons in the walls.*

Keywords*: Static analysis, Push-over, 3D masonry structures, Holonomic-plastic behaviour, No Tension model*

PAC0562: DIFFUSION-CONTROLLED CRACK PROPAGATION AT DIFFERENT TIME SCALES

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Abstract. *In this work, we consider the diffusion-controlled axisymmetric fracture in an infinite space and half-space. An important example of diffusion-controlled fracture growth is given by hydrogen induced cracking. In metals, hydrogen is typically dissolved in the proton form. When protons reach the crack surface, they recombine with electrons and form molecular hydrogen in the crack cavity. Then, the fracture can propagate even in the absence of any external loading, that is, only under the excessive pressure of gas hydrogen accumulated inside the crack. Our results show that in the long-time asymptotic approximation (based on the quasi-static solution), the diffusion-controlled delamination propagates with constant velocity. We determine a maximum critical concentration that limits the use of the quasi-static solution. A transient solution, representing a short-time asymptotic approximation, is used when the concentration of gas exceeds the critical concentration. We then match these two end-member cases by using the method of Pade approximations and present closed-form solutions for both internal and near-surface diffusion-controlled crack propagation at different time scales.*

Keywords*: Diffusion, Crack Propagation, Asymptotic Analysis, Pade Approximation.*

9. GENERAL INTEREST

NOTES

PAC0062: RECENT AND CONTINUING ACTIVITIES IN VERIFICATION & VALIDATION BY STANDARDS AND OTHER GROUPS

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Abstract. *This presentation provides an overview of some of the international activities in the area of verification and validation in computational mechanics, with an emphasis on those organizations developing standards. A brief history of verification and validation formalism provides a background for describing some of the most recent standards related activities and documents.*

Keywords*: Verification, Validation, Standards*

PAC0120: SALTED CODFISH DRYING KINETICS: UTILIZATION OF A SEMI-EMPIRICAL SIMULATION MODEL

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Abstract. *The relevance of drying operations within a vast range of industrial processes is unquestionable: drying is present in the chemical, agricultural, wood processing, food, ceramics, and pulp and paper industries, among others. It is estimated that drying operations are responsible for 10% to 25% of the national energy consumption in developed countries. The correct definition of drying procedures of a vast range of products is crucial in what concerns energy minimization and minimal time of kiln residence without compromising the final product quality. Drying can change the sensory characteristics and nutritional value of foods, and the intensity of these changes depends upon the conditions used in the drying process and the specific characteristics of each product. Several external parameters namely, air temperature, relative humidity and velocity, influence the time required to reduce the moisture content of the product. For whole salted codfish, drying prevents the utilization of temperatures above 20°C-22°C, since they lead to an inevitable deterioration of the product. Taking into account these limitations, whole codfish convective drying kinetics were determined for a temperature of 20°C, initial moisture contents comprised between 57% and 65% (wet basis), air velocities of 1,5m/s and 3m/s and drying air relative humidities of 40% and 70%, which replicate the conditions found in the codfish processing industry. A semi-empirical drying model was developed and validated. The obtained data has revealed the existence of two decreasing drying rates with different slopes. The results show that lower relative humidities led to faster drying and that air velocity influences drying rates particularly at high relative humidities.*

Keywords*: drying, codfish, simulation, mathematical models*

PAC0124: STUDY OF REPLICATION IN PRINTING BY SCROLLING IN PMMA

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Abstract. *This paper studies patterns for large scale production of microstructures, using the rolling microstamping process with heated substrate. Its working principle is a roll with microgrooves that spins over the heated substrate. The microdeformations will be generated by the heat and pressure undergone by the photopolymer, in other words, microimpressions, thus obtaining microlenses or microstructures. One of the advantages of the rolling microstamping process with respect to other processes used for manufacturing microlenses, such as photopolymerization by UV light, photolithography, microinjection, thermoforming, cold molding and modified alloy, are: the use of simpler machines, no high temperatures and pressures, reduced time, among others. The materials used for the mold and replica are aluminum alloy 7075 and* **polymethacrylate** *(PMMA), respectively. A groove of 0.10 mm deep by 0.5 mm wide is machined on the mold (roll), which have been replicated in the substrate. The pressure of the roller, temperature of the substrate and speed of lamination are assessed. Lastly, the capability of reproducing the generated profiles by the rolling is evaluated in terms of dimensional and structural quality, with promising results obtained.*

Keywords*: Production, Rolling microstamping, replication*

PAC0140: SCHEMES FOR APPLYING ACTIVE LUBRICATION TO MAIN ENGINE BEARINGS

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Abstract. *The work presented here is a theoretical study that describes two different schemes for the oil injection system in actively lubricated main engine bearings. The use of active lubrication in journal bearings helps to enhance the hydrodynamic fluid film by increasing the fluid film thickness and consequently reducing viscous friction losses and vibrations. One refers to active lubrication when conventional hydrodynamic lubrication is combined with dynamically modified hydrostatic lubrication. In this case, the hydrostatic lubrication is modified by injecting oil at controllable pressures, through orifices circumferentially located around the bearing surface. The pressure distribution of the hydrodynamic fluid film in journal bearings is governed by the Reynolds equation, which is modified to accommodate the dynamics of active lubrication, and which can be numerically solved using finite-difference method. The computed bearing fluid film forces are coupled to the set of nonlinear equations that describes the dynamics of the reciprocating engine, obtained with the help of multibody dynamics (rigid components) and finite elements method (flexible components). The main equations that govern the dynamics of the injection for a piezo-actuated oil injector and a mechanical-actuated oil injector are presented in this study. It is shown how the dynamics of the oil injection system is coupled to the dynamics of the bearing fluid film through equations. The global system is numerically solved using as a case of study a single-cylinder combustion engine, where the conventional lubrication of the main bearing is modified by applying radial oil injection using piezo-actuated injection. The performance of such a hybrid bearing is compared to an equivalent conventional lubricated bearing in terms of the maximum fluid film pressures, minimum fluid film thicknesses and reduction of viscous friction losses.*

Keywords*: fluid film bearings, active lubrication, machinery dynamics, mechatronics*

PAC0166: CONSTRUCTION AND CALIBRATION OF THERMAL TRANSDUCERS FOR THE MEASUREMENT OF WATER CONTENT OF SOILS

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Abstract. *The knowledge of the soil characteristics and properties are fundamental for agriculture and engineering. The present water in the soil influences those properties strongly and for that, the accurate, fast and of low cost measurement of the water content is a necessity in projects of scientific research, irrigation, constructions of dams and highways. The workimg principle of the thermal transdutor to measure the water content, proposed in this work, is the variation of the thermal diffusivity in function of the soil water content. The diffusivity was estimated through the heat transfer inverse problem. The direct problem was modeled using the energy equation in cylindrical coordinates, with first kind boundary conditions, determined experimentally. The inverse problem was solved by the Search in Net Modified Method .Calibration curves were built with the diffusivity data in function of the water content, using no lineal adjusts of a sigmoid function, for each soil type. The precision of the transdutor was analyzed calculating the standard deviation of the diffusivity measures. The mistake of a double standard deviation in diffusivity estimation results in a mistake smaller than 10% in the calculation of the water content. The thermal transducers can be used in situations where they are installed in the same position for all measures, such as in the irrigation by aspersion or by dripping and laboratory experiments.*

Keywords*: Soil Water Content, Thermal Transducers, Soil Thermal Properties, Calibration Curves, Inverse Problems*

PAC0174: NUMERICAL ANALYSIS ON THE HIGHLY FREQUENCY GROUP OF THE SUPPORT IN METRO OF CARACAS

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Abstract. *This word focus in the determining the state of strength and deformation of the supports of the automatic pilots system, emphasizing in the cause of the presence of cracks in the supports and the improve in their performance. The analysis of finite elements was the method used to do the resistance mechanical study and the mode analysis of the some element, we determined the relation of only 1,25 between the values of the own frequency of the actual produced model, and the predominant maximum frequency the graphic of spectral density and irregularities of the rail, in brings out as consequence high dynamism in the applied load on the supports, being the main cause of the existence of high values of tension and quick development of cracks, leading to the breaking of the element. We design a new model of support when not only writhe the improvement of the resistance of the element but as well the improvement of its perforce the dynamic loads.*

Keywords*: finite elements, mode analysis, vibrations, support*

PAC0179: STABILIZATION OF AN INVERTED PENDULUM BUILT ON A HORIZONTAL DISK

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Abstract. *The inverted pendulum history in Control, in the last 50 years, is a successful one. It has been used as a handy device for representing several types of unstable systems, like rocket boosters, robot arms, winch booms and, more recently, PPCars. In addition to that role inthe design of technological tools, inverted pendulums are importantand desired devices in most academic departments around the world: they make the teaching of Control and Dynamic Systems easy and interesting.*
This work is based on a thorough study of Prof. Furuta's inverted pendulum, followed by the design and construction of a prototype inthe laboratories of the Engineering School of UFF. The control was implemented with an AVR micro controller, using the LQR (LinearQuadratic Regulator) techniques. In addition to a detailed descriptionof the prototype design, this work presents simulated and measured results and conclusions. The device will be used in the Engineering School of UFF and in IF Fluminense as an academic tool in Controland Systems courses.

Keywords*: Automation and Control, LQR, Linear Quadratic Regulator, Inverted Pendulum*

PAC0195: A STUDY ON PARAMETRIZED APPLICATION PROGRAMMING FOR MANUFACTURE OF ELLIPTICAL CAVITY IN CNC MACHINES

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Abstract. *The computer numerical control (CNC) machines can be programmed. They have functions that help to get different superficies of varied geometry in the manufacturing process of mechanical parts. This research has the purpose to present a methodology of application of the resources of parametrized programming for the developing of manufacturing cycles to a machine (CNC). The parametrized programming seems to be an efficient tool to implement routines that the machine does not have. By using traditional programming resources, it reduces the number of programming lines in relation to more used methods. This work shows a technique that increases the machine operational efficiency by increasing the programming resources, and also add value to the use of the machine in the operational production process.*

Keywords: *computer numerical control, parametrized programming, manufacturing cycles, manufacture*

PAC0213: INFLUENCE OF AIR VELOCITY, TEMPERATURE AND INITIAL MOISTURE CONTENT OF GRAIN IN THE SOYBEAN DRYING

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Abstract. *The production of soybean requires that the product is collected healthy and in advance, to minimize losses caused by the attack in the field of insects, diseases and microorganisms. Therefore and due to high moisture content at harvest, drying is one of the operations of primary importance among the techniques involved in the conservation of desirable qualities of products of plant origin. The objective of this work is to obtain the drying curves of soya, in the range of drying air temperature between 45 and 90°C, for the initial moisture content between 0.13 and 0.32 and drying air velocity of 0, 0.5, 0.9, 1.5 and 2.5m/s to determine the influence of these parameters in the process. The*

experimental phase was performed using a prototype of which was a hair metal tube with 0.15m in diameter, insulated throughout its surface with glass wool and canvas. The air was heated by six electrical resistance with power of 600W, while the temperature was controlled with the aid of thermocouples connected to the drying equipment. Were also performed numerical simulations, where the mathematical model used was proposed by Khatchatourian (2003), and this search has changed the equation that describes the flow of mass, it is entering the parameters of air velocity and initial moisture content, obtaining a good agreement between experimental and simulated data. Was observed that the drying air velocity presents significant influence on the process, there is an increased withdrawal of water during the first hours of drying. Note that the influence of air temperature on the rate of drying is higher at the beginning of the experiment, reducing the processing time. The higher the temperature and airflow, the greater the drying rate and lower the total time of exposure to heated air.

***Keywords**: drying, soybean, numerical simulations*

PAC0230: EXPERIMENTAL AND THEORETICAL STUDY OF SOYBEAN DRYING IN THIN-LAYER

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***Abstract.** Drying tests of soybean disposed as a thin-layer were conducted for a temperature range of 45-100oC, velocity range of 0-3 m/s, grain moisture content of 13-30% and a variation of air relative humidity of 10-50%. In order to generate the required air humidity, water vapor was injected in the flow, after the air heater. The influence of these parameters on drying rate is observed during drying process. At the beginning of the time period, the main resistance for the mass transfer is on the contact surface between soybean seed and air. In posterior time, the humidity diffusion process inside soybean seed begins to limit the mass flux. For the initial time period, as the air velocity is increased, the drying process also increases, for all the moisture contents and temperatures, confirming the essential role of mass transfer on grain periphery. This behavior is more pronounced for drying at higher temperatures. As the the moisture content is reduced along the drying process, the role of mass diffusion inside grain become more important, reducing the air velocity influence. At absence of airflow (V=0), and for moisture contents grater than 19%, the drying rate practically does not depend of the initial moisture content. At small moisture contents (13 %), the drying process is essentially slowed down. To use the obtained results in models for deep beds, it was proposed to consider the grain composed by two compartments with different mass transfer coefficients.*

***Keywords**: grain drying, mathematical modeling, heat and mass transfer coefficients*

PAC0254: SINGLE LAP JOINT BONDED WITH ADHESIVE

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Abstract. *Bonded structure has been widely studied in the last years. There are many applications to the use of adhesives in place of mechanical joint (fastened or welded joint). Aerospace industries are developing new techniques to joint parts with structural adhesive. One of the best advantages of this process is the weight reduction and increase in fatigue life for the structure. The bonded joint will be effective if a good surface preparation is done. This study illustrates different configurations of superficial pre-treatments, behavior of contact angle and roughness. Single lap joint bonded specimen has been tested and different strength was found.*

Keywords*: Bonding, lap joint, adhesive, surface preparation*

PAC0262: EVALUATION OF THE IMPACT OF A TOLL PLAZA CONCERNING THE INCREASE OF TRAVEL TIME, CONSUMPTION OF FUEL AND THE GENERATION OF POLLUTANTS

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Abstract: *The toll plaza is an intervention installed in the road that requires a lower speed of travel by the vehicles. This change in velocity profile increases the travel time, generates an extra fuel consumption and increases the production of pollutants coming from the combustion of fuel. This research evaluates light, medium and heavy trucks, crossing the toll plaza of Jacarei at the President Dutra Highway km 165. The time required for a truck to cross the plazas area of influence and the delay to complete a transaction at a toll booth were measured. A computer simulation model, developed on Matlab Simulink platform, was used to estimate the consumption of fuel by the trucks. Field data was collected on a test truck using the Velocity Box (VBOX). Velocity and position were measured from the truck while crossing the plaza's area of influence to evaluate the performance of the System of Electronic Toll Collection (ETC). Results show that the use of Automatic Vehicle Identification (AVI), used in the form of "ETC", which enables the payment required in motion, softens the impacts involved. A medium truck, which travels from São Paulo to Rio de Janeiro fifteen times per month, has the travel time decreased in two hours and the fuel consumption in 30.2 liters, as a consequence of the use of AVI. An annual forecast of expenditure with fuel and emission of pollutants was made for the region under study. The effect of a toll plaza in the production of pollution was evaluated*

Keywords: *Toll, Fuel, Pollutants, AVI, Electronic toll collection*

PAC0280: CONTROL OF MICROBIAL CONTAMINATION IN METALWORKING FLUIDS AT LOW TEMPERATURES

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Abstract. *The continual expansion of industrialization has made production line procedures ever more important; however, too often certain aspects of these procedures have not been properly studied. Example of this is metalworking fluids, whose importance has long been known. Reports state that, in 1980, Taylor discovered that cooling with water greatly aided the cutting process. During the 20th century, crude oil derivatives were gradually incorporated into the lubrication and cooling process and their use became widespread. The association of these elements resulted in a system with numerous applications, offering the advantages of cooling by water and lubrication by oil derivatives. However, the water/oil system provides a favorable environment for the proliferation of microorganisms that alter the properties and reduce the service life of metalworking fluids. This makes it necessary to discard the contaminated oil is an undesirable process. Because it is a highly polluting substance for the environment, its disposal requires special care, which represents high costs for production systems. The specialized literature reports that millions of tons of these products are used annually, and it is obvious that these lubricants end up being discharged into nature in one form or another. Moreover, the presence of microorganisms in metalworking fluids is also a concern due to their potential health risks for workers. In view of these considerations, and taking into account that low temperatures hinder the reproduction of microorganisms, this study evaluated the effects of cutting fluid applied at low temperatures on the microbial population contaminating the fluid. This investigation involved the use of a simple, low cost cooling device composed of a coiled tube immersed in ice which considerably lowers the temperature of the cutting fluid as it passes through the coil. The procedure proved highly effective in controlling microbial proliferation in the cutting fluid, thereby prolonging its service life.*

Keywords*: metalworking fluids, microorganisms, contamination, hypothermia*

PAC0313: THE STRUCTURAL BEHAVIOR OF THE CATHEDRAL OF SÉ IN SÃO PAULO

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Abstract. *The Cathedral of Sé in São Paulo was inaugurated in 1954, when the fourth centenary of the foundation of the city was commemorated. Compared to the existing buildings in the region, its architecture is differentiated and it stands out for its predominantly Gothic style with a Renaissance dome. Its structure and behavior are studied with the aid of computational modeling, a practice that is very adequate for the analysis of complex structures in terms of geometry and materials. This article presents a study on the qualitative behavior of the church and the importance of some of its key structural elements for the equilibrium of the building.*

Keywords*: computational mechanics; numerical modeling; Cathedral of Sé in São Paulo; structural behavior*

PAC0315: APPLICATION OF NUMERICAL MODELING IN PREDICTING THE BEHAVIOR OF GROUP EXCAVATIONS IN SHANGHAI

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Abstract. *The construction of the Theme Park interchange station of Metro Line No. 6, No. 8, and No. 11 of Shanghai involves five deep excavations. All excavations are supported by diaphragm walls which are shared by neighbouring excavations. Therefore, a careful assessment of the interaction between the neighbouring excavations is required. These circumstances are relatively new and only limit information is currently available. To study the complex performance of the group excavations, three-dimensional finite element analysis assuming anisotropic soil stiffness are conducted to simulate the construction of five excavations. The predicted wall deflections of five excavations are compared with the field monitoring results. It is shown that the numerical simulation with anisotropic soil stiffness yields a reasonable prediction of the excavation deformation. Based on the field observations and three-dimensinal finite element analysis, it is found that the deformation of the shared diaphragm wall between neighbouring excavations is influenced by the construction sequences of the related excavations. The effect of the excavation on the diaphragm walls of neighbouring excavations decreases with increasing distance from the excavation. Ground surface settlement outside the group excavations is influenced by the shape of the group excavations. The maximum ground surface settlement is located at the intersection of five excavations.*

Keywords*: Group excavations, Three-dimensional finite element method, Anisotropic stiffness, Wall deflection, Ground surface settlement*

PAC0326: PROPOSAL FOR AN INTRODUCTORY COURSE OF INDUSTRIAL ROBOTICS WITH MULTIDISCIPLINARY SYLLABUS

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Abstract. *All over the world the industry's and students' interest by Robotics has increased. In addition to the fascination involving the subject, this is due to the fact that the robot manipulators can replace humans in dangerous, unhealthy and tedious tasks, in a viable economically and efficiently way. Thus, there is a need to expand and improve the education in this area, in accordance with the professional world. Several Universities are including a basic industrial Robotics course in their undergraduate and/or graduate curricula. However, most of these courses are strictly technical and do not approach other important issues related to the subject. The industrial Robotics has been evolving quickly and it is complex and multidisciplinary. Besides Mechanical, Electrical, Control and Computing, it also involves Production, Administration and Economy, among others. To elaborate a syllabus with all these topics with suitable depth is a hard task. Moreover, the limited time available for a semester course is an obstacle. The paper presents a proposal of an introductory course on industrial Robotics, multidisciplinary in nature, which provides solid theoretical foundations. This is a way of trying to unify the introduction to industrial Robotics in the Universities. It describes the prerequisites, the course content, the modalities of evaluation and the bibliographical references. According to the results of teaching it during four years for undergraduate students, the course has been proving to be effective. It can be offered in the final years of undergraduate or at the beginning of graduate Engineering educations.*

Keywords*: Education, Teaching, Industrial Robotics, Robotic Manipulators*

PAC0376: PROPOSAL OF A SOLID STATE SWITCHING AND SIGNAL CONDITIONING SYSTEM FOR STRUCTURAL HEALTH MONITORING BASED ON PIEZOELECTRIC SENSORS/ACTUATORS

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Abstract. *The Structural Health Monitoring – SHM method based on electrical impedance has been developed as a promising tool for structure failure identification in real time and is considered a novel non-destructive evaluation method. The piezoelectric - PZT impedance can be directly associated to the structure's mechanical impedance where de PZT is bonded. Assuming that the mechanical PZT properties do not change over the monitoring time, the electrical PZT impedance can be used for monitoring structural health. The use of each PZT as both sensor and actuator reduces the total number of sensor and wires connecting them to the switching circuit. The technique consists in obtaining Frequency Response Functions - FRF, with the related signal modification, periodically. Modifications in the FRF of each PZT would indicate structural changes and, therefore, a possible failure. The required number of PZTs will be determined by the dimensions of the monitored structure and the precision required for locating a possible failure. To obtain the FRF of the entire monitored structure it is used a switching and signal conditioning system that continuously activate and deactivate each PZT. This paper proposes a solid state, low power, small sized and low signal distortion switching system. The system is quite modular and each module can manage 16 PZTs. It is possible to expand the sensing net by interconnecting a non limited number of modules. Descriptions of the working principles, circuits used and experimental results are presented.*

Keywords*: Structural Health Monitoring, PZT, Piezoceramic material, Switching System*

PAC0387: RESIDUAL STRESS EVALUATION IN FLAT CARBON STEEL PLATES , APPLIED TO LASER CUTTING PROCESS, BY ANISOTROPY PLANAR METHOD

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Abstract. *The present article evaluates a methodology for material analysis, especifically hot rolled carbon steel plates, in relation to residual stress. It was also introduced topics referred to the manufacturing process, material obtainment, anisotropy and extensometric measurement methods for residual stress analysis.. The aim of this*

work is the study of residual stress in materials (carbon steel plates) that can cause interference in the quality of processing needed for good effectiveness in laser cutting process. The presented results were based on the analysis of samples used in the industry and point out a way of evaluating whether certain material can present stresses that are harmful to the process during the laser cutting. One of the main causes of non-conformities is the collision between the head-cutting device and the material. With the results of this work aim to reduce machine stoppage, discard of material and non-expected maintenance. The method is suggested with the aid of planar anisotropic evaluation and their results were validated via residual stresses analysis by means of extensometric uniaxial techniques. A series of tests were performed with the proposed method and their results showed the performance obtained and its employability.

***Keywords**: Residual stress, anisotropy, extensometry, laser cutting*

PAC0396: MECHANICAL CHARACTERISTICS OF CHEMICALLY DEGRADED SURFACE LAYERS OF WOOD

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***Abstract.** The aim of this research was to find out whether the effect of chemical corrosion changes mechanical characteristics of surface layers of wooden construction elements. Degradation of the surface layers of wood was caused by chemical reactions of the basic substances of wood mass with compounds contained in antifire coatings. Fire retardants containing corrosive substances were often and repeatedly used in the Czech Republic on many wooden building constructions. This process of chemical corrosion is in practise called as "surface defibering of wood". This contribution presents standard and special experimental methods used for measuring the selected mechanical characteristics (compression strength, tension strength, bending strength, hardness and impact resistance) in the damaged surface layer of wooden construction elements. The material for experimental measuring was a construction element removed from a historical roof (ca 150 years old). Mechanical characteristics of the surface layer of the defibered element were compared with the values measured in the deeper subsurface layer of non-damaged wood. The results of the experiments proved loss of cohesive strength and decrease of mechanical characteristics of wood only in a thin surface layer.*

***Keywords**: wood, corrosion, defibering, mechanical properties*

PAC0413: DYNAMIC MODELLING AND SIMULATION OF A SIX WHEEL AUTOMATIC GUIDED VEHICLE

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Abstract. *This work describes the construction of a dynamic model of the suspension and locomotion subsystems of an Automatic Guided Vehicle (AGV). The vehicle has six wheels, four are caster type in the corners and the other two in the center of the AGV are driven by electric motors with gearboxes. The vehicle has a straight displacement when the two wheels have the same speed and are used for differential steering of the vehicle when one of the wheels have a higher or lower speed than the other. All the six wheels joint to the vehicle chassis by a suspension, which is composed by a spring and a damper for each wheel. The model is made using the software Universal Mechanisms for the simulation of kinematics and dynamics of planar and spatial mechanical systems. The model is tested and adjusted to meet the real AGV constructed at the Mechanical and Mechatronics Department of the National University of Colombia, at Bogota. The future utility of the model is to be used for the design and test of the motor controllers to follow programmed paths.*

Keywords*: Dynamics, Car modeling, Automatic guided vehicle, Simulationv*

PAC0415: FINDING OPTIMAL GENETIC ALGORITHM PARAMETERS FOR A COMPOSITE WING OPTIMIZATION

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Abstract. *The optimization target is to minimize the structural weight of a composite wing. All laminates are defined using 202 variables. The sample space being studied has $7.2x10^{133}$ possibilities of lamiantes. It is then necessary to use a proper search algorithm. The multi-objective genetic algorithm (MOGA-II) was chosen. Conventional crossover is comapared to directional crossover ove and the influence of population size reduction while raising the number of generations is studied. A commom computer has been used – CPU with a 2.7GHz Core 2 Duo Intel Processor and 2.0 Gb 1066Mhz RAM (Dual Channel). The single objective is to minimize the structural weigh. The single design constrain applied is to keep bucklin laod factor equal of higher than 1 (one).*

Keywords*: composite, genetic algorithm, optimization, genetic algorithm parameters*

PAC0432: AIRFOILS CLASSIFICATION USING PRINCIPAL COMPONENTS ANALYSIS (PCA)

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Abstract. *The importance of air transport has grown considerably in recent decades. Therefore, much research on the aircraft is made. Research on airfoils, or aerodynamical profiles, is an example of a focus of study. Basically, the airfoils consist of a two-dimensional section used in order to fly with changes of velocities of a flux around the airfoil. In aircrafts, the airfoils are present in the wings and empennage, being the former generally asymmetric airfoils (generating lifting and greater moment, so the drag is lower), and for the second, as symmetrical airfoils. The objective of this study is to classify airfoils using principal components analysis (PCA), which is a statistical technique that aims to find patterns to represent changes in many variables, using a smaller number of factors. Its operation is to build a new system of principal components for the representation of the samples, so less dimensions can be considered. Thus, this method presents a lower computational complexity and also the benchmark to obtain results is reduced. The methodology to be developed is as follows: Initially, the data are digitalized. In the next stage, pre-processing is carried out. Subsequently, the correlation matrix is estimated. In the fourth stage, the eigenvalues and eigenvectors of correlation matrix are determined, so that the eigenvectors are indexed by increasing order of eigenvalues. Then, the eigenvalues and the more representative associated eigenvectors are chosen, in order to form the characteristic vector. Subsequently, the sample is projected into a new sub-vector space. Finally, the image is classified with the database formed. The results were favorable, in order to classify airfoils using principal components analysis; this was achieved with a computer algebraic system.*

Keywords*: airfoils, Principal Components Analysis, computer algebraic system, correlation matrix*

PAC0436: ROVER 1/S60 TURBOSHAFT PERFORMANCE AND EMISSIONS ANALYSIS WITH BIODIESEL/ AVIATION KEROSENE BLENDS

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Abstract. *The transesterfication process is the reaction between a triglyceride (animal or vegetal fatties) with a primary alcohol (methanol or ethanol) in a catalyst presence producing glycerol l and a mixture of fatty esters. This mixture of esters has physical-chemical properties similar to Diesel fuel derivate from petroleum and is called Biodiesel. Several tests have been performed comparing diesel and several kinds of esthers (biodiesel), most in reciprocating engines but also in micro-gas-turbines. This work studies a stationary turboshaft Rover 1/S60 performance and pollution emissions in the utilization of several blends of aviation kerosene and biodiesel. The tests also show that no significative changes occurred in turboshaft operation. This study also shows an increase of fuel consumption and a decrease in thermal efficiency and a decrease of pollutant species emission as the higher biodiesel proportion at blends are used at turboshaft operation.*

***Keywords**: Biodiesel, Gas turbines, Pollutant emissions, Aviation kerosene, Turbine performance*

PAC0554: AN OVERVIEW OF THE END TO END EXAMPLE: AN ILLUSTRATION OF THE CONCEPTS OF VERIFICATION AND VALIDATION

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***Abstract.** The American Society of Mechanical Engineers (ASME) Standards Committee on Verification and Validation in Computational Solid Mechanics (V&V 10) approved their first document (Guide) in July 2006. The Guide has been approved by ASME and the American National Standards Institute (ANSI) for public release. The Guide is available through ASME publications as V&V 10-2006: Guide for Verification and Validation in Computational Solid Mechanics http://catalog.asme.org/Codes/PrintBook/VV_10_2006_Guide_Verification.cfm in developing the Guide, the Committee was constantly aware of the lack of both examples and in depth discussion of the many topics comprising Verification & Validation. The Committee intended, and is now taking action, to provide examples and in depth discussions. The Committee's first offering in this planned series of documents is the present End-to-End Example. The Committee hopes to approve this document and have it published in early 2010.*

***Keywords**: Verification, Validation, Computational Mechanics*

PAC0560: FRP COMPOSITES FOR THE REINFORCEMENT OF NT PLANE STRUCTURES: THEORETICAL AND EXPERIMENTAL RESULTS

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Abstract. *A computational procedure for two-dimensional equilibrium problems, which are representative of the behaviour of masonry walls loaded by in-plane forces, is analysed in the paper. The solution is searched through an optimisation procedure according to the conjugate gradient method interpolated with relaxation intermediate steps. The procedure is tested from the point of view of accuracy and convergence, with reference to a masonry wall with openings, stringcourses and architraves, subject to a horizontal force. Finally some laboratory experiments concerning the lateral loading of a door-panel are reported, and the comparison with the numerical results relevant to a FEM no-tension model of the specimen is discussed.*

***Keywords**: Masonry walls, No Tension model, FRP, theoretical approach, Experimental tests*

NOTES

A. INSTABILITY PHENOMENA IN MATERIALS AND STRUCTURES

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INVITED LECTURE

CONTINUOUS - AND DISCRETE - TIME MODELS FOR THE PEDESTRIANS - FOOTBRIDGES SYNCHRONIZATION

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ABSTRACT. *In this work a relatively novel instability phenomena of monodimensional structures is investigated in depth. We study the synchronization of the pedestrians motion with the lateral motion of slender footbridges, which attracted the attention of researchers mainly after the Millennium Bridge well known event. We consider two models to detect the phenomenon. A continuous-time bridge-pedestrians model initially developed by Strogatz and co-workers is improved to better understand some aspects of the underlying mechanical phenomena. We perform extensive parametric investigations by means of systematic numerical simulations. This permits to highlight the parameters which mainly affect the trigger and the development of the phenomenon of synchronous lateral excitations, thus allowing a good understanding of the physical event and an evaluation of the engineering reliability of the model. Then, in order to obtain analytical instead of numerical predictions, a nonlinear discrete-time model based on stroboscopic Poincarè map is considered. It is able to provide a reliable value of the number of pedestrians which trigger the synchronization, thus predicting the onset of instability which is also the onset of crowd synchronization. From a dynamical system point of view, the main result is that the model highlights how the phenomenon can be seen as a perturbation of a classical pitchfork bifurcation, which is then shown to be the underlying dynamical event.*

Acknowledgement. This lecture was made possible through financial support from Pró-Reitoria de Pós-Graduação (PRPG/USP).

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NOTES

PAC0075: VORTEX-INDUCED INSTABILITIES IN OFFSHORE CATENARY RISERS: A NON-LINEAR NORMAL MODE APPROACH

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Abstract. *Offshore catenary risers are used in the exploitation of deep-water oil and gas fields, such as those along the Brazilian Southeast coast. They are subjected to severe dynamical loads, such as those related to inside flow of fluids under high pressure, external flow of sea currents and imposed motion by the floating production platform, due to sea waves. In this paper, an introductory study is presented that addresses the dynamic instability due to VIV (vortex-induced vibrations) caused by sea currents. The motion of the TDP (touch-down point), where the riser touches the seabed, and the mooring motion at the riser top end,where it meets the floating unit, are neglected here for the sake of simplicity, although it is known that they play an important role in the dynamic response of catenary risers, to be addressed in a future work. The non-linear normal modes of a finite-element model of a catenary riser with fixed ends are initially determined, using a computational tool [8] based on the invariant manifold procedure, proposed by Shaw and Pierre [9]. Then, a mode that is particularly prone to be excited by VIV is selected and a reduced mathematical model that couples the structural modal response and the fluid dynamics of the VIV, as described by a van der Pol oscillator [3], is used to foresee the post-critical vibration amplitudes. Results are compared with those coming out from a linear analysis.*

Keywords: *Risers, Catenary, VIV, Non-Linear Modes, Finite Element Method, Offshore*

PAC0095: DYNAMIC INSTABILITY OF INCLINED CABLES UNDER COMBINED WIND FLOW AND SUPPORT MOTION

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Abstract. *In this paper the combined effects of external plus parametric excitation and a Hopf bifurcation are investigated on an inclined cable. A nonlinear 3D continuous model of inclined sagged cable is adopted and a sinusoidal, vertical motion of given amplitude and frequency is imposed on the lower end. A uniform wind flow, blowing perpendicularly to the plane of the static configuration, is also considered. The resulting equations are discretized via the Galerkin method, by assuming one in-plane and one out-of-plane modes. The two resulting second-order, non-homogeneous, time-periodic, ordinary differential equations are coupled in the nonlinear part, containing quadratic and cubic nonlinearities, both in the displacements and velocities. They are tackled by the Multiple Scale perturbation method, which leads to three first-order amplitude-phase modulation equations, governing the slow dynamics of the cable. Three control parameters appear, namely, the wind speed, the amplitude and the frequency of the support motion. Numerical integrations provide bifurcation diagrams as functions of the control parameters, able to highlight the interactions between the two sources of excitation.*

Keywords*: Inclined cable, support motion, aeroelastic instability, external excitation, parametric excitation*

PAC0102: POST-BUCKLING BEHAVIOR OF RESTRAINED THIN-WALLED STEEL BEAMS USING GENERALIZED BEAM THEORY (GBT)

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Abstract. *A numerical investigation on the local, distortional and global post-buckling behavior of restrained thin-walled steel beams is reported. All the results are obtained by means of geometrically non-linear analyses based on a recently developed Generalized Beam Theory (GBT) formulation that incorporates the influence of non-standard support conditions. The results presented, most of which are compared with values yielded by shell finite element analyses (for validation purposes), include critical buckling loads and mode shapes, post-buckling equilibrium paths, deformed configuration representations and nornal stress distibutions. Taking advantage of the GBT modal nature, these results are discussed in detail and it is possible to unveil, explain and/or shed some new light on a number of interesting and scarcely known behavioral aspects.*

Keywords: *Thin-walled steel members, Post-buckling behavior, Non-linear Generalized Beam Theory, GBT-based beam finite element, Localized displacement restraints*

PAC0112: ELASTIC PROPERTIES OF ZINC OXIDE NANOWIRES – BRIDGING THE GAP BETWEEN EXPERIMENTS AND THEORY

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Abstract. *Nanowires made of semiconducting materials, like zinc oxide (ZnO) and gallium nitride (GaN), exhibit outstanding optoelectronic, piezoelectric and biocompatible properties. These nanowires, therefore, constitute suitable building blocks for the next generation of nano devices with potential applications in sensing and actuation. For such nanoscale devices to perform optimally and reliably, unambiguous characterization of material properties is crucial, particularly because properties different from bulk emerge when the characteristic dimension of nanostructures falls below 100 nm. However, experimentation at the nanoscale has proven challenging and elusive. In this presentation, the usage of a micro-electro-mechanical system (MEMS) based nanoscale material testing system as a platform for in-situ electron microscopy testing of one dimensional (1-D) nanostructures will be discussed. In this paper, the relevance of boundary and loading conditions applied in these experiments is illustrated by considering "elastic properties of ZnO nanowires" as a case study. Experiments reveal a size dependent elastic modulus for ZnO nanowires below a wire diameter of approximately 80nm. The experimental findings are analyzed by means of atomistic simulations, therefore, bridging the gap between experiments and theory. A direct comparison between experiments and simulations is possible mainly due to the well-defined boundary/loading conditions in the experiments, which were implemented in our computational models with minimal assumptions. A detailed analysis of computational results is carried out to provide an atomistic understanding of the origin of the observed elasticity size effects. In particular, the effect of surface reconstruction in reducing the interatomic spacing of surface atoms, with respect to bulk, is discussed in the context of nanowire surface to volume ratio.*

Keywords*: MEMS, In situ testing, Size effects, Semiconducting nanowires, Molecular Dynamics*

PAC0113: FAILURE MECHANISMS OF ZINC OXIDE NANOWIRES

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Abstract. *Nanowires have conceptually been shown as potential building blocks for next-generation nano devices. For instance, nanowires made of semiconducting material like zinc oxide (ZnO) act as nanogenerators due to their electromechanical behavior. When mechanically deformed, an electrical voltage develops across these nanowires, which can be extracted to operate small-scale devices with low power requirements. The voltage output from these nanowires is proportional to the applied mechanical strain. To optimize the performance of such nanowire-based devices, it is crucial to characterize their failure and piezoelectric properties at the single wire level. In this paper, failure mechanisms for ZnO nanowires will be discussed. Experiments revealed brittle fracture at strains ranging from 3% to 6%, which are much higher than the strains at which bulk material fails. The higher failure strains were correlated to the defect-free single crystalline morphology of the nanowires as observed by high resolution electron microscopy. However, the variation observed in fracture strains suggested the need for modeling, for which atomistic simulations were performed. Molecular dynamic simulations, based on a Buckingham-type pairwise interatomic potential, predicted a stress-induced phase transformation from a wurtzite (WZ) to a body-centered tetragonal (BCT) crystal packing at ~6% strain. This WZ-BCT transformation was not observed experimentally. To validate the accuracy of the interatomic force fields, first principles-based calculations were performed using density functional theory (DFT) with the Perdew-Burke-Ernzerhof functional and a double-zeta plus polarization orbital basis set. DFT studies also revealed a phase transformation, but at a much higher strain of ~19%. Possible reasons for the observed differences in experiments and theoretical predictions and new directions of inquire to resolve them will be discussed.*

Keywords*: Fracture mechanisms, Phase transformation, Molecular dynamics, Quantum mechanics*

PAC0168: A COMPARISON OF TWO MICROPLANE CONSTITUTIVE MODELS FOR MODELING QUASI-BRITTLE MATERIALS

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Abstract. *This article presents a comparison of two Microplane Constitutive Models. The basis of the microplane constitutive models are described and the adopted assumptions for the conception of these models are discussed, with regard to: decomposition of the macroscopic strains into the microplanes, definition of the microplane material laws, including the choice of variables that control the material degradation, and homogenization process to obtain the macroscopic quantities. The differences between the two models, with respect to the employed assumptions, are enphasized and expressions to calculate the macroscopic stresses are presented. The models are then used to describe the behavior of quasi-brittle materials by Finite Element simulations of uniaxial tension and compression and pure share stress tests. The results of the simulations permit to compare the capability of the*

models in decribing the post critical strain-softening behaviour, without numerically induced strain localization.

Keywords*: icroplane Constitutive Models, Finite Element Method, Nonlinear Analysis, Quasi-Brittle Materials*

PAC0201: PLASTIC BUCKLING OF CONCRETE FILLED CIRCULAR TUBULAR (CFT) STEEL COLUMNS

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Abstract. *Local buckling of axially compressed concrete-filled tubular (CFT) steel columns of circular section (i.e., circular cylindrical shells) is considered. The concrete fill is assumed not to have any bond with the shell wall, and is therefore assumed incapable of providing any tensile resistance to the outward buckling of the wall. However, by virtue of contact, the fill is considered to offer compressive resistance against the inward buckling. Furthermore, it is assumed that the thickness of the shell is such that the buckling occurs beyond the elastic limit, in the plastic strain-hardening range. The problem is tackled by employing exact mathematical analysis, as the elastic/plastic bifurcation of an axially loaded circular cylindrical shell of infinite length resting against a tensionless (one-way) foundation. The plastic behaviour of steel is modeled by the deformation theory of strain hardening plasticity. On the other hand, the tensionless foundation provided by the concrete fill, is assumed to remain elastic in compression. It is shown that the failure loads calculated as the sum of the predicted bifurcation loads of the steel shell plus the crushing loads of the concrete agree very well with the experimentally determined buckling loads of other researchers.*

Keywords: *Filled Circular Shells, One Way Buckling, Elastic Foundation, Plasticity, CFT Columns*

PAC0216: INFLUENCE OF AXIAL LOAD UNCERTAINTIES ON THE NONLINEAR OSCILLATIONS OF CYLINDRICAL SHELLS

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Abstract. *The aim of this work is to investigate the influence of axial load uncertainties on the nonlinear vibrations of simply-supported cylindrical shells. The axial load is composed by both harmonic deterministic and random terms; the random term depends on the parameters of the harmonic deterministic load. Donnell's nonlinear shallow shell equations in terms of the in-plane and transversal displacements are used to study the nonlinear vibrations of the shell. To discretize the partial differential equations of motion, first, a general expression for the transversal displacement is obtained by a perturbation procedure which identifies all modes that couple with the linear modes through the quadratic and cubic terms in the equations of motion. Then, a particular solution is selected which ensures the convergence of the response up to very large deflection. Finally, the in-plane displacements are obtained as a function of the transversal displacement by solving the in-plane equations analytically. So, the proposed solution satisfies all boundary, continuity and symmetry conditions. Substituting the modal expansion of the transversal displacement into the equation of motion and applying the Galerkin's method, a discrete system in time domain is obtained. Several numerical strategies are used to study the nonlinear behavior of the shell under an axial load with uncertainties. Special attention is given to the influence of the random term on the parametric*

instability and escape loads.

***Keywords**: Dynamic instability, Load uncertainties, Nonlinear analysis, Cylindrical shells*

PAC0279: THE EFFECT OF SUPPORT SPRINGS IN AN ENDS WELDED GAP HOLLOW YT-JOINT

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***Abstract.** This paper presents an analysis of the effect of support springs in an ends circular hollow steel sections welded into a YT joint. The overall behavior and failure of the joint were characterized under axial compression of the lap brace. Two joint failure modes were identified: chord wall plastification (Mode A) and cross-sectional chord buckling (Mode F) in the region below the lap brace. The system was modeled with and without support springs using the numerical finite element program Ansys. Model results were compared with experimental data in terms of principal stress in the joint intersection. The finite element model without support springs proved to be more accurate than that with support springs.*

***Keywords**: Support Springs, Hollow Structures, YT Joints, Numerical Analysis, Experimental Analysis*

PAC0301: EXPERIMENTAL DETECTION OF INSTABILITY IN MATERIALS AND STRUCTURES

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***Abstract.** This paper aims to introduce a new nondestructive testing technique in use for detecting the occurrence of material instability and a specific data reduction procedure to assess damage accumulation. An input-output non-parametric procedure based on ultrasonic pulse propagation, and a nonlinear analyzer were chosen to portray the unstable behavior of brittle rock material under static compressive loading. It can be used to monitor nondestructively and continuously the overall alteration or damage process so that damage mechanisms could be quantitatively estimated by a dimensionless parameter the so-called nonlinearity ratio.*

***Keywords:** Material Instability, Nondestructive Testing, Nonlinear Analyzer, Nonlinearity Ratio, Ultrasound Propagation*

PAC0304: AN APPROXIMATE ANALYTICAL SOLUTIONS OF MECHANICAL PROBLEMS FOR STRUCTURES WITH VARIABLE PARAMETERS

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Abstract *This paper deals with some new asymptotic solutions for actual mechanical problems of structures with variable parameters. A number of complex mechanics problems can be significantly simplified due to application of hybrid asymptotic approaches. Such solutions can be used as an approximation for the further numerical calculations. to A wide variety of deformable structures with variable geometry and time dependent parameters, reduced to singular differential equations with variable coefficients and boundary problems, can be solved analytically only in exceptional cases. Since the field of the most known asymptotic solutions application is limited, hybrid asymptotic methods are in the stage of developing. Phase integral – Galerkin (or WKB-G) technique proposed by the author has already shown its advantages in different branches of mechanics and it enables to find an approximate solution as an asymptotic one. The hybrid technique permits to obtain especially good results in solution of singular differential equations. New results of application of a hybrid WKB-G method for the deformation and shape control problems, buckling and vibration of structures, heat transfer and comparison with known analytical and numerical results are given. The obtained solutions possess a high accuracy and can be useful in a wide variety of applications. Some problems for father investigations are discussed.*

Keywords*: variable geometry, time dependent parameters, hybrid WKB-G method, buckling and vibration*

PAC0305: NON-LINEAR DYNAMICS AND IMPERFECTION SENSITIVITY OF AUGUSTI'S MODEL

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Abstract. *The influence of material and geometric imperfections on the non-linear behavior and stability under static and dynamic loads of Augusti's model is analyzed in this paper. This 2DOF lumped-parameter system is an archetypal model of modal interaction in stability theory representing a large class of structural problems. When the system displays coincident buckling loads, several post-buckling paths emerge from the bifurcation point (critical load) along the fundamental path, in particular unstable post-buckling paths that control the nonlinear dynamics of the systems for load levels lower than the critical load. Systems displaying unstable post-buckling behavior are particularly sensitive to initial imperfections. They decrease the static buckling load and distort the topology of the safe potential well. Herein, coupled/uncoupled dynamic responses, bifurcations, escape from the pre-buckling potential well, stability and space–time-varying displacements, attractor-manifold-basin phase portraits are numerically evaluated with the aim of enlightening the system imperfection sensitivity. In particular, the investigation of basins evolution due to variation of system parameters leads to the determination of erosion profiles and integrity measures which enlighten the loss of safety of the structure due to penetration of eroding fractal tongues into the safe basin.*

Keywords*: Augusti's Model, Modal Coupling, Non-Linear Oscillations, Imperfection Sensitivity, Dynamic Instability.*

PAC0329: WIND BUCKLING OF METAL TANKS DURING THEIR CONSTRUCTION

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Abstract. *Shell structures are usually designed by considering their final shape and configuration, so that it is assumed that stability during the construction will be satisfied without further thought. However, evidence from recent collapses of metal tanks under moderate winds shows that this is a matter that requires special attention. This paper reports analytical studies of tanks for the oil industry that failed during their construction in the Argentinean Patagonia under moderate winds. The cylindrical part of the tanks was set up in place with point welding, but the roof was not yet in place at the time of collapse. To understand the mechanism of failure, static, geometrically nonlinear finite element modeling of the tanks was carried out, in which the shell was represented as close as possible to the actual conditions during the construction stage at which it failed. The results show that for the wind velocities prevalent at the time of collapse, an explanation of the failure mechanism can only be achieved by taking into account several special features of the structure under construction, i.e. the localized nature of welding and the influence of the incomplete junction with the bottom plate.*

Keywords*: Buckling, Finite Elements, Structural Collapse, Tanks, Wind*

PAC0352: CYCLIC BUCKLING AND POSTBUCKLING BEHAVIOR OF LAMINATED STRINGER STIFFENED COMPOSITE CYLINDRICAL PANELS WITH DAMAGE

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Abstract. *Curved blade stringer-stiffened composite panels were tested under axial compression to yield the "first" buckling and postbuckling behavior till collapse. Except for one panel, used as a reference panel, all of the panels had stringers without drop-off layers. Some panels contained either artificial type damage or both artificial and impact induced damage. Cyclic/repeated buckling was applied well in relatively "deep" postbuckling region. It was demonstrated that neither repeated buckling, within the number of cycles applied in the present program, and/nor the artificial damage and the induced impact damage, that were introduced into the panels, resulted in stiffness degradation of the panels. No premature failure of any of the tested panels was observed within their expected life cycle, i.e. exposure to a few hundred of cycles deep in the postbuckling region, even in presence of either type or combination of the above damage. All of the tested panels sustained repeated postbuckling loading till they were subjected to static loading aimed at determining their collapse loads. In spite of the present design, i.e. stiffeners with no drop-off plies that aimed amongst other at providing a mechanism for initiating stiffener debonding no skin-stringer separation was encountered till collapse of the panels. It was found that composite stringer-stiffened panels can be safely and repeatedly loaded in their deep postbuckling range with no degradation in their stiffness. Damage, either due to manufacturing or impact, that usually will result in rejection of a structural element neither affect the load carrying capacity nor the capability to withstand repeated loading in relatively very deep postbuckling range within the designed life cycle of the element. It was realized that manufacturing complexities and consequently costs can be reduced by employing a simplified design configuration where the use of a drop-off ply of the stringer base was eliminated.*

Keywords: *Cyclic buckling, Postbuckling behavior, Stringer-stiffened curved panel, Artificial damage, Debonding and Impact damage*

PAC0353: THERMAL STRESSING EFFECTS IN MATERIAL WITH ROUGH COATING CAUSED BY ELECTROMAGNETIC RADIATION ENERGY DISSIPATION

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Abstract. *Thermal stressing effects caused by heat evolution due to dissipation of energy of a pulse of electromagnetic radiation in material with coating are addressed. The heat evolution is averaged over the time period, which is much greater than a characteristic period of electromagnetic vibrations and much smaller than the pulse typical duration . The coating surface is assumed stress-free, and quasi-static conditions are considered. Provided that the radiation typical wave length exceeds well the roughness typical step and the radiation intensity varies gradually enough along the coating surface, compressive thermal stresses (basic stresses) appear, beneath it, act and vary gradually enough along it, experiencing relatively small roughness-induced disturbances. Two effects of the basic stresses are considered: (i) the relatively small effect of the thermal compressive stress concentration on rough surface and (ii) the effect of instability of the coating brought about by the basic stresses, which effect may appear in the presence of a long enough crack within the coating-substrate interface, and subsequent behavior of the coating, including its progressive detaching (the effect of roughness being neglected). The result of consideration of effect (i) has been obtained, as first approximation with respect to basic stresses treated, as zero approximation. This result allows find the onset of attaining the elasticity limit at roughness determined most dangerous places and may, in particular, be applied to predict fatigue longevity of mirrors used to reflect intensive enough radiation and experiencing multiple impacts of the above type pulses. The result of consideration of effect (ii) may be applied to estimate the degree of danger of lengthy enough zones of essential weakening of adhesion between the coating and the substrate.*

Keywords: *Thermoelasticity, Coating, Rough Surface, Stress Concentration, Fatigue, Instability*

PAC0373: INSTABILITIES IN ARCH SHAPED MEMS

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Abstract. *Arch shaped microelectromechanical systems (MEMS) have been used as mechanical memories, micro-relays, micro-valves, optical switches, and digital micro-mirrors. A bi-stable structure is characterized by a multivalued load deflection curve. Here, the symmetry breaking, the snap-through instabiity, and the pull-in instability of a sinusoidal shaped MEMS under static and dynamic electric loads have been studied. Unlike mechanical loads, the electric load is a nonlinear function of the a priori unknown deformed shape of the arch, and is thus a follower type load. The nonlinear partial differential equation governing transient deformations of the arch is solved numerically using the Galerkin method and the resulting ordinary differential equations are integrated by using the Livermore solver for ordinary differential equations. For the static problem, the pseudo-arc length continuation method is used to obtain the bifurcation curve of the MEMS displacement versus a load parameter. Two distinct mechanisms of the snap-through instability for the dynamic problem are demonstrated. It is found that critical loads and geometric parameters for instabilities of an arch under an electric load with and without the consideration of mechanical inertia effects are quite different.*

Keywords: *Symmetry breaking, pull-in parameters, snap-through instability, bi-stability, pseudo-arc-length continuation*

PAC0440: INSTABILITY ANALYSIS USING A WAVELET-BASED MULTIRESOLUTION METHOD

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Abstract. *The use of multiresolution techniques and wavelets has become increasingly popular in the development of numerical schemes for the solution of partial differential equations (PDEs), like the wavelet-Galerkin method. Therefore, the use of wavelets as basis functions in computational analysis holds some promise due to their compact support, orthogonality, localization and multiresolution properties, especially for problems with local high gradient, which would require a dense mesh in tradicional methods, like the FEM. Another possible advantage is the fact that the calculation of the integrals of the inner products of wavelet basis functions and their derivatives can be made by solving a linear system of equations, thus avoiding the problem of approximating the integral by some numerical method. These inner products were defined as connection coefficients and they are employed in the calculation of stiffness, mass and geometry matrices. The formulation of a wavelet-based analysis is demonstrated for a one-dimensional problem using interpolating wavelets (Interpolets). Static and Instability examples are proposed.*

Keywords*: Wavelets, Interpolets, Multiresolution, Instability*

PAC0463: COMPOSITE PIPING DYNAMICS UNDER INTERNAL FLOW

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Abstract. *This work presents the simulation of a composite piping system under different flow velocities. The fluid and structural domain are modeled as unidimensional problem while the fluid behavior is described in velocity formulation. For the coupled fluid-structure problem the Finite Element Method is employed to solve the final linearized system. The behavior of the system frequencies under internal flow are used to asses the reinforcement. Remarks are made about structural reinforcement and its boundary condition. The structural problem uses simplified models for both composite and sandwiched structures.*

Keywords*: Composite piping, fluid-structure interaction, Structural vibration, finite elemente method*

PAC0532: AXIAL COMPRESSION PROPERTY OF L-SHAPED COLUMN COMPOSED OF CONCRETE-FILLED SQUARE STEEL TUBES

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Abstract. *An L-shaped column composed of concrete-filled square steel tubes (LCFST) was tested and analyzed by three methods: Axial compression experiment, Finite element analysis and Analytical method. The ultimate loads of the three methods were in agreement with each other well. All three methods indicate that the LCFST column fails in a flexural-torsional buckling mode.*

Keywords: *LCFST column, Stability, Axial compression experiment, Finite element analysis, Analytical method*

B. CONTROL METHODS FOR MECHANICAL SYSTEMS

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NOTES

PAC0079: SPEED ESTIMATION IMPROVEMENT USING KALMAN FILTER FOR A HAPTIC INTERFACE

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Abstract. *A haptic system is an articulated mechanical structure with motors, position sensors as well as embedded electronics allowing force feedback. It enables the user to interact with an image in virtual reality through the sense of touch and sight. Our test bench is a single degree of freedom system, which is part of six degrees of freedom Surgicobot surgical robot. The speed of such robots is imposed by the user. Thus, the user can freely move the robot handle away from critical regions and when necessary, the robot generates force constraints to prevent unwanted motion. The robot speed is calculated from the position information. Our testbed is a single degree of freedom haptic interface driven by Permanent Magnet Synchronous Motor (PMSM). PMSM offers low rotor inertia, efficient heat dissipation and compact volume and the control algorithm is implemented using the TMS320F2812 fixed point DSP. This paper describes the implementation of a Kalman filter for speed estimation and compares its performances to the Synchronous Constant Elapsed Time (SCET) method. The SCET method estimates the rotor speed by using rotor position samples coming from a FIFO stack so as to caculate the average speed. The filter design criteria for haptic interface are analyzed. Their influence on system stiffness is illustrated. The effects of the control loops sampling period and Kalman filter cut-off frequency on speed estimation quality and the obtained stiffness are discussed. It is shown that the proposed speed estimation method enhances the speed estimation quality and increases the stiffness by 44% compared with the one obtained by using the SCET method.*

Keywords*: Kalman filter, Haptic interface, Permanent Magnet Synchronous Motor (PMSM), Stiffness, speed estimation*

PAC0107: A ROBUST CONTROL STRATEGY FOR DRAG REDUCTION IN FLUID MECHANICS

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Abstract. *This paper is devoted to the problem of defining a control strategy to minimize the drag of a bluff body in an incident 2-D cross-flow. After discretizing the Navier-Stokes equations, the reduced model is obtained using the classic Karhunen-Loève statistical reduction. An optimal orbit in the phase space, minimizing a quadratic criterion, is obtained using an open-loop control strategy. Since the deviations are meant to remain small, the non-linear flow model can be linearized around the optimal orbit at each time instant. To compensate deviations from the optimal orbit, a closed-loop control is sought. In this paper, a robust controller is designed. Such a design is a hard problem for several reasons, namely a large number of state space variables, the presence of conflicting specifications and parameter uncertainties; furthermore the model is a time-varying process, such that LTI~(Linear Time Invariant) methods cannot be directly applied.*

Keywords*: drag reduction, robust control, model reduction, linear time-varying control*

PAC0125: POSITION CONTROL STRATEGIES OF A STEWART PLATFORM MANIPULATOR

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Abstract. *Due to its mechanical advantages, the Stewart Platform Manipulator is used in many applications such asflight simulators, parallel kinematics machine tools, biped locomotion systems and surgery manipulators. This paperpresents the elaboration of a comprehensive Matlab-Simulink™ virtual environment of a Stewart platform. This simulation tool includes the kinematic and dynamic modeling of the platform, along with the control loops of the actuators and coupled to a trajectory generation module, it also offers complete visualization features through a dedicated graphic user interface. This simulator was modularly designed following open architectureprinciples, with plug and play modules allowing a global kinematics, dynamics and control of the machine integral analysis. The first part of the paper focuses on the features of this simulator, by describing the different availablemodels and tools. Based on this computer-aided control system design environment, then the second part develops acomparison between two different control strategies, on the one hand, the classical PID joint control structure and on the other hand, the Generalized Predictive Control (GPC) strategy. Both controllers are structured in the polynomial RST form, as a generic framework for numerical control laws, satisfying open architecture requirements. Finally, thevirtual environment provides time domain results and performance comparison, in addition the spatial tracking error is analyzed for both controllers, showing better accuracy with the GPC one.*

Keywords*: Predictive control, Simulation, Robot control, Stewart Platform Manipulator , Virtual environment*

PAC0176: DEVELOPMENT OF FIELDBUS ARCHITECTURE FOR TELEOPERATION AND DISTRIBUTED CONTROL OF A MOBILE ROBOT

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Abstract. *A current trend in the agricultural area is the development of mobile robots and autonomous vehicles for "in-field" data acquisition and remote sensing. These robots and vehicles developed with the same technologies existing in agricultural machinery can be more efficient doing these specific tasks than traditional large tractors. One of the major challenges in the design of these robots is the development of the electronic architecture for the integration and control of the several devices related to the motion, navigation, data acquisition and communication systems. An electronic architecture must be robust and reliable, provide quick and ease maintenance and have modularity and flexibility to allow future expansions and connections of new equipments. Recent applications of mobile robots have used distributed architectures based on fieldbus networks to meet these requirements. This work describes our approach to designing and implementing a teleoperated distributed control system based on CAN protocol for a mobile agricultural robot. The discussions are focused on the developed electronic fieldbus architecture, the*

wireless communication system for teleoperation and the distributed control over the CAN network. The evaluation of the developed system was based on the analysis of performance parameters such as motors response and architecture time delay obtained with the robot operation. The results show that the developed fieldbus architecture can be applied for teleoperation and distributed control of agricultural mobile robots meeting the requirements for an accurate robot movement and an acceptable response time for control commands and supervision.

***Keywords**: agricultural robot, CAN protocol, networked control design, teleoperation*

PAC0204: ROBUST STEERING CONTROL OF HOT STRIP MILL

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***Abstract.** In this article, a H_2 steering control is proposed to guarantee the stability of the hot strip mill system and improve its performances. The aim of the rolling process is to obtain a metal strip with constant and desired thickness. The lateral movement of the strip may induce a decrease of the product quality and rolls damage. Hence, this displacement must be reduced to improve the process reliability. Experimental results concerning the ArcelorMittal hot strip mill of Eisenhüttenstadt are presented.*

***Keywords**: Steering control, Singular perturbation, H_2 control design*

PAC0261: PERFORMANCE ANALYSIS OF A HELICOPTER BLADE-SAILING AEROSERVOELASTIC SYSTEM WITH INDIVIDUAL BLADE ROOT CONTROL AND REVERSE-FLOW EFFECTS

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***Abstract.** This paper analyzes the vibration-reduction performance of a proposed blade-sailing aeroservoelastic system with individual blade root control (IBRC), including aerodynamic reverse-flow effects. IBRC-based actuation, in the rotating frame, allows the compensation of aerodynamic forces by superimposing a blade pitch angle variation at the blade root to the collective/cyclic commands. The objective is the reduction of flapping deflections and the suppression of tunnel strikes for articulated rotors, considering steady-flow conditions during engagement shipboard operations. The aeroservoelastic modeling includes a nonlinear structural dynamics related to the droop/flap stops, blade-element aerodynamics with reverse-flow effects, a linear gust model for the ship airwake, gravity effects and an active lift compensator. The performance analysis considers a proportional-integral-derivative (PID) individual-blade-root controller with actuator constraints for the lift/angle-of-attack compensation associated with the stiffness and damping enhancement of the flapping oscillator. The closed-loop blade-sailing dynamics*

constitutes a forced parametric oscillator with nonlinear stiffness and time-varying coefficients and it is simulated for an articulated rotor whose properties are based on the H-46 shipboard rotor. The PID control parameters are varied in order to analyze the effects of the closed-loop stiffness and damping on the alleviation of flapping vibrations. The simulation results show that the proposed PID-IBRC aeroservoelastic system yields tunnel-strike suppression and it is associated with blade-sailing reduction of nearly 50% in upward deflections and nearly 35% in downward deflections for an incoming wind velocity of 45 kt, by using blade-root-actuator limits of ± 6 deg.

***Keywords**: helicopter blade sailing, individual blade root control, PID control, aeroservoelasticity, reverse flow*

PAC0321: CONTROL OF PARALLEL MANIPULATORS FOR VERY HIGH ACCELERATIONS: THE MECHANICAL VIBRATIONS ISSUE

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***Abstract.** This paper deals with the issue of mechanical vibrations in control of parallel robots. The proposed control strategy consists in a nonlinear adaptive dual mode controller applied to the actuation redundant parallel manipulator Par2. In this context, the experimental testbed is not equipped with velocity sensors. Therefore, a high-gain observer has been used to estimate the articular velocities. Real-time experiments show the effectiveness of the proposed control scheme, as well as the arised mechanical vibrations that increase with acceleration (becoming an important issue for accelerations higher than 20G). Some promising possible solutions to deal with the problem of mechanical vibrations have been discussed for future implementation.*

***Keywords**: Nonlinear Adaptive Control, Trajectory Tracking, Parallel Robots, Pick-and-Place, Mechanical Vibrations*

PAC0340: LPV MODELING AND CONTROL OF A 2-DOF ROBOTIC MANIPULATOR BASED ON DESCRIPTOR REPRESENTATION

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***Abstract.** This paper deals with the practical applicability of the control design methods that are based on the descriptor representation for robotic manipulators. The nonlinear model of a manipulator can be reformulated as a linear parameter varying (LPV) model with rational parametric dependence. The state-space LPV model can then be converted into a LPV descriptor model with affine parametric dependence by using a linear fractional representation (LFR). In this paper, a two degrees of freedom (2-DOF) robotic planar manipulator is considered. The affine dependence allows to derive analysis and design procedures that consist in a finite set of LMI conditions. Such an approach is used for the design of an output-feedback LPV controller which guarantees the stability and the H_∞ performance of the closed-loop system. The validity of the H_∞ control scheme is evaluated through simulations.*

***Keywords:** robotic manipulator, LPV systems, descriptor representation, H_∞ control*

PAC0362: A COMPLIANCE CONTROL APPROACH FOR MACHINING TASKS USING ELASTIC JOINT MANIPULATORS

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Abstract. *In this paper is presented the development of an indirect force control for robot manipulators with elastic joints employed in machining tasks. Based on the study of centralized compliance control for rigid manipulators, it is proposed an extension for robots with torsional flexibility in the joints structured as a cascade control. Additionally, it is proposed a reduced force model, based on existing dynamic models of the reaction forces, that agree with the reaction forces generated by the cutting tool in contact with the environment. The present two-dimensional model relies on the tangential and normal forces on the surface, allowing to analyze the stability of the system and to obtain gain preconditions for the proposed controller, considering the parameters of the machining process. A machining task is specified and simulation results for this task are presented to analyze the effectiveness of the proposed controller.*

Keywords*: Machining Tasks, Manipulators, Flexibility, Compliance Control*

PAC0410: ON A WHEELED MOBILE ROBOT TRAJECTORY TRACKING CONTROL: 1st and 2nd ORDER SLIDING MODES APPLIED TO A COMPENSATED INVERSE DYNAMICS

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Abstract. *In this paper, a trajectory tracking control for a nonholonomic wheeled mobile robot based on the compensated inverse dynamics approach combined with sliding mode control strategies is investigated. The main advantages of using sliding mode control are robustness to parameter uncertainty, insensitivity to load disturbance and fast dynamics response. The major drawback of sliding mode control is the so called chattering phenomenon. As an initial procedure a first order sliding mode control law in connection with inverse dynamics is described. In this case the chattering effects appear directly in the control signal, because it acts in first order derivative of the sliding surface. To overcome this situation higher order sliding modes were proposed in literature, in which the control acts on a high order derivative of the surface σ(x).Therefore a second order sliding mode control is used in this paper. It consists of forcing a second order sliding mode on a surface σ(x), in the system state space, with σ(x) identically equal to zero, by using a control signal depending on σ(x), but directly acting only on σ(x). The advantage of this approach is mainly related to its chattering reduction capability. Analysis and numerical simulations are provided to show the effectiveness of the investigated control strategy.*

Keywords*: nonholonomic wheeled mobile robot, compensated inverse dynamics, sliding mode, trajectory tracking, dynamic control*

PAC0467: ACTIVE VIBRATION CONTROL OF COMPOSITE PIEZOELECTRIC PLATES USING A LINEAR QUADRATIC REGULATOR

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Abstract. *The goal of this work is to propose a theoretical approach and a numerical scheme for the active vibration control of composite piezoelectric plates using optimal control. The first order Mindlin theory for laminated plate is employed together with the coupling electromechanical effect due to the use of laminas of piezoelectric materials used for vibration control. The piezoelectric laminae work as actuators and sensors. A finite element model, considering that piezoelectric material has a linear behaviour, is used. In order to perform the active vibration control of the plate structure, the finite element model is converted to a state space model and a linear-quadratic regulator is applied, using an observer to estimate states evolution.*

Keywords*: Active Vibration Control, Piezoelectric Composite Plate, Linear-Quadratic Regulator, State Observer*

PAC0499: ADAPTIVE FUZZY SLIDING MODE CONTROL WITH APPLICATION TO A CHAOTIC PENDULUM

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Abstract. *Chaos control may be understood as the use of tiny perturbations for the stabilization of unstable periodic orbits embedded in a chaotic attractor. The idea that chaotic behavior may be controlled by small perturbations of physical parameters allows this kind of behavior to be desirable in different applications. In this work, the application of a variable structure controller to second order nonlinear systems is discussed. The approach is based on the sliding mode control strategy and enhanced by an adaptive fuzzy algorithm to cope with modeling inaccuracies and external disturbances. The general procedure is applied to a nonlinear pendulum and numerical results are presented in order to demonstrate the control system performance. A comparison between the stabilization of general orbits and unstable periodic orbits embedded in chaotic attractor is carried out showing that the chaos control can confer flexibility to the system by changing the response with low power consumption. Since noise contamination is unavoidable in experimental data acquisition, it is important to evaluate its effect on chaos control procedures. This work also investigates the effect of noise on the proposed control scheme, verifying the influence on the system stabilization and on the required control action.*

Keywords*: Adaptive algorithms, Chaos control, Fuzzy logic, Nonlinear pendulum, Noisy signal, Sliding modes*

PAC0510: ON THE INFLUENCE OF THE HALL SENSOR POSITION ON THE ACCURACY OF LINEAR MOTOR SUB MICROMETRIC POSITIONING SYSTEMS

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Abstract. *The growing need for very high quality surface finishing and sub-micrometric dimensional uncertainty has challenged researches in the area of ultra-precision machine tools. With the employment of ultra-precision technology, it can be obtained high quality components with dimensional uncertainty in the range of 0.2 µm up to 10 nm and rugosity smaller than 25 nm. Such is the case of cylinders for photocopiers, special lenses for photographic cameras, plane mirrors for laser-based measurement systems, etc. The ultra-precision machining, capable to produce components with such characteristics, especially uses high precision machine tools made of monocrystalline diamond designed for this purpose under controlled conditions of temperature, humidity and environment. Precision tool machines require positioning systems with electro-mechanics structures capable of providing sub-micrometric positioning and tracking errors. Reducing positioning errors in this range require sophisticate mechanisms and advanced control devices. This paper presents the experimental results of a positioning system that employs a linear DC brush-less motor. In order to obtain a smooth and precise displacement it was necessary to modify the linear motor configuration. The pros and cons of the employment of a modified linear motor in positioning systems are discussed. The proposed setup can be used in a precision tool machines that are capable to produce parts with sub-micrometric precision.*

Keywords: *Sub micrometric positioning, positioning systems, linear motors*

PAC0546: AN LPV APPROACH FOR SEMI-ACTIVE SUSPENSION CONTROL

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Abstract. *In this paper, a new LPV control approach for semi-active automotive suspension equipped with a Magneto-Rheological (MR) damper is presented. The interest of the approach is (1) to embed the model of semi-active suspension in a linear system design and (2) to allow limiting the damper force so that the controlled semi-active suspension works within its admissible region. First, a semi-active suspension model of an MR damper is reformulated in the LPV framework, which provides an LPV model for the vertical car behaviour. Then, by using the H_∞ control approach for polytopic systems, an LPV controller is synthesized to improve the passenger comfort while keeping the road-holding performances. The performances of the LPV controller are analyzed, based on simulations using the embedded nonlinear model of the MR damper.*

***Keywords**: automotive control, semi-active suspension model, LPV system, robust control.*

C. ADVANCES ON BOUNDARY ELEMENT METHODS

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INVITED LECTURE

LEVEL SET-BOUNDARY INTEGRAL SIMULATIONS OF MOVING BOUNDARY PROBLEMS

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ABSTRACT. *Moving boundary problems have many important applications, and a boundary integral equation formulation is advantageous for their solution. Compared to working with the new volume, it is clearly an easier task to re-mesh the evolving boundary at every time step. Moreover, these simulations generally require knowledge of the surface gradient of the principal function, and these derivatives can be accurately obtained from the integral equations. In this talk, recent work on the coupling of the integral equation formulation with the powerful level set method for tracking surface evolution is described. The two calculations to be discussed are the modeling of two-dimensional wave breaking over a sloping beach, and the pinch-off of an inviscid fluid column based upon a potential flow model with capillary forces (raleigh-taylor instability). In both cases the interface velocity is obtained from a linear element galerkin boundary integral solution of the laplace equation (2d and 3d axisymmetric, respectively); the algorithm for the critical post- processing evaluation of the surface potential gradient will be discussed. The free surface, together with its (potential) boundary values, are evolved using level set techniques on a fixed domain. The raleigh-taylor simulations demonstrate that the algorithm is capable of handling topological change (pinch-off) and after pinch-off events. Near pinch-off, excellent agreement is obtained between the simulations and known scaling laws.*

Acknowledgement. This research was supported by the Office of Advanced Scientific Computing Research, U.S. Department of Energy, undercontract DE-AC05-00OR22725 with UT-Battelle, LLC. Partial support from National Council for Scientific and Technological Development (CNPq).

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NOTES

PAC0074: THE USE OF THE SUBREGION-BY-SUBREGION ALGORITHM FOR DEVELOPING GENERAL PARALLEL-PROCESSING BOUNDARY-ELEMENT CODES

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Abstract. *In this work, a generic subregion-by-subregion (SBS) algorithm is employed to develop general BE parallel codes. In this algorithm, the interactions between the subdomains are taken into account only during the solution of the system by a Krylov iterative method. Thereby, significant reduction of memory and CPU-time consumption is achieved as the global system matrix is not explicitly treated. On the other hand, special integration procedures for calculating nearly-strongly-singular integrals make the use of discontinuous boundary elements (in which quasi-singular integrals occur) possible. In fact, discontinuous elements are very useful for establishing BE models for complex heterogeneous domains. A matrix-copy option, useful for modeling systems with repeated parts, as identical fiber reinforcements, is also available. To verify the performance of the code, the 3D microstructural analysis of carbon-nanotube-reinforced composites (CNT composites) is considered. Particularly, mechanical properties of composites are measured. The representative volume elements (RVEs) adopted consist of carbon-nanotubes (shell-like elements) coupled with a polymeric material matrix.*

Keywords*: 3D standard BE formulation, parallel processing, CNT-based composites, thin-walled elements, subregion-by-subregion technique*

PAC0083: BEM IMPLEMENTATION OF THE ENERGY DOMAIN INTEGRAL FOR THE SOLUTION OF THREE-DIMENSIONAL INTERFACE CRACKS IN TRANSVERSELY ISOTROPIC BIMATERIALS

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Abstract. *The overall mechanical properties of composite materials depend heavily on the nature of the bond at bimaterial interfaces. Interfacial delamination and fracture are commonly observed problems that may ultimately limit the use of these materials. A general numerical tool for the analysis of three-dimensional transversely isotropic bimaterial interface cracks is presented in this paper. The proposed tool is based on a multidomain formulation of the Boundary Element Method (BEM) with the crack located at the interface. J-integral is computed along the three-dimensional crack fronts using the Energy Domain Integral (EDI) methodology. The implementation takes advantage of the efficiency of the boundary integral equation to directly obtain the required displacement derivatives, stress and strain fields from their boundary integral representations. The capability of the procedure is demonstrated by solving an example.*

Keywords*: interface cracks, composite laminates, boundary elements, J-integral*

PAC0115: ADVANCES AT TELLES METHOD APPLIED IN SCIENTIFIC VISUALIZATION

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Abstract. *Accurate numerical integration of line integrals is of fundamental importance for any reliable implementation of the boundary element method. The Telles transform introduces an efficient means of computing singular or nearly singular integrals currently found in two-dimensional, axisymmetric and three-dimensional applications. Recently, the authors started to develop a dedicated software for scientific visualization applications. The initial procedure was writen in Java, employing the Visualization Toolkit (VTK). VTK is an open-source, freely available software for 3D computer graphics, image processing, and visualization; this consists of a C++ class library and several interpreted interface layers including Tcl/Tk, Java, and Python. However, problems can occur if abrupt changes of stress values are to be accomodated since this needs special treatment when it comes to scientific visualization and numerical accuracy. The Telles transform is a good alternative to solve the problem of numerical accuracy. Recent research suggests that the use of the transformation for internal points near the boundary and in regions with severe stress gradients can improve the look and consistency of scientific visualization representing the solution to the problem. Thus, the present work discusses some advances in the Telles transformation for efficient use in scientific visualization. Examples are included to illustrate details in the implementation and the efficiency of the method.*

Keywords*: Boundary Element Method, Telles transform, Scientific Visualization*

PAC0159: WINKLER PLATES BY THE BOUNDARY KNOT METHOD

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Abstract. *This paper describes the application of the Boundary Knot Method (BKM) in the solution of problems regarding Kirchhoff plates resting on a Winkler foundation. This is the first time the BKM is applied to this kind of problems. The BKM is a boundary, meshless and integration-free method. To solve problems of plates resting on a Winkler foundation, the inhomogeneous term is approximated considering known particular solutions. The Kelvin and the modified Kelvin non-singular functions are used to approximate the homogenous term. Even though the approach of the BKM is similar to the Method of Fundamental Solutions (MFS), it only uses non-singular general solutions, therefore, the artificial boundary used in MFS is not required. The BKM is validated through its application to several problems with different boundary conditions: clamped, simply supported and free edges were considered. Several cases are discussed and compared with solutions obtained using the Finite Element Method (FEM).*

Keywords*: Winkler plate, Boundary Knot Method*

PAC0167: AN ALTERNATIVE TECHNIQUE FOR TANGENTIAL STRESS CALCULATION IN DISCONTINUOUS BOUNDARY ELEMENTS

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Abstract. *Continuous and discontinuous boundary elements obtain non-continuous and low accuracy results for the tangential component of stress, which is usually post-processed in the boundary element method (BEM). This paper presents a new proposal for calculation of this component for linear and quadratic discontinuous elements. The standard application of Hooke's law uses functions with different degrees of interpolation, since the tangential component of deformation is obtained from the derivative of the interpolation functions of displacement. Therefore, the proposed technique is based on the use of a smaller number of points with higher convergence in the application of the Hooke's law. The efficiency and capacity of the proposed technique is checked by solving static problems of elasticity with linear and quadratic elements, for different geometries and boundary conditions.*

Keywords*: Boundary elements method, discontinuous elements, stress recovery, tangential stress*

PAC0170: A SMOOTHING TECHNIQUE FOR DISCONTINUOUS BOUNDARY ELEMENTS RESULTS IN 2D ELASTICITY

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Abstract. *The use of discontinuous elements in the boundary element method (BEM) does not provide continuous results across the boundary mesh, i.e. variables are not single valued across element interfaces. This work proposes the implementation of a smoothing technique for these elements in two-dimensional elasticity. The technique, able to achieve continuous (smoothed) results, is implemented for linear and quadratic elements. The methodology is based on least-squares fit of the values at the physical nodes. These approximations are made for patches of two elements and therefore the values of stresses or displacements at the geometric node shared by the patch can be recovered. New solutions with the same degree of interpolation of the original ones are obtained in each element from these recovered values and, consequently, a continuous solution is obtained. The efficiency of the proposed technique is checked through the numerical solution of known static 2D elasticity cases.*

Keywords*: Boundary elements method, discontinuous elements, variable recovery, variable smoothing*

PAC0171: BEM SOLVER IMPLEMENTATIONS WITHIN A DISCRETE METHODS APPLICATION FRAMEWORK

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Abstract. *A practical strategy to increase the software reliability and to reduce programming time is to implement the code using Application Frameworks (AF). It is presented in this work a strategy for the implementation of a Boundary Element Method (BEM) solver within a discrete methods Application Framework (AF). The rationale behind this methodology lies in the possibility of reusing existing code to implement BEM. Thus, the effort put into the implementation of the BEM code is much less than that required for an ad-hoc development from scratch. A classical bechmark is solved in order to validate the developed code. Obtained results are compared to a direct BEM formulation in terms of execution times and memory requirements. The proposed approach was found to be an effective means for the implementation of Sparse BEM formulations some of which were evaluated in this work.*

Keywords: *Boundary Element Method, Finite Element Method, Application Frameworks*

PAC0220: CRACK ANALYSIS OF CONCRETE BY THE CONTINUUM STRONG DISCONTINUITY APPROACH AND BOUNDARY ELEMENT METHOD

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Abstract. *A Boundary Element Method (BEM) formulation is proposed for the numerical simulation of strong discontinuity formation and propagation in solids. Strong discontinuities are characterized by discontinuities in the displacement field, associated with crack formation in brittle or quasi-brittle materials. The proposed BEM formulation is based on the Continuum Strong Discontinuity Approach (CSDA), in which the formation of the strong discontinuity is assumed as a limit situation of inelastic strain localization, when the localization bandwidth tends to zero. The same methodology used to embed cracks into finite elements is employed to enrich internal cell strain fields to represent the effects of a discontinuity. An implicit BEM is formulated from standard BEM integral equationsfor solids with initial strains. Concrete fracture tests are numerically simulated to assess the performance of the formulation***.**

Keywords*: crack, concrete, boundary elements, strong discontinuity*

PAC0222: SIMPLE BENDING ANALYSIS OF BUILDING FLOOR STRUCTURES BY A BEM FORMULATION BASED ON REISSNER'S THEORY

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Abstract. *In this work, the plate bending formulation of the boundary element method - BEM, based on the Reissner's hypothesis, is extended to the analysis of plates reinforced by beams. Equilibrium and compatibility conditions are automatically imposed by the integral equations, which treat this composed structure as a single body. In order to decrease the number of degrees of freedom, some approximations are considered for the displacements and tractions along the beam width. Therefore the problem values remain defined only on the beams axis and on the plate boundary without beams. The accuracy of the proposed model is showed by comparing the numerical results with a well-known finite element code.*

Keywords*: Plate bending, Boundary elements, Building floor structures, Reissner's theory*

PAC0224: LINEAR BENDING ANALYSIS BY THE BOUNDARY ELEMENT METHOD OF BUILDING FLOOR STRUCTURES WITH COLUMNS DEFINED IN THE DOMAIN

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Abstract. *In this work, the building floor structure is modelled by a BEM formulation based on Kirchhoff's hypothesis. The presented BEM formulation to perform linear bending analysis is derived by applying the reciprocity theorem to zoned plates, where the beams are treated as thin sub-regions with larger rigidities. This composed structure is treated as a single body, being the equilibrium and compatibility conditions automatically taken into account. In order to reduce the number of degrees of freedom some kinematics hypothesis are assumed along the beam cross section. Thus the values remain defined on the beam skeleton line instead of its interface. The columns are introduced into the formulation by considering domain points where tractions can be prescribed. Some numerical examples are presented to show the accuracy of the proposed model.*

Keywords*: Plate bending, Boundary elements, Building floor structures*

PAC0245: STRESS INTENSITY FACTOR BY DUAL BEM USING ANY ORDER CURVED BOUNDARY ELEMENTS

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Abstract. *This paper presents the numerical implementation of the dual boundary element method (DBEM), for two-dimensional linear elastic crack problems. Isoparametric boundary elements of any order as well as discontinuos curved crack elements are considered. The subtraction of singularity method (SSM) has been used of singular boundary integrals. The J-integral technique is used to evaluate the stress intensity factor (SIF) for mixed-mode cracks. Comparisons are made between the numerical solution and analytical values found in literature.*

Keywords: *DBEM, Any Order Approximation, SSM, Stress Intensity Factor, J-Integral*

PAC0252: IMPLEMENTATION OF THE BOUNDARY ELEMENTS METHOD FOR 2D ELASTOSTATICS ON GRAPHICS HARDWARE – GPU

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Abstract. *Due to its architecture, the graphics processing unit (GPU) is specially well-suited to address problems that can be expressed as data-parallel computations with high arithmetic intensity. One example of such problem is the Boundary Elements Method (BEM). This work addresses the implementation of the direct version of BEM for 2D elastostatics. For the present implementation, constant boundary elements are used. According to the formulation of BEM, every term of both influence matrices (G^{ij} and H^{ij}) is independent of each other. In classical CPU serial implementations, these terms are calculated in a sequence of two loops: for the field point i and for the source point j. On the other hand, from the point of view of the GPU parallel processing paradigm, the calculation of every one of these terms can be assigned to a thread (GPU's elementary unit of calculation) and calculated simultaneously. The transposition of the influence equation to an algebraic linear system of equation is also parallelized. Standard Gaussian quadrature is applied to integrate each term of influence matrices. The code was developed on a NVidia CUDA programming environment and executed on a GeForce GTX 280 graphics card hosted by a regular Intel Core2Duo CPU. The efficiency of the implemented strategies are investigated by solving a classical elastostatics problem.*

Keywords*: High Performance Computing; Graphics Hardware; Boundary Elements Method*

PAC0308: AN ALTERNATIVE BEM FORMULATION FOR PLATE BENDING PROBLEM

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Abstract. *This work presents a BEM formulation to analyze reinforced plate bending problems. The formulation is an extension of a previous work in which the reinforcement effects were computed using a simplified rigidity corrections. As the reinforcements, usually beam elements, are enough narrow, we could correct the stiffness using only one stiffener coefficient, i.e. only one degree of freedom was needed for each node defined along the reinforcement skeleton line. In this article, the formulation is modified to take into account three stiffener coefficients, i.e. three degrees of freedom are taken into account for each beam axis node to simulate the actual*

stiffness of the reinforced plate. In this formulations bending, shear and torsional effects due to the presence of the embedded beam are considered. Although the shear and torsional stiffness effects are usually much reduced for plates reinforced by beams, there are many situations when they cannot be neglected. The rigidity corrections are formulated by considering a correcting moment field that is applied over the sub-domain defined by the beam. The equations are similar to the ones derived for the nonlinear plate bending analysis. Domain integrals containing the applied correcting moment field modify the standard integral equations for plate bending. These new terms are approximated by assuming linear approximation along the reinforcement axis and constant across its width. Examples are shown to confirm the accuracy of presented formulation, pointing out the approximation level when we simplify the model by reducing the number of degrees of freedom per beam axis node.

Keywords: plate bending, reinforcements, boundary elements

PAC0346: APPLICATION OF THE BOUNDARY ELEMENT METHOD TO VISCOELASTIC AND VISCOPLASTIC ANALYSIS

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Abstract. *In the current work two time-dependent boundary element method formulations are shown. The first one is developed to an analysis on a viscoelastic media. The Kelvin-Voigt viscoelastic material model is chosen to simulate the time-dependent behavior. The second one deals with an analysis on a viscoplastic media. An elasto/viscoplastic material model is chosen alongside Perzyna's flow rule to simulate the time-dependent behavior. A procedure to automatic generate cells in the zones of the domain that yielded is used. Examples using both formulations are analyzed and the results are compared with the exact and Finite Element Method (FEM) results.*

Keywords: *boundary element method, viscoelasticity, viscoplasticity, automatic cell generation*

PAC0348: A NUMERICAL CONVERGENCE STUDY OF THE RELAXED CONTINUITY APPROACH FOR SELF-REGULAR TRACTION-BIE

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Abstract. *Self-regular BEM algorithm avoids Cauchy principal value or Hadamard finite part evaluations as regularization is applied prior to discretization. Smoothness requirement for traction BIE is more stringent ($C^{1,\alpha}$ for displacement). Boundary discretization into standard continuous elements leads to a loss of the smoothness required. Relaxation of the smoothness requirement has been proposed using C^0 continuous elements with collocation points at the intersection between elements. Some researchers claim that this procedure cannot be*

theoretically justified. Interpolation of displacement tangential derivative an 'relaxed continuity' hypothesis are pointed out as possible sources of error introduced on the discretization of self-regular traction-BIE. Discontinous elements are implemented in order to verify the possible sources of error. Such elements allow the split of these sources of error. Numerical results show that the 'relaxed continuity' hyphotesis seems to be the dominat source of error. Apparently the smoothness requirement for the self-regular traction-BIE must be preserved to guarantee converge.

***Keywords**: boundary element method, self-regular traction-BIE, elasticity, convergence of self-regular BEM*

PAC0478: ON THE SPECTRAL PROPERTIES OF THE DOUBLE LAYER POTENTIAL MATRIX H OF THE BOUNDARY ELEMENT METHODS

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***Abstract.** The double-layer potential matrix $\boldsymbol{H}$ of the conventional, collocation boundary element method (CBEM) is singular, as referred to a static problem in a bounded continuum. In elasticity, the singularity of $\boldsymbol{H}$ means that no balanced forces can be related to rigid body displacements, which always have a simple representation and are spanned by the null space N($\boldsymbol{H}$). On the other hand, the properties of N($\boldsymbol{H}^T$), usually not relevant in the CBEM but of paramount importance in the variational implementations, may become quite intricate, as they are intimately related to concavities (notches, cracks, holes) of the discretized domain as well as to material non-homogeneities, as a result that local stress gradients can be represented by fundamental solutions only in a global sense. Symmetries and antisymmetries are also reflected in N($\boldsymbol{H}^T$). The properties of $\boldsymbol{H}$ and $\boldsymbol{H}^T$ are investigated, also showing that in the usual implementations of the CBEM with real fundamental solutions, all eigenvalues λ of $\boldsymbol{H}$ are real, $\lambda \in \boldsymbol{H}$, $0 \leq \lambda < 1$, for a bounded domain.*

***Keywords**: Boundary elements, Hybrid boundary elements, Spectral properties, Variational methods*

PAC0511: SIMULATION THE PIEZOELECTRIC EFFECT IN HUMAN BONE HEALING BY USING BEM

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***Abstract.** In this paper we present the BEM simulation of the piezoelectric effect on bones when the shearing force is applied to the collagen fibres to make them slip past each other. The bone is considered a homogenous and anisotropic solid. The Radon transform is used to derive the anisotropic piezoelectric fundamental solutions. The integration of these fundamental solutions is performed numerically using the linear Lagrangian interpolation on*

a grid of 200 x 400 points. The values of the displacement, potential, traction and charge coupled functions are stored in this process.

***Keywords**: Piezoelectric bone, Boundary Element Method, Anisotropic solid*

PAC0524: NUMERICAL MODELLING OF SEASONAL AND SPATIAL CHANGES IN WATER TABLE USING THE BOUNDARY ELEMENT METHOD

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***Abstract.** Ground water resources play an important role in environmental, agricultural, and industrial processes. Efficient management of aquifers requires a rational estimate of sustainable yield that does not distress the porous medium and lead to depletion of ground water. Uncontrolled exploitation of ground water in the absence of proper estimates may result in lowering of ground water table and consequent environmental damage. The modeling of steady ground water flow in anisotropic porous medium using the Boundary Element Method (BEM) is presented in this paper. The BEM offers the advantage of reduced nodes by discretising the domain along the boundary of the basin. The method is applied to a basin of 211 sq km comprising crystalline rocks of Archaean age; the pink and grey granites are highly disjointed and intruded with dolerite dykes and quartz veins. The velocity of ground flow and water table elevation are computed for pre-monsoon and post-monsoon seasons considering the seasonal flow into the basin, and the data are compared with the measured water table elevations. The paper presents briefly the details of the basin, method of analysis, computations, estimation of the ground water available, and comparison with the available data.*

***Keywords**: boundary element method, flow potential, ground water, velocity of flow, water table*

PAC0528: COMPUTATIONAL WAVE SIMULATION OF 3D WAVES IN CHANNELS USING THE BOUNDARY ELEMENT METHOD

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***Abstract.** The purpose of this work is to present a numerical simulation for the generation and propagation of waves in channels in two and three dimensions using the Boundary Element Method. Initially, a mixed formulation is applied to transform the original problem in a sequence of boundary value problems. The velocity field at each instant for the free-surface is computed by a Boundary Element Method program. A Finite Difference Scheme is used to update the free surface's geometry and its potential and, the Bernoulli's equation is applied to update the boundary conditions. The waves are generated by a piston-type wavemaker, and kinematical and dynamical boundary conditions are added. Through two examples, in two and three dimensions, the applicability of the formulation is shown.*

***Keywords:** wave propagation problem, potential problems, boundary element methods*

PAC0544: A DUAL-BOUNDARY-ELEMENT FORMULATION INCORPORATING A COHESIVE ZONE MODEL FOR ELASTOSTATIC CRACKS

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Abstract. *A single edge crack containing a cohesive model was studied using the dual boundary element method. Isoparametric linear boundary elements were used with nodal parameters fixed at the ends and collocation points positioned inside the elements. The strategy allows conformal interpolations to be used on the crack surfaces. A linear cohesive model in terms of two parameters was considered and two iterative procedures were used in the analysis. In the first procedure, the obtained forces in the cohesive region at the end of each loading step were introduced into the next loading step, as being the existing forces in the cohesive region. In the other procedure, the obtained forces in the cohesive region were computed according to the actual separation value of the crack surfaces at the loading step and considered to be the existing forces in the cohesive region. The results of both models were compared with those obtained without the cohesive region effect to show the changes introduced by the cohesive region and the iterative procedures.*

Keywords*: Cohesive models, Elastic fracture mechanic, Boundary element method, Dual boundary element method*

PAC0552: NEW DEVELOPMENTS OF THE BOUNDARY ELEMENT METHOD WITH INTERNAL CELLS

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Abstract. *The Boundary Element Method (BEM) is very rarely used for the simulation of problems in geomechanics even though it can mean a considerable improvement in user-friendliness, efficiency and accuracy compared to currently used domain based methods because only surfaces have to be discretized. The main reason why the BEM is not applied is because currently there are missing efficient and user-friendly capabilities to deal with non-linear material behavior, heterogeneous ground conditions, various types of ground support and sequential excavation. The paper will describe some innovative developments which include the efficient implementation of non-linear material behavior with an adaptive cell generation/refinement algorithm, the treatment of heterogeneous ground conditions and pipe roofs using an iterative procedure and cells, the treatment of rock bolts as linear inclusions via one-dimensional cells. Finally, verification results are presented, which demonstrate the accuracy and user-friendliness of the innovative methods.*

Keywords*: Numerical simulation, Boundary Element Method, Internal cells, Tunneling*

PAC0556: HYBRID NUMERICAL SIMULATION OF FLOW-INDUCED RADIATION OF AIR-DUCTING STRUCTURES LINED WITH POROUS MATERIAL

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Abstract. *Airflow plays a vital role in a significant number of today's appliances, e.g. in heating, ventilation, air condition (HVAC), intakes, exhausts. The expectations from their users are not restricted to proper operation but also include aspects of comfort, especially in terms of low noise emission. Air flow through structures generally generates two types of sounds: the aero-acoustic sound resulting from turbulences within the flow, and the sound radiated from the structure which undergoes excitation due to the flow. In this work, the latter case will be examined and the effectiveness of porous liners in order to reduce structural vibrations and hence sound radiation is studied. The chosen approach builds a model made up from four interacting parts: air flow, porous liner, structure and surrounding space. ANSYS CFX - a commercial computational fluid dynamics (CFD) software which makes use of the Reynolds Averaged Navier-Stokes equations in a Volume-of-Fluid method - is used to simulate the air flow. The liner is represented by Biot's theory for poroelastic materials and is discretized by means of the finite element method (FEM) as continuum elements. The structural part is modeled as a shell, also using FEM. The boundary element method (BEM) is chosen to simulate radiation into the surrounding air.*

Keywords*: Flow-induced sound radiation, coupling CFD/FEM/BEM, porous material*

NOTES

D. MICROMECHANICAL MODELING OF ADVANCED COMPOSITE MATERIALS

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NOTES

PAC0071: SELF-CONSISTENT ANALYSIS OF WAVES IN PIEZOELECTRIC COMPOSITES WITH MULTIPLE INCLUSIONS

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Abstract. *An analysis of the wave propagation is done using the self-consistent method for piezoelectric composites, based on a previous work of Sabina (1993) for elastic composites. The numerical solutions of the dynamic effective properties are obtained by using an iterative scheme. Some different situations are studied: comparisons, for the static case, of values obtained by the effective medium method developed in this work with previous results using effective field method and results for the dynamic case in composites with spheroidal inclusions with variations of the frequency interval. Analysis show that the variation of the dynamic effective properties is not significantly different for large values of wave frequency.*

Keywords*: piezoelectric, composite, self-consistent, wave, dynamic*

PAC0111: DETERMINATION OF EFFECTIVE ELASTIC COEFFICIENTS USING THE STANDARD MECHANICS APPROACH: APPLICATION TO TRABECULAR BONE TISSUE

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Abstract. *The human bone tissue is a natural composite material with a complex microstructure optimized for withstanding functional loads. It is extremely difficult to analyze the mechanical response of the trabecular bone considering each structural entity due to its high degree of heterogeneity. The typical way to overcome this difficulty is to find an equivalent material model that characterizes the average material mechanical behavior in the macroscopic scale. It is presented in this paper a method to compute the macroscopic effective stiffness matrix of the trabecular bone via the so-called standard mechanics approach. To this end, the finite element (FE) method is used to conduct a stress analysis a representative volume element (RVE) of the trabecular microstructure. The FE results are processed in order to compute the local structure tensor M, which relates the local tissue strain tensor to the average strain tensor. Finally, the M tensor is used to compute the elastic coefficients for the equivalent continuum material in the macroscopic level. The method is used to obtain the equivalent elastic coefficients for idealized trabecular geometries in 2D. The effect of the RVE size is analyzed and discussed.*

Keywords*: Bone tissue, effective elasticity tensor, finite element analysis*

PAC0121: A NUMERICAL HOMOGENIZATION TECHNIQUE FOR PIEZOELECTRIC COMPOSITES WITH ARBITRARY FIBER DISTRIBUTION

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Abstract. *In this paper a numerical technique for calculating effective properties of piezoelectric fiber composites with arbitrary fiber distribution is introduced. The method is based on finite element modeling of a unit cell. Due to the involved systematic scheme of appropriate boundary conditions and loads for ensuring periodicity this technique can be applied to composites with various fiber volume fractions and fiber distributions, from square over hexagonal and rhombic to random arrangements. That means in contrast to many published approaches the developed technique allows the extension to composites with arbitrary geometrical inclusion configurations and provides a powerful tool for fast calculation of their effective material properties. The geometrical generation of random distribution of fibers in the three dimensional unit cell is based on a modified random sequential adsorption (RSA) algorithm. By using the finite element code ANSYS with its included ANSYS Parametric Design Language (APDL) a high automation can be achieved for generating the model, applying the boundary conditions and calculating the full set of elastic, piezoelectric and dielectric effective material coefficients. For some test cases the results are compared and verified with analytical and other numerical solutions.*

Keywords*: Homogenization, Unit cell, Piezoelectric composite, Finite Element Method*

PAC0154: A BAR WITH VOIDS: MULTIFIELD AND CLASSICAL CONTINUUM SIMULATIONS

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Abstract: *This work is based on the formulation of a continuum model with microstructure for the study of the mechanical behaviour of complex materials. Such a continuum model is named multifield continuum because it is characterized by different field descriptors representing the material internal structure. According to the approach of the classical molecular theory of elasticity, this model has been obtained by the determination of an appropriate discrete micromodel and by linking different material scales (multiscale modelling) via an energy equivalence criterion. The constitutive relations for the stress measures of the macromodel have been explicitly identified by selecting the response functions of the interactions of the discrete model. These relations depend on the geometry and orientation of the material's internal phases. In the present paper attention is focused on theoretical and numerical investigations on a one-dimensional fibre-reinforced microcracked bar. The disturbance due to the*

presence of fibres and microcracks is represented by the additional kinematical fields, which represent the rotation of the fibres and the smeared displacement jump over the microcracks. The validity of the proposed multifield model is investigated by making a comparison between the solutions obtained by using multifield simulations and the numerical solutions obtained by using finite element simulations for a linear elastic strip with a distribution of voids. The results obtained prove the effectiveness of the multifield model in representing the gross mechanical behaviour of the composite material, taking into account the presence of the internal structure, with respect to the classical anisotropic model.

Keywords: *multifield models, multiscale modelling, microcracked materials.*

PAC0207: INFLUENCE OF BOUNDARY CONDITIONS ON THE DETERMINATION OF EFFECTIVE MATERIAL PROPERTIES FOR ACTIVE FIBER COMPOSITES

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Abstract *The study of Active Fiber Composites (AFC) in aerospace applications has increased due to the potential of manufacturing structures that satisfy high performance requirements needed in this area. Intelligent structures can be designed as sensors and actuators for applications such as structure health monitoring, vibration control or suppression, precision positioning and others. In this work, a model of AFC composed of lead zirconate titanate (PZT) and polymeric matrix is studied. Numerical simulations using finite element method are presented, considering the AFC with different fiber arrangements. Piezoelectric composites can be classified into 14 types, depending on the nature of fiber distribution in the matrix, and divided in 3 groups: unimodal-periodic, bimodal–periodic or aperiodic, concerning the periodicity of fiber distribution and size of fiber cross-sectional area. Simulations of relevant cases of the first group are presented. The AFC is modeled in a micro-mechanical view through Representative Volume Element (RVE - unit cell), appropriately chosen for each fiber arrangement with suitable boundary conditions applied to make the unit cell provide the entire behavior of the piezoelectric composite. The material properties of each component of the composite are known, which permits to estimate the effective properties of the AFC by applying different loading cases to the unit cell. The results are discussed and compared with previous results found in literature, investigating the influence of the applied boundary conditions.*

Keywords: *piezoelectric fiber composite, boundary conditions, effective material properties, finite element analysis, unit cell*

PAC0211: EVALUATION OF ELASTIC AND VISCOELASTIC PROPERTIES OF FIBER REINFORCED CONCRETE BY MEANS OF A MICROMECHANICAL APPROACH

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Abstract. *Some aspects of fiber reinforced concrete (FRC) are investigated within a micromechanical framework.*

Reasoning on the representative elementary volume of such a composite, the linear elastic behavior is first examined from the knowledge of the elastic properties of its individual constituents. Modeling the fibers as prolate inclusions embedded within the concrete matrix, the Mori-Tanaka scheme is used to derive estimates of the elastic coefficients. Subsequently, the formulation of the non-aging viscoelastic behavior is obtained by making use of results from elasticity and the Elastic-Viscoelastic Correspondence Principle. Adopting a Zener model for the behavior of the concrete matrix, the homogenized relaxation moduli are derived analytically. The validity of the model is established by means of comparison with available experiment measurements of creep strain of steel FRC under compressive load. Finally, the model predictions are compared to those derived from analytical models formulated within a one-dimensional setting.

***Keywords**: fiber reinforced concrete; micromechanics; elasticity; viscoelasticity*

PAC0236: MICROMECHANICAL CHARACTERIZATION OF THE EFFECTIVE PROPERTIES FOR ANGULAR PIEZOELECTRIC FIBROUS COMPOSITES WITH IMPERFECT CONTACT CONDITION

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***Abstract.** A fiber-reinforced periodic piezoelectric composite where the constituents exhibit transverse isotropic properties, is considered. The fiber cross-section is rhombic and the periodicity is the same in two oblique directions. Imperfect mechanic contact conditions at the interphase between the matrix and fibers are represented in parametric form. The effective piezoelectric properties are obtained by means of the Asymptotic Homogenization Method (AHM). Some comparisons with other theoretical models are shown.*

***Keywords**: Asymptotic homogenization, piezoelectric composites, linear spring interface model, imperfect contact*

PAC0244: HOMOGENIZATION AND UNIVERSAL RELATIONS IN MAGNETO-ELECTRO-ELASTIC PERFORATED STRUCTURES

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Abstract. *The homogeneous Neumann problem for periodically perforated linear magneto-electro-elastic (MEE).structures with rapidly oscillating coefficients is investigated via the asymptotic homogenization method. The corresponding homogenized system is considered for the particular case of porous materials consisting of identical parallel empty cylinders periodically distributed in a transversely isotropic MEE and homogeneous medium. New relationships involving the six effective (elastic, dielectric, magnetic, piezoelectric, piezomagnetic and magnetoelectric) properties were derived from the stated anti-plane shear MEE problems. Such relations are truly unrelated to the geometry of the cross section of the empty fibers. The derivation was performed taking the free-space constants (i.e. the dielectric permittivity and the magnetic permeability) into account. The importance of these relationships to control numerical codes is illustrated.*

Keywords*: Effective Properties, Universal Relations, Perforated Periodic Structures, Magneto-Electro-Elasticity*

PAC0263: VARIATIONAL BOUNDS FOR NONLINEAR MAGNETO-ELECTRO-ELASTIC COMPOSITES

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Abstract. *The estimation the effective behavior of nonlinear magneto-electro-elastic composites is addressed here by obtaining bounds on the energy functional from the minimum-energy and Hashin-Shtrikman generalized variational principles associated to the relevant boundary-value problem. The estimation is improved by taking a linear comparison composite with the same microstructure as the nonlinear one, so the nonlinear bounds now depend on linear bounds or estimations of the effective properties of the comparison composite. Finally, an optimization process is applied to select the comparison composite which generates the best bound.*

Keywords*: Nonlinear Magneto-Electro-Elastic Compositte, Variational Bounds*

PAC0267: EXPLICIT CROSS-PROPERTY CONNECTIONS FOR MATERIALS WITH ANISOTROPIC CONSTITUENTS

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Abstract. *The paper addresses the problem of the connection between effective elastic stiffnesses and dielectric permeabilities of heterogeneous materials with transversely-isotropic matrix. These connections allow one to predict the entire set of macroscopic elastic stiffnesses through one or two measurement of dielectric permeability. The explicit solutions are obtained for fiber reinforced composites and for porous materials. As a side result, it is*

shown that the mutual positions of inhomogeneities produce only a minor effect and that applicability of the non-interaction approximation is much wider than expected.

***Keywords**: effective moduli; cross-property connections, anisotropic constituents*

PAC0295: A THEORY OF LONGITUDINALLY POLARISED PIEZOCOMPOSITE ROD BASED ON Mindlin-Herrmann MODEL

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***Abstract. .** The conventional theory of the piezoelectric rod is based on an assumption that its lateral vibrations are negligible. In this case the rod, vibration could be described in terms of one-dimensional wave equation and a set of mechanical and electric boundary conditions. However, the main assumption of the model is only valid in the case of long and relatively thin rods. As a rule, the linear dimensions of piezoelectric components used in real transducers are comparable with the characteristic dimensions of their cross-sections, and hence, their lateral displacements have to be taken into consideration. In the present paper, the theory of the piezoelectric rod is developed on the basis of the Mindlin-Herrmann model. In the frame of this theory, the longitudinal and lateral displacements are described by two independent functions and vibration of the rod is obtained in terms of a system of two partial differential equations. The Hamilton variational principle is used for derivation of the system of equations of motion and for obtaining the mechanical and electric boundary conditions. On the basis of the formulated Mindlin-Herrmann model, the electric impedance of the piezoelectric rod is calculated. Possible generalizations of the proposed approach are considered and conclusions are formulated. An example of the application of the piezoelectric rod based on the Mindlin-Herrmann theory is given.*

***Keywords**: lateral displacement, Mindlin-Herrmann model, piezoelectric, thick rod*

PAC0296: STRESS-WAVE INDUCED FRACTURE OF UNIDIRECTIONAL COMPOSITES: AN EXPERIMENTAL STUDY USING DIGITAL IMAGE CORRELATION METHOD

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***Abstract.** Fracture behavior of unidirectional graphite/epoxy composite materials is investigated. Single-edge*

notched coupons are studied under geometrically symmetric impact loading. The notch orientation parallel to or at an angle relative to the fiber orientation is considered to produce mode-I as well as mixed-mode fracture. Stress-wave induced crack initiation and rapid crack growth events are studied using the digital correlation technique and high-speed photography. Surface deformations histories in the crack-tip vicinity are obtained by analyzing speckle image recordings. Measured deformation fields are used to extract mixed-mode fracture parameters and examine the effect of fiber orientation on crack initiation and growth behaviors. The maximum crack speed observed is the highest for mode-I dominant conditions and decreases with increasing fiber orientation angle. With increasing fiber orientation angle, crack takes longer to attain the maximum speed upon initiation. The crack initiation toughness values decrease with increasing degree-of-anisotropy.

***Keywords**: dynamic fracture, graphite/epoxy composites, digital image correlation, high-speed photography*

PAC0334: THE EFFECT OF THE SHAPE OF THE INCLUSIONS IN IDEALLY PLASTIC MATRIX-PARTICULATE COMPOSITES

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***Abstract.** We consider fiber reinforced composites where both the matrix and the fibers are made of ideally plastic materials with the fibers being much stronger than the matrix. We restrict our attention to microstructures and applied stresses that lead to both microscopic and macroscopic antiplane shear deformations. We obtain a bound on the yield set of the composite in terms of the shapes of the fibers, their volume fraction and the yield set of the matrix. We construct examples of composites showing that our bound is essentially optimal.*

***Keywords**: ideal plasticity, fiber reinforced composites, homogenization, translation method, antiplane shear*

PAC0335: ANALYSIS OF A TOY MODEL OF IDEALLY PLASTIC POLYCRYSTALS

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***Keywords**: ideal plasticity, polycrystals, homogenization, translation method, antiplane shear*

PAC0369: EFFECT OF PARTICLE SIZE DISTRIBUTION ON FRACTURE TOUGHNESS OF POLYMERS

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***Abstract.** Fracture toughness of particle reinforced polymers is strongly affected by the particle size, respectively their size distribution. Toughness can be improved or reduced depending on the materials used, the volume fractions at which the values are compared as well by the bonding quality at the particle/matrix interface as the parameters of particle size distribution. Several dissipation mechanisms are responsible for the characteristic behavior, and*

particle debonding is one important process, which is considered herein. If only the adhesive energy per volume is considered it can be concluded that smaller particles are favorable to increase that value. But the product of this specific debonding energy with the dissipation volume is the decisive quantity that determines fracture toughness. Depending on the used debonding criterion, i. e. critical stress or critical energy, different conclusions can be drawn. The critical stress criterion applied to composites with particles of a Gaussian size distribution leads to the conclusion that the debonding processes inducing fracture toughness to increase with decreasing mean particle diameter, $d_{p,mean}$. The increase is lower for larger standard deviations, s_N, of the distribution. Contrary to this, the application of the energy criterion provides fracture toughness independent of mean particle size.

***Keywords**: particle composites, particle size distribution, crack resistance*

PAC0398: INFLUENCE OF POLARIZATIONS ON THE EFFECTIVE PROPERTIES OF MAGNETO-ELECTRO-ELASTIC TWO-LAMINATED COMPOSITES

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***Abstract.** In this work, using the Asymptotic Homogenization Method, the effective coefficients of periodic magneto–electro–elastic layers with triclinic constituents or other type of symmetry are obtained. These coefficients are obtained in a matrix form. Using this matrix the characteristics of a two-layerd composite formed by $BaTiO_3$ and $CoFe_2O_4$ were calculated. The effect of the polarization orientation on their effective properties in multilaminated magneto-electro-elastic composites is studied. The direction of the piezoelectric polarization and the direction of the discontinuity of the layers are the same, while the magnetization direction of the ferrite has been changed different angles with respect to the direction of the discontinuity of the layers.*

***Keywords**: Piezoelectric, Piezomagnetic, Homogenization, Effective Properties, Magneto-Electro-Elastic*

PAC0401: DERIVATION OF GENERALIZED INNER BENDING CONTINUA FOR LINEAR FIBER REINFORCED MATERIALS

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***Abstract** This paper deals with the effective behaviour of elastic materials periodically reinforced by linear slender elastic inclusions. Assuming the scale separation between the cell size (of the order of the section of the inclusions) and the macroscopic deformation, the homogenization method of periodic media enables to identify the macro-*

behaviour at the leading order. With a systematic use of scaling and of the 1D geometry of the inclusions, the analysis is performed by considering large contrast (relatively to the scale ratio ε) between the shear modulus of the material μ_m and of the inclusions μ_p. It opens the possibility of enriched local kinematics involving inner deformation and inner bending according to studied configuration. The most interesting case is reached when the contrast μ_m / μ_p is of the order of ε^2. It leads to a full coupling between the beam behaviour of the inclusions solely and the elastic behaviour of the continuum material. Under macroscopic transverse motions the description is that of a generalized continua that accounts for the inner bending and inner rotation introduced by the reinforcements. Instead of the second degree balance equation of elastic Cauchy continua, the governing equation is of the fourth degree and differs from that of a Cosserat media. This general situation degenerates either into the usual continua behaviour of elastic composite materials when the contrast is reduced, i.e. taken of the order or larger than ε, or into the usual Euler-Bernouilli beam behaviour when the contrast is taken smaller than ε^2. Simple criteria are given to identify the appropriate model for real reinforced materials under given loadings.

***Keywords**: Generalized Continua, Reinforced material, Homogenization*

PAC0408: 3D CREEP MODELLING OF A SHORT FIBRE REINFORCED ALUMINIUM ALLOY: INTERCONNECTIVITY AND LOAD SEQUENCES

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***Abstract.** Long-term isothermal creep with load changes is investigated by means of experimental tests and computational mechanics on two composite materials, commercially pure Al and AlSi-based alloy reinforced with 15 vol% of Al_2O_3 short fibres. Three-dimensional periodic unit cell models are developed based on statistical parameters, and for the AlSi composite two interconnectivity conditions for Si and short fibres are considered. Simplified materials consisting of Al, eutectic Si (except for the Al composite) and short fibres are proposed. Finite element method is applied in order to compute the stationary creep behaviour of each model. Results obtained from simulations compared to measured creep tests are in agreement. These results confirm the sensitivity of the creep behaviour with respect to load sequencing and interconnectivity of the rigid phases.*

***Keywords**: creep, finite element method, metal matrix composite, unit cell, load sequences*

PAC0453: THERMAL BUCKLING ANALYSIS OF PIEZOELECTRIC COMPOSITE PLATES USING FINITE LAYER METHOD

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***Abstract.** The finite layer method is applied to 3D thermal buckling analysis of antisymmetric angle-ply piezoelectric composite plates. The effects of material properties and structural geometry are investigated and the results are compared with available solutions.*

***Keywords:** Finite layer method, 3D thermal buckling analysis, antisymmetric angle-ply laminate, piezoelectric composite plates*

PAC0471: A HYBRID FINITE ELEMENT IMPLEMENTATION OF GRADIENT ELASTICITY

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Abstract. *The gradient elasticity theory has recently become the subject of a large number of analytical and experimental investigations motivated by the development of new structural materials together with the increasing use of micromechanical devices in the industry. The present paper is the sequel of a work recently developed by the authors that revisits the strain gradient theory and shows that Aifantis' proposition may be used in the frame of the Hellinger-Reissner potential, in a novel formulation that naturally leads to hybrid finite/boundary element implementations. The non-singular formulation for 2D and 3D elasticity problems (not shown in the paper) has been developed, which enables the construction of hybrid finite element families of general shape and number of degrees of freedom.*

Keywords*: Gradient elasticity, Variational methods, Hybrid finite elements*

PAC0491: PLASTIC DEFORMATION OF POROUS MATERIALS DURING CONSOLIDATION PROCESS

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Abstract. *Designing of machines for densification and compression of structural and waste materials plays a major role in development of new processing techniques. The processes of densification and compression are utilized in the production of certain kinds of biomasses as an environment friendly and renewable source of energy. Moreover, specific physical properties may be obtained in the superficial layer of material, an example of which could be improving the quality of wood surface by hot rolling. For modeling of compression and plasticization of loose materials and materials with porous and anisotropic characteristics the primary parameter is the critical strain at which plastic flow commences. The critical strain value, which depends on the thermo-mechanical properties of the material and the key parameters of the process, is critical for effective plasticization. The strength of certain materials such as wood and sawdust significantly decreases with temperature. Therefore, temperature distribution, especially in the thin superficial layer, is one of the main characteristics taken into account in formulating constitutive equations concerning thermal conductivity and plasticity.*

Keywords*: yield condition, critical load, temperature, porosity, loose material*

PAC0502: MODELLING OF PIEZOCOMPOSITE FUNCTIONALLY GRADED PLATES FOR ACTIVE VIBRATION CONTROL

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Abstract. *The study develops models of active laminated plates containing monolithic piezopolymer sensor layers and actuator layers of a functionally graded piezoelectric material (FGPM). The considered FGPM actuator is a multi-layered material stacked of distinct piezoelectric fiber composite laminae. The laminae differ each other with amount of piezoceramic fibers to change the actuator electromechanical properties across the thickness. Two distribution functions, which estimate the gradient of volume fraction constituents, are applied i.e. power and parabolic. The performance of the FGPM actuators equipped with interdigitated electrodes refers to the longitudinal*

poling direction. The dynamic analysis, based on the classical laminated plate theory, concerns the transverse vibration suppression of rectangular simply supported symmetrically laminated plates. Numerical simulations are performed to recognize the influence of the applied pattern of the piezoceramic fraction distribution on the active plate structural response presented in terms of amplitude-frequency characteristics. The changes in both the natural frequencies and resonant amplitudes are compared and the influence of the piezoceramic material gradation on the control system operational effectiveness is also discussed.

Keywords: *laminated plate, piezoelectric control, piezoceramic fibers, functionally graded actuator*

PAC0506: YIELD CRITERION OF THE SOFT WOOD WITH VARIABLE HUMIDITY AND TEMPERATURE

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Abstract. *The paper presents the yield criterion for wood changing its moisture, temperature and a critical load in three anatomic directions. The basis for this criterion is the Hill criterion for anisotropy. It is known that mechanical properties of wood change during its heating and moistening in the range from dry and cool state to the fiber saturation point in higher temperature. It can be assumed that in the case of wood which undergoes simultaneously loading, heating and wetting the physical relations are functions of moisture contents and temperature. Thus, we have automatically included the effect of coupling between stresses, temperature and moisture. The values of material constants and coefficients such a plastic strain ratio and factors of proportionality represent the anisotropic qualities of wood and are taken from our experiments. On the basis of proposed yield condition the critical load of wood elements as a function of temperature and humidity may be calculated.*

Keywords*: yield condition, temperature, moister, porosity, orthotropy*

PAC0539: ELECTRO-ELASTIC DISLOCATION FIELDS IN A PIEZOELECTRIC SANDWICH STRUCTURE

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Abstract. *The coupled 2D electro-elastic fields are found in the piezoelectric sandwich structure (substrate-layer-substrate) of unrestricted anisotropy containing the straight-line source parallel to the interfaces. The general line source consists of the four coinciding sources: the line of forces, the charged line, the dislocation line and its electrostatic analogue. The obtained solution is presented in a form of convergent Fourier integral. The integrand is implicitly expressed in terms of the eigenvalues and the eigenvectors of the generalized Stroh matrix. Determination of these eigenvalues and eigenvectors requires additional computing. Specific features of the found fields are analyzed*

Keywords*: piezoelectricity, anisotropy, 1D inhomogeneity, line defect*

PAC0550: STRUCTURAL INTEGRITY AND THE IMPLEMENTATION OF ENGINEERING COMPOSITE MATERIALS

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Abstract. *Predicting precisely where a crack will develop in a material under stress and exactly when in time catastrophic fracture of the component will occur is one the oldest unsolved mysteries in the design and building of large-scale engineering structures. Fitness considerations for long-life implementation of aerospace composites include understanding phenomena such as impact, fatigue, creep, and stress corrosion cracking that affect reliability, life expectancy, and durability of structure. Structural integrity analysis treats the design, the materials used, and figures out how best components and parts can be joined; furthermore, SI takes into account service duty.*

Keywords*: multi-scale modeling, failure mechanisms, life prediction, damage mechanics, physical modeling, structural integrity, computer simulation*

E. EXPERIMENTAL AND NUMERICAL BEHAVIOR OF MEMBRANES AND BIOMEMBRANES

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NOTES

PAC0093: SOFT TISSUE CHARACTERIZATION AT MACRO TO NANO SCALES USING DIGITAL SPECKLE PHOTOGRAPHY

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Abstract. *Mechanical characterization of soft tissue often presents a challenge to experimental mechanics practitioners. One obviously cannot use strain gauges that are made of metallic foil or other material whose stiffness is higher than that of the soft tissue itself. In measuring the strain of myocardium, for example, the "gold standard" technique is to use minute ultrasonic transducers implanted into the heart muscle whose separation is measured by the time of travel of the ultrasound. More advanced techniques employ isolated paper markers strategically placed on the epicardium and their movements are monitored by a digital camera. In this paper, we present the technique of digital speckle photography for measuring soft tissue strain at various length scales. Speckles are nothing but an array of small particles that are to be spread onto the surface of the soft tissue specimen. When the specimen is loaded these speckles follow the deformation accordingly. The speckles' movements are recorded by a digital camera such as a CCD camera. The digitized speckle images are divided into subimages with 32x32 pixels, for example. The speckle patterns before and after deformation are "compared" via an efficient software based on Fast Fourier Transform. The result is a displacement vector map from which strain (be it linear or non-linear) can be calculated. Applications of this technique to measuring strain distribution in pig skin (to study the strain concentration effect on wound healing), myocardium (to study the effect of ischemia on muscle stiffness), and cancerous tissue (to study the effect on skin stiffness due to cancer) are presented. In the first two cases, recordings are done with an optical camera. In the third case, the test is performed in-situ inside the chamber of a scanning electron microscope.)*

Keywords*: Skin, Myocardium, Speckles*

PAC0103: EXPERIMENTAL MEASUREMENT OF ARTERIAL MECHANICAL PROPERTIES

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Abstract. *Any simulation requires adequate and correct information about mechanical properties of a given structure. To ensure the optimal way of arterial surgery requires the knowledge of arterial mechanical properties. Therefore this contribution is dealing with the methodology of measuring mechanical properties of arteries namely Young's modulus and Poisson's ratio assuming an isotropic behaviour. These parameters have been found experimentally by means of specially developed device. To verify our methodology the specimens have been taken from pork arterial system and subsequently fixed in a measuring device firstly. The supports of both ends allowed us to apply theory of thin walled-pressure vessels for determining mechanical parameters. Then the longitudinal and transversal deformations were measured due to the increase of inner pressure of physiological dilution where both specimen and measuring device have been placed. Finally to get both mechanical parameters we have applied the above mentioned theory of thin-walled pressure vessels. Thus obtained experimental data we have used for the simulation of blood flow in the artery using ANSYS WORKBENCH Version 11. The results obtained seem to be realistic.*

Keywords*: Experimental measuring, Mechanical properties, Artery, Simulation*

PAC0184: NUMERICAL SIMULATION OF BIOFILM GROWTH ON A DEFORMABLE SUBSTRATUM USING A MIXED CELLULAR AUTOMATON/FINITE ELEMENT MODEL

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Abstract. *A mixed Cellular Automaton/Finite Element model is proposed to provide the basis for a numerical simulation of the coupling between a biofilm growing on a deformable substratum and the deformability of the substratum. The Cellular Automaton is based on a modification of the fully quantitative Cellular Automaton model proposed by "Pizarro et al.(2001)". In addition to a modification of the rules proposed therein to cover more general three-dimensional situations, these rules are further supplemented with an influence arising from the present state of deformation of the substratum. In this model, it is suggested that regions of higher positive curvature will act as attractors. The deformability of the substratum is modeled by a conventional Finite Element model. The load arising from the weight of the biofilm clearly changes in time, according to the growth rules provided by the Cellular Automaton. Consequently, an active two-way coupling between the two mechanisms arises naturally within the procedure. Numerical examples are presented in two- and three-dimensional settings. In the first example, a simply supported beam with a small, but finite, flexural stiffness is subjected to an initially uniform and horizontal biofilm load. As a slope develops, the biofilm tends to migrate towards the middle of the span, as expected. A second example repeats the previous situation, but taking into consideration the contribution of the biofilm to the flexural stiffness of the composite. As a result, the migration of biofilm is slowed down and a final steady state is achieved with the biofilm distributed over a wider area than in the first case. These examples are then repeated for a rectangular membrane and similar results are obtained.*

Keywords*: Biofilm, Deformation, Substratum, Cellular Automaton, Finite Element*

PAC0217: NON-LINEAR VIBRATIONS OF HYPERELASTIC CIRCULAR MEMBRANES WITH CONTINUOUSLY VARYING THICKNESS

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Abstract. *Although dozens of theoretical studies have been published on linear vibrations of membranes with continuously varying density,little is known in the literature on the linear and nonlinear vibrations of hyperelastic membranes with varying thickness. So, the aim of the present work is to investigate the nonlinear vibration response of a pre-stretched circular hyperelastic membrane with varying thickness subjected to finite deformations. The membrane is composed of an isotropic, homogeneous, incompressible and hyperelastic material, which is modeled a neo-Hookean material. Initially the density of membrane is considered variable and later the thickness is considered variable, both along your radial direction. First the solution of the membrane under a uniform radial stretch is obtained. Then the equations of motion of the pre-stretched membrane are derived. From the linearized equations, the natural frequencies and mode shapes of the membrane are obtained analytically. The solutions are obtained in terms of hypergeometric functions. Then the natural modes are used to approximate the nonlinear deformation field using the Galerkin method. The results are compared with the results evaluated for the same membrane using a nonlinear finite element formulation. Excellent agreement is observed up to very large deflections. The results show the strong influence of the stretching ratio on the linear and nonlinear oscillations of the membrane.*

Keywords*: circular membranes, hyperelastic material, non-linear vibrations, varying thickness*

PAC0223: NUMERICAL AND EXPERIMENTAL ANALYSIS OF INFLATED MEMBRANE OVER ELASTIC FOUNDATION

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Abstract. *Despite the knowledge of the behavior of structures on elastic foundation being very important for structural engineering, not much has being researched in inflated membranes over elastic foundation. This work is focused in Biomechanical Engineering and was motivated by the puzzlingly results obtained during skin expansion done , in certain body regions of patients. The expansion of the skin is a physiological process, defined as the capacity that the skin has to increase its superficial area due to an imposed deformation. During the expansions it could be observed that depending on the region where the expander is implanted its behavior could be very diverse. This work is pioneer in investigating numerical and experimentally the behavior of an inflated hyperelastic membrane over rigid and elastic foundations, comparing its behavior. Several well known constitutive equations were studied, looking for the one that better described the behavior of the hyperelastic membrane used in the experimental analysis, and the Neo-hookean formulation was chosen. The numerical and experimental results of the expansion of the membrane presented a good agreement. This is important to the medical Doctors that will realize a skin expansion surgery.*

Keywords: *Expansion of membranes; Biomembranes, Hyperelastic membranes, Skin, Elastic foundation*

PAC0228: TRANSVERSE DEFLECTIONS OF A NATURAL RUBBER MEMBRANE DUE TO INDENTER LOADING

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Abstract*. The paper presents the results of a series of membrane indentation tests performed on a natural gum rubber membrane. The indentation tests were carried out on natural rubber membranes that were fixed along a circular boundary and the indenters had either a spherical shape or a flat circular shape. The paper presents experimental results for the load-displacement relationship for the indenter, which can be used to examine the range of applicability of various constitutive models that describe hyperelastic rubber-like material behaviour.*

Keywords: *indentation of rubber membranes, experimental modelling*

PAC0497: FINITE ELEMENT MODELING OF BIO-TISSUE FOR OPTIMAL FLEXIBLE MEMBRANE DESIGN OF A MEMS TACTILE SENSOR FOR USE IN MINIMALLY INVASIVE SURGERY

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Abstract. *Currently, Minimally Invasive Surgery (MIS) performs through keyhole incisions using commercially available robotic surgery systems. One of the most famous examples of these robotic surgery systems is the da Vinci surgical system. In the current robotic surgery systems like the da Vinci, surgeons are faced with problems such as lack of tactile and haptic feedback during the surgery. Therefore, providing a real-time tactile feedback from interaction between surgical instruments and tissue during the MIS can help the surgeons to perform this kind of surgery more reliably. The present paper proposes a model for simulating the interaction between a flexible membrane and bio-tissue based on the finite element methods. The tissue is considered as a hyperelastic material with the material properties similar to the heart tissue. The flexible membrane is assumed as a thin layer of silicon which can be microfabricated using the technology of Micro Electro Mechanical Systems (MEMS). The simulation results are used to optimize the geometric design parameters of a proposed MEMS tactile sensor for use in robotic surgical systems to perform MIS.*

Keywords*: Finite Element Analysis, Tissue Modeling, Flexible Membrane Design, Tactile Sensor, Minimally Invasive Surgery, Micro Electro Mechanical Systems*

PAC0534: DEVELOPMENT OF BIO-MIMETIC MORPHING SKINS FOR MICRO-UAVS

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Abstract. *This paper presents work on the optimization of NextGen Aeronautics' successful shear-morphing wing skin design, consisting of high-strain silicone "facesheets" supported by an intricate aluminum under-structure made of thin, closely-spaced aluminum ribbons or "strands" glued to the face-sheets. The strand design was optimized through ANSYS/non-linear finite element simulation and experimentation, resulting in a wing structure with greatly reduced actuation forces and much simpler manufacturing process, while still maintaining out-of-plane airfoil shape and limiting overall weight. The design variables included the pre-strains in the face-sheet and the geometric parameters defining a panel and its subcomponents such as spacing, thickness, depth, angle, etc. The key to optimizing the design was to reduce high levels of strain in the strand by incorporating a central strain-relieving feature in each strand. With these low-strain strands, the facesheet became the largest contributor to the actuation force, so correspondingly, ANSYS simulations were run with strand and facesheet together to optimize the design for minimum energy while maintaining airfoil profile (not violating out-of-plane displacement criteria or causing the facesheet to wrinkle). The final optimal flexible skin strand design for a shear-morphing wing uses a Gaussian shape. Though originally designed for use with a larger UAV, this design was further modified for smaller micro-UAV (MAV) scales, specifically for morphing/perching bio-mimetic flight. For the MAV application, the vision is to develop a single-DOF morphing wing with two stable states – one for minimum drag cruise flight and the other for high L/D landing/perching.*

Keywords: *morphing aircraft, bio-mimetic structures, non-linear finite element analysis, large-strain morphing skins, micro-UAVs*

F. STOCHASTIC MODELING AND UNCERTAINTIES IN SOLID MECHANICS

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INVITED LECTURE

A CONSPECTUS OF MODERN STOCHASTIC MECHANICS THEMES

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ABSTRACT. *A presentation of methods which are currently used in stochastic mechanics applications will be attempted. Particular attention will be devoted to methods, such as equivalent linearization and equivalent quadratization, for random response determination of nonlinear dynamic systems. Furthermore, efficient methods for the simulation of multi-variate and multi-dimensional stochastic processes using digital filters in the context of Monte Carlo analyses will be discussed. Appended to this theme will be a recent stochastic solution to the problem of synthesizing time histories compatible with a described shock spectrum commonly prescribed in dynamic applications. Also, approaches for determining the stochastic response of nonlinear systems involving terms with fractional derivatives will be presented. Finally, the option of capturing localized temporal and spatial effects in dynamic system responses via the family of harmonic wavelets will be discussed. Examples from the fields of material engineering, earthquake engineering, wind engineering, and offshore engineering will be presented.*

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PAC0072: ON THE EFFECTS OF UNCERTAINTY ON OPTIMUM STRUCTURAL DESIGN

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Abstract: *In this paper, the effects of uncertainty on optimum structural design are investigated, by comparing three distinct formulations of the structural optimization problem. The paper presents some case studies, highlighting the differences in the optimum designs obtained via Deterministic Design Optimization (DDO) , Reliability-based Design Optimization (RBDO) and Reliability-based Risk Optimization (RBRO). Reliability-based Risk Optimization looks for the optimum structural configuration and for the optimum point of balance between safety and economy. The study leads to a better understanding of the limitations of each formulation in the solution of structural optimization problems. It is shown that DDO reduces material or manufacturing costs, but compromises structural safety. As a consequence, expected costs of failure are increased. RBDO allows the optimization to be performed without compromising safety. However, since RBDO does not account explicitly for the cost of failure, it can lead to a structure that has higher expected costs of failure, even when respecting target failure probabilities. The optimum structure can only be found by RBRO, which explicitly accounts for uncertainty, and for the expected costs of failure.*

Keywords*: Structural optimization, optimum design, DDO, RBDO, reliability analysis*

PAC0073: RELIABILITY ANALYSIS IN STRUCTURES SUBMITTED TO FATIGUE USING THE BOUNDARY ELEMENT METHOD

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Abstract: *In this paper, the boundary element method and reliability analysis are used to model and solve structural problems involving uncertainty, stress concentrations singularities and crack propagation. Particularly, the dual boundary element formulation is adopted for the analysis of solids with cracks. This procedure is shown to be efficient and sufficiently accurate. Both crack faces are described by the same geometry and no singularity appears. Since crack propagation parameters show large variability, it is particularly important to include uncertainty in the analysis. This is done by coupling the boundary element crack propagation model with structural reliability models. Two ways of performing this coupling are considered in this work. In the response surface method, the numerical (mechanic) limit state surface is appoximated by an analytical, surrogate model, as the search for the design point is performed. The second scheme is referred herein as numerical gradients. In this method, gradients of the limit state function are computed directly, based on the numerical response of the mechanical model. The limit state function remains implicit. The two schemes are applied to some example crack propagation problems. It is shown that the numerical gradients technique leads to much faster convergence, in comparison to the traditional response surface method.*

Keywords*: Boundary Element Method, Structural Reliability, Fatigue, Crack Propagation, Uncertainty*

PAC0080: DRILL-STRING WITH UNCERTAINTY IN THE BIT ROCK INTERACTION

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Abstract. *In this paper a probabilistic model is proposed for the bit-rock interaction model of a drill-string system. ProceeA new strategy to take into account uncertainties in a local constitutive nonlinear equation using the nonparametrici probabilistic approach is developed. The deterministic model considers the main forces that are applied to the column such as bit-rock interaction, fluid-structure interaction and impact forces. The nonlinear Timoshenko beam theory is applied and the system is discretized by means of the Finite Element Method.*

Keywords*: drill-string dynamics, nonlinear dynamics, bit-rock probabilistic model, local nonlinearity*

PAC0082: STOCHASTIC MODEL OF A CRACKED ROD

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Abstract. *Small defects such as cracks can be obscured by modal approaches because such phenomena have a local nature and only affect significantly the high frequency behavior. Investigating this phenomenon using traditional finite or boundary element method require a very fine mesh to correctly predict the frequency response. This approach can became prohibitive for considering uncertainties, since it is necessary to perform stochastic analysis. To overcome that, a spectral element method is used to model a cracked rod, whose crack is modeled as a localized flexibility changing. Uncertainties must be taken into account for a robust analysis and to increase the predictability of the model. To model the uncertainties, the parametric approach and probability theory is employed and the Maximum Entropy Principle is used to propose a probability density function for the crack flexibility. Monte Carlo simulation is performed in order to estimate the frequency response function envelopes.*

Keywords*: Dynamical system, Wave propagation, Uncertainty quantification, Stochastic analysis, Reliability analysis*

PAC0101: ANALYSIS OF RANDOM VIBRATION FIELDS USING ORTHOGONAL DECOMPOSITIONS

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Abstract. *Orthogonal decomposition provides a powerful modal transformation tool for stochastic dynamics analysis. The most popular decomposition is the Karhunen-Loève Decomposition (KLD), also named Proper Orthogonal Decomposition (POD). The KLD is based on the eigenvectors of the correlation matrix of the random field. Recently, a modified KLD/POD named Smooth Karhunen-Loève Decomposition (SKLD) appeared also in the literature. It is based on a generalized eigenproblem defined from the covariance matrix of the random field and the covariance matrix of the associated time derivative random field. The SKLD appears to be an interesting tool to do modal analysis. Although it does not satisfy the optimality relation of a KLD, and hence it is not a good candidate to build reduced models, as the KLD is, the SKLD gives access to the modal vectors independently of the mass distribution. In this paper, the main properties of the SKLD will be described and compared to the classical KLD. Reduced models were constructed, and compared, with KL, SKL, and also normal modes. The behavior of the the reduced models were investigated for linear and nonlinear systems with uncorrelated and correlated excitation.*

Keywords*: Karhunen-Loève theory, modal analysis, nonlinear random vibrations, orthogonal decomposition, reduced models*

PAC0177: PARAMETERS SETTING THROUGH OPTIMAL EXPERIMENTAL DESIGN FOR A TWO-MASS VOCAL FOLDS MODEL

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Abstract. *In this work, a methodology for solving an inverse problem using neural networks is proposed, and then applied on the Lous's et al. two-mass model for the vocal folds used in the generation of voiced sounds. Voice signals are generated by variating three chosen mechanical parameters of the model. For each set of these three parameters, a glottal signal is obtained and three of its parameters are extracted. The aim is to solve the inverse problem; that is, given the three parameters extracted from the glottal signal, to obtain the three parameters chosen as input of the model. However, a neural network is used to solve the inverse problem, and not the original model. As the voice production process is stochastic, random variables are associated to the parameters and probability density functions are constructed. The original parameter and that obtained by the solution of the inverse problem are compared. It was observed that good accuracy was achieved for the estimation of one of the parameters, the so-called tension of the vocal folds. On the other hand, the model was not suitable to estimate the other two parameters, the pressure at the lungs and the neutral glottal area.*

Keywords*: Neural Networks, voice production, vocal folds , two-mass model*

PAC0187: HOMOGENIZATION OF POLYCRYSTALLINE MATERIAL PROPERTIES USING A PERTURBATION STOCHASTIC FINITE ELEMENT SCHEME

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Abstract. *This work presents a study of the uncertainties on the macroscopic (homogenized) elastic properties of poly-crystalline materials as a function of uncertainties on the material texture and microstructure geometry. We study the variance on the homogenized elastic property of the material around its nominal < 111 > texture. To perform this analysis, the perturbation stochastic finite element method (PSFEM) is coupled to the mathematical theory of homogenization (MTH) leading to a second-order perturbation-based homogenization method. This method is able to evaluate the mean and variance of a given homogenized property as a function of the grain orientation uncertainty. The multiscale formulation is implemented in a plane-stress linear elastic finite element framework based on a multigrain periodic unit cell generated by Voronoi tessellation. The PSFEM is applied to evaluate the uncertainty on the macroscopic elastic properties of the polycrystalline material associated with different levels of uncertainty in grains. To study the influence of the unit cell size, the PSFEM is used to evaluate the variance of the elastic property for unit cells of different sizes. The uncertainty due to grains geometry and orientation randomness is evaluated by coupling PSFEM and Monte-Carlo method, with the uncertainty due to grains geometry quantified by Monte-Carlo method, and the PSFEM used to evaluate the influence of the orientation for each realization of the unit cell. Considering both uncertainty sources as independent, the variance of the homogenized elastic properties is calculated by the total law of variance.*

Keywords*: Perturbation stochastic finite element method, homogenization method, poly-crystalline material*

PAC219: OPTIMIZATION OF A FLEXIBLE ROTOR-BEARING SYSTEM CONSIDERING UNCERTAINTIES

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Abstract. *The aim of this work is to propose a methodology to optimize the performance of a flexible rotor-bearing system taking into account parameter uncertainties. The rotor-bearing system considered is a continuous dynamical system modeled using the Euler-Bernoulli beam theory and discretized by means of the Finite Element Method. The idea of the optimization problem is to find the values of a set of parameters (e.g., flexibility of the bearing, diameter, etc.) for which the natural frequencies of the system are as far away as possible from the rotational speeds of the machine. For this purpose, the Campbell diagram is used and penalty functions are introduced to penalize natural frequencies close to the rotational speeds of the machine. The uncertainty of the parameters (e.g., in the flexibility of the bearing, in the elasticity modulus of the material, etc) was taken into account by modeling them as random variables and constructing their probability density functions using the Maximum Entropy Principle. The global and bounded Nelder-Mead optimization algorithm is employed to minimize the proposed multi-objective function. The methodology proposed in this work is directly extended to complex rotor-bearing systems.*

***Keywords**: rotor dynamics, optimization, Campbell diagram, uncertainty, robust optimization.*

PAC0226: SAFETY ASSESSMENT OF COMPOSITE CONNECTIONS IN SINUSOIDAL-WEB GIRDERS

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***Abstract.** Steel girders have been successfully used for many years in the composite construction market. Further developments and advances in fabrication technology have led to a new generation of structural shapes. One of these developments, the composite sinusoidal-web girders, has been recently introduced in the Brazilian market. In spite of the advantages this type of composite construction may offer, there are no design standards dealing with the behavior of such girders. As a result, there is a need to develop design recommendations that properly address the flexural capacity of these elements and their connections to the adjacent members. Following the current trend of using semi-probabilistic codes, these design recommendations shall be developed within the concepts and methods of Structural Reliability. In this paper, reliability-based design recommendations for connections in steel-concrete composite construction are proposed. To this end: (i) experimental tests of connections on cruciform arrangements were performed, (ii) finite-element models for the connections and the composite girders have been developed, (iii) finite-element models were validated by experimental data, and (iv) a theoretical model is proposed. It is shown that the proposed theoretical model, despite all the complexities involved, is in good agreement with both experimental and numerical analyses. Additionally, the safety levels implicit in the proposed recommendations are assessed. First, statistical descriptions of the random variables involved have been investigated. This includes the description of model errors estimated from both experimental and numerical analyses. Second, a reliability evaluation using Monte Carlo simulation was performed and reliability indexes were computed. It is found that the safety levels resulting from the proposed design recommendations are consistent with current trends in structural engineering practice.*

***Keywords**: safety, sinusoidal-web, reliability, composite connection, Monte Carlo simulation*

PAC0242: APPLICATION OF GALERKIN METHOD TO BENDING OF STOCHASTIC KIRCHHOFF PLATES

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***Abstract.** In this paper, the method of Galerkin and the Askey-Wiener scheme are used to obtain approximate solutions to the stochastic displacement response of Kirchhoff plates with uncertain parameters. Uncertainty in plate stiffness is modeled using parameterized stochastic processes, indexed in uniform random variables. The space of approximate solutions is built using results of density between the space of continuous functions and Sobolev spaces. The Lax-Milgram lemma is used to guarantee existence and uniqueness of the solution. From the approximate Galerkin solutions, first and second order moments of the displacement response are derived, and compared with corresponding estimates obtained via Monte Carlo simulation. Numerical results for an example*

problem show very fast convergence to the exact solution, at excellent accuracies. The Askey-Wiener Galerkin scheme presented herein is shown to be a theoretically sound and efficient method for the solution of stochastic problems in engineering.

***Keywords**: Kirchhoff plates, chaos polynomials, Galerkin method, Askey-Wiener scheme, stochastic processes*

PAC0247: GALERKIN SOLUTION TO FREE VIBRATION OF ROD WITH UNCERTAIN ELASTIC PROPERTIES

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***Abstract.** This paper applies the Galerkin method to obtain numerical solutions for the generalized eigenvalue problem associated to free vibrations of a rod with uncertain properties. The uncertainty is modeled by random variables. The space of approximate solutions is obtained from the tensorial product between Sobolev and measure spaces. The Askey-Wiener scheme is used to represent the random behavior of the approximate solution. Statistical moments of first and second order are obtained, based on the approximate solution, for the first two natural frequencies. These moments are compared with the corresponding estimates obtained via Monte Carlo simulation. The first results obtained for this problem are far from ideal, but the problem is still under investigation. The author's experience with the performance of the Chaos-Galerkin solution for other problems of mechanics suggests that the present results can become much better.*

***Keywords**: Uncertainty, stochastic processes, Askey-Wiener scheme; free vibration; Galerkin method*

PAC0288: RELIABILITY SENSITIVITY ANALYSIS: AN EFFECTIVE TOOL IN RELIABILITY-BASED OPTIMIZATION OF DYNAMICAL SYSTEM

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***Abstract.** This contribution presents a novel approach for solving reliability-based optimization problems based on an efficient reliability sensitivity analysis. In particular, the reliability-based optimization of structural systems under stochastic loading is considered. The approach is based on a descent-feasible direction and a line search strategy. Starting from a feasible design, a descent-feasible direction is determined, i.e. a direction that improves the objective function while ensuring the fulfillment of the probabilistic and deterministic constraints. Once a feasible direction is determined a line search strategy is employed to determine a new candidate design. Then, the design is updated and the process continues until convergence is achieved. For determining the gradient of the reliability constraints, an efficient sensitivity technique is used. The proposed approach is monotonically convergent, that is, it generates a sequence of steadily improved feasible designs. A numerical example showing the efficiency and effectiveness of the proposed approach is presented.*

***Keywords**: descent-feasible direction, line search, reliability-based optimization, sensitivity analysis*

PAC0322: STOCHASTIC DYNAMICS OF AN AIRFOIL FORCED TO OSCILLATE BY THE FLOW

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Abstract. *A stochastic approach for a flow-induced vibration problem of hydrofoil is developed. This model is applied to study the dynamics of the distributor's blades in a Kaplan turbine. This kind of mathematical model often contains input parameters, which are subjected to inherent physical randomness. During the past decade, no-linear models to study the flow induced vibrations in an airfoil were developed, otherwise these models do not take into consideration the randomness of the incident flow on the blades. Time-dependent solutions of non-linear dynamical system are known to be sensitive to small input variations. Then for a robust modelling of the dynamic behaviour of this airfoil, the use of a stochastic model is necessary. Considering the movement restrictions on the distributor blades, it is proposed a one degree of freedom stochastic model to study the dynamical stall induced by the flow acting on blades of a Kaplan turbine distributor, which is modelled considering its randomness. CFD studies on the flow inside the spiral cases of the Kaplan units in hydro power plant of Coaracy Nunes were used as basis to estimate the stochastic profile of velocity. The perturbation method was applied to solve the stochastic problem.*

Keywords*: Kaplan Turbines, stochastic dynamics, airfoil, flow induced vibration*

PAC0433: RELIABILITY BY MONTE CARLO SIMULATION STRUCTURAL WITH ADAPTIVE IMPORTANCE SAMPLING TECHNIQUE

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Abstract. *This work presents a Monte Carlo Simulation Method review, with the aim of assessing the reliability of a structural component or system. The traditional Monte Carlo Method consists basically on repeatedly sampling each random variable involved in the problem and verifying if the limit state function is violated. Obviously the slow convergence is a severe penalty for this method. One way to bypass this problem is using the so-called variance reduction techniques, like importance sampling method, in which an importance-sampling function emphasizes the domain of failure. This technique´s efficiency depends on a good importance sampling function choice, which is possible only with a previous knowledge about the region of failure. Using the fact that after each sampling the knowledge about the failure region increases, one can modify the importance sampling function. This adaptive technique can lead to a proper importance sampling function, that reduces the number of simulations needed*

to accurate predict the probability of failure. So, this work presents details of the adaptive importance sampling computational implementation and some examples to demonstrate its efficiency.

Keywords: *structural reliability, Monte Carlo simulation, importance sampling*

PAC0536: NONLOCAL ANALYSIS OF DYNAMIC INSTABILITY OF MICRO-AND NANO-RODS

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Abstract. *he dynamic stability problem is solved for onedimensional structures subjected to time-dependent deterministic or stochastic axial forces. The stability analysis of structures under time-dependent forces strongly depends on dissipation energy. The simplest model of viscous damping with constant coefficient was commonly assumed in previous papers despite the fact that there are other more sophisticated theories of energy dissipation according to which different engineering constant have different dissipative properties. The paper is concerned with the stochastic parametric vibrations of micro- and nano-rods based on the Eringen's nonlocal elasticity theory and Euler-Bernoulli beam theory. The asymptotic instability, and almost sure asymptotic instability criteria involving a damping coefficient, structure and loading parameters are derived using Liapunov's direct method. Using the appropriate energy-like Liapunov functional sufficient conditions for the asymptotic instability, and the almost sure asymptotic instability of undeflected form of beam are derived. The nonlocal Euler-Bernoulli beam accounts for the scale effect, which becomes significant when dealing with short micro- and nano- rods. From obtained analytical formulas it is clearly seen that the small scale effect decreases the dynamic instability region. Instability regions are functions of the axial force variance, the constant component of axial force and the damping coefficient.*

Keywords*: Nonlocal continuum mechanics, Stochastic parametric vibrations, Dynamic instability, Energy-like functional, Liapunov method*

G. NONLINEAR AND CHAOTIC PHENOMENA IN ENGINEERING

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NOTES

PAC0091: CLUSTERING OF HUYGENS' CLOCKS

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Abstract. *In the XVIIth century Ch.Huygens showed that a couple of mechanical clocks hanging from a common support were synchronized. However, the precise dynamics of the n clock hanging from the common support is unknown. Here, we study a synchronization problem for n pendula hanging from an elastically fixed horizontal beam. Each pendulum performs a periodic motion which starts from different initial conditions. We show that after a transient, different types of synchronization between pendula can be observed; (i) the complete synchronization in which all pendula behave identically, (ii) pendula create three or five clusters of synchronized pendula, (iii) antiphase synchronization in pairs (for even n). Our results demonstrate that other stable cluster configurations do not exist.*

Keywords*: pendulum, clocks, synchronization, clustering*

PAC0127: NONLINEAR ANALYSIS OF THE RESPONSE OF AN AEROELASTIC SYSTEM USING SHAPE MEMORY ALLOYS

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Abstract. *In this paper, a theoritical simulation study of the nonlinear response of a two degree of freedom typical airfoil section using a Shape Memory Alloy (SMA) is presented. The model is integrated into a numerical solution of the aeroelastic nonlinear dynamic system that results from the inclusion of Shape Memory Alloy components in a dynamic structural system. The objective of the present work is to obtain bifurcation diagrams of a two degree of freedom airfoil subjected to two-dimensional incompressible flow taking into account structural nonlinearities, where the simulations are investigated employing a numerically refined approach. In the present investigation, concentrated the SMA nonlinearities in the airfoil pitch. The integro-differential aeroelastic equations of motion for the two degree of freedom airfoil are reformulated into a system of eight first-order autonomous ordinary differential equations. The term bifurcation is used to describe qualitative changes that occur in the orbit structure of a system, as a consequence of parameter changes. Numerical simulations show that the coupled nonlinearities can generate a variety of motions*

Keywords*: Aeroelasticity, Shape Memory Alloy, Nonlinear Dynamic, Bifurcation*

PAC0141: INFLUENCE OF TORSIONAL VIBRATION DAMPING ON CRITICAL STATES OF NONLINEAR SYSTEMS

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Abstract. *Modern structures made of the most resistant materials are becoming more and more elastic. Thus, the main calculation criterion constitutes a rigidity and not a static strength. Such change of a conceptual approach requires unceasing improvements of methods and calculation tools. In a considerable measure this problem concerns power transmission systems. We are dealing with a situation when elastic rotating elements are placed on deformable supports being components of a light supporting structure. One of the basic hazards of rotation systems are critical states. The critical states theory implemented in engineering practice is totally based on simplified linear models and does not take into consideration the coupling of transverse and torsional vibrations. This coupling is visibly observable especially in situations when system elements (bearings, couplings, gears) as well as supports fixed to deformable structures have nonlinear characteristics and a motion is unstable. No coherent uniform theory - concerning minimisation of amplitudes and changes of the transverse vibration frequency response of nonlinear systems by suppression of torsional vibrations - exists in the world scientific literature. The application possibility of torsional vibration dampers - of a typical structure – for influencing transverse vibrations, especially in the vicinity of critical states, in the cases when both the power transmission system and its foundation have strongly nonlinear elastic characteristics, are discussed in the hereby paper. Examples of such systems are the power transmission systems with machine shafts made of carbon composites as well as multi-joint systems fixed to a strongly deformable foundation. It has been shown that in both mentioned cases damping of torsional vibrations significantly influences the critical states.*

Keywords: *Damping of Vibrations, Torsional Vibrations, Nonlinear Systems*

PAC0152: INSTABILITY ZONES IDENTIFICATION IN MULTIBLADE ROTOR DYNAMICS

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Abstract. *Helicopter ground resonance is an unstable dynamic phenomenon which can lead to the total destruction of the aircraft during take-off or landing phases. Studies have been developed by researchers which considered a simplified mathematical model. With the goal of further comprehend the phenomenon, predictions of unstable motions are done and compared. First, Floquet's theory is applied to solve the linear equations of motion including parametric and periodic terms. Then, the multiple scales method is applied on the nonlinear model. The analyses highlight that, by keeping the nonlinear terms in the equations, other instability zones are identified.*

Keywords: *Ground Resonance, Nonlinear Dynamics, Floquet Method, Multiple Scales Method*

PAC0155: PHASE-LOCKED SOLUTIONS IN A HUB CONNECTED OSCILLATOR RING NETWORK

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Abstract. In this work, we analyze a type of system called the hub connected oscillator ring (HCOR) network. The model consists of 3 sub-rings each coupled to a central hub oscillator with a bi-directional coupling constant, α*. When uncoupled from the hub, each substructure is characterized by 3 identical oscillators with natural frequency* ω_i *and bi-directional coupling constant,* α_i*. The conditions necessary for existence of phase-locked solutions were derived and their associated stability criteria were determined. The synchronization tree for phase-locked solutions was also developed. A bifurcation analysis of the system was conducted. Finally simulations were carried out to validate the analytically derived results; these results agreed well with the theory.*

Keywords*: Phase-only oscillators, nonlinear dynamics, bifurcations*

PAC0175: GEOMETRIC NONLINEAR ANALYSIS OF TENSEGRITY SYSTEMS

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Abstract. *This paper presents a study on the nonlinear behavior of two tensegrity topologies when subjected to static loading. The geometric nonlinearity is considered here with the aid of a simple formulation, based on the Finite Element Method (FEM), but using as unknowns of the problem nodal positions rather than nodal displacement. The strains are evaluated directly from the proposed position concept, using a coordinate system fixed in space. Some numerical simulations are presented to illustrate the behavior of this structural system.*

Keywords*: tensegrity, nonlinear analysis, static loading*

PAC0206: WHY ARE FRACTALS OBSERVED IN ELASTIC-PLASTIC MATERIALS?

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Abstract. *While it is well known that many materials display fractal characteristics, very little work was done on fractals in elasto-plasticity, except for ridges in ice fields and shear bands in rocks. Recently, fractal patterns have*

been found to form in 2D aggregates of grains of either elastic-perfectly plastic type, or elastic-hardening-plastic type, or elastic-plastic type with residual strains. The grains are either isotropic or anisotropic, with random, spatially non-fractal perturbations in properties such as moduli, yield stresses or residual strains. The flow rule of each grain follows associated plasticity wtih loading applied through either one of three macroscopically uniform boundary conditions admitted by the Hill-Mandel condition. Following an evolution of a set of grains that have become plastic, we find that it is monotonically plane-filling with an increasing macroscopic load. The set's fractal dimension increases from 0 towards 2, with the response under kinematic loading being stiffer than that under mixed-orthogonal loading, which in turn is stiffer than the traction controlled one. In essence, any non-zero noise in grains' properties gives rise to fractal patterns of plastic grains. While the grains possess sharp elastic-plastic stress-strain curves, the overall stress-strain responses are curved and asymptote toward perfectly-plastic flows; these responses and the fractal dimension-strain curves are almost identical for three different loadings. All these responses display smooth transitions but, as the randomness in properties decreases to zero, they turn into conventional curves with sharp kinks of homogeneous materials. To answer the question posed in the title, even very weak material randomness in material parameters of elastic-ductile materials causes plastic slip-lines and shear bands to eveolve as fractals.

Keywords: *random heterogeneous material; elastic-to-plastic transition, fractal*

PAC0215: A NONLINEAR MODEL OF THE SEISMIC BEHAVIOR OF THE INTERNAL PARTS OF AN ENVIRONMENTAL CONTROL SYSTEM

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Abstract. *In this paper, we present the derivation of a nonlinear model of the seismic behavior of the internal parts of an environmental control system. The device, an Electrostatic Precipitator, is basically composed of a large elevated metal box containing hung positive and negative electrodes that produce the effect of capturing suspension materials of industrial flue gases. These pendulum like parts are quite affected by seismic motions and we endeavor to generate a model to analyze the problem. In our model we consider only horizontal seismic displacements, as it is usually done. Of special interest is the fact that the electrodes are free to swing in one plane but not in the other perpendicular to it. Our model considers a vertical flexible pole with a pendulum pinned to its upper end. The two horizontal displacements of this top node and the angular displacements of the pendulum are the generalized coordinates. Other displacements are computed using a cubic polynomial shape function. We adopted the Lagrangian formulation to derive the equations of motion of the model. The obtained second order ODE three equations system displays some interesting nonlinear features. The seismic motions, which are stochastic in nature, will be latter considered to be a superposition of harmonic functions. Finally, numerical step-by-step time integration will be performed.*

Keywords*: Nonlinear dynamics, Structural Dynamics, Earthquake Engineering*

PAC0218: On AN ENERGY TRANSFER AND Nonlinear, Nonideal and Chaotic Dynamics OF A MACRO Tuning Fork Beam (TFB), under an Electro-Dynamical Shaker Excitation (EDS)

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Abstract. *In this paper, the dynamical behavior (quasi-periodic motion, beat phenomenon and intermittent chaos of a tuning fork beam (TFB), under the excitation of an electro-dynamical shaker (EDS) with limited power supply is investigated. The (TFB) apparatus was itself approximated as two inverted pendulums supported by a linear oscillator in the horizontal and vertical directions*

Keywords*: Tuning Fork Beam, Electro-Dynamical Shaker Excitation, Non-Ideal problem, Nonliner Dynamics, Chaos*

PAC0317: GEOMETRICALLY NONLINEAR ANALYSIS OF HYPERELASTIC PLATES WITH LARGE STRAINS VIA *p*-FEM

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Abstract. *The objective of this study is to develop a computer code for geometrically nonlinear analysis of hyperelastic plates in isothermal conditions, under in-plane statically external forces and considering large strains. Such program uses, among other things, the following concepts: positional Lagrangian formulation of the finite element method (FEM), equilibrium via the principle of minimum total potential energy, shell-like element with seven nodal parameters and cubic approach for positions, iterative method of Newton-Raphson, numerical integration and multiplicative decomposition of the deformation gradient. The degrees of freedom are current kinematic variables of the nodes. The constitutive laws are described by the three-dimensional specific strain-energy function, also called Helmholtz free energy, which is expressed per unit initial volume of the analyzed body and which is, in the present work, decomposed into volumetric and isochoric parts. Nonlinear relations are adopted for these laws, which are more appropriate, when compared to the linear ones, to reproduce numerically the mechanical behavior of highly deformable materials - such as polymers - in structural problems. Furthermore, the resulting formulation was used in both simple - such as uniaxial tension and simple shear - and complex numerical analysis - as the Cook's membrane. Another important topic to be highlighted is the seventh parameter of the element, which represents the linear rate of change of deformation along the thickness and thus enriches the strain field. Finally, the performed simulations presented good convergence of results and corroborated the existent data of the scientific literature, which shows the efficiency and the accuracy of the proposed method.*

Keywords*: Hyperelasticity, p-FEM, Finite Strains, Geometrically Nonlinear Analysis, Plates*

PAC0330: NON-LINEAR DYNAMICS OF CABLE-STAYED MASTS

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Abstract. *Cable-stayed structures are widely used to build towers and bridges, cover wide spans and in off-shore structures, among others. In this work, the non-linear finite element method, using an updated Lagrangian formulation, is used to study the non-linear vibrations of cable-stayed masts subjected to axial time dependent loads. The non-linear equations are solved using the Newton-Raphson method associated to an arc-length technique and the Newmark method is used to calculate the time responses of the system. Validation examples are presented and the influence of initial geometric imperfections and cable tensioning is studied when stayed towers are subjected to dynamic loads. Using the Budianski´s criterion, the loss of stability under sudden and harmonic loads is also analyzed. Obtained numerical results show the influence of both cable tensioning and cable positioning on the non-linear behavior of the system and could be used as a tool for an analysis of the nonlinear dynamics of the structure previous to design.*

Keywords*: Cable-stayed structures, Non-linear oscillations, Non-linear finite element, Dynamic instability*

PAC0347: FINITE VOLUME SOFTWARES FOR GASDYNAMICS AND MAGNETOGASDYNAMICS EQUATIONS

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Abstract. *Two codes for computers have been developed. One, to study flows in which an electrically conducting gas moves in a magnetic field and the other one to solve Euler equations. The first code solves 2D, time-dependent, viscous and resistive MGD flows. Its numerical approach is based on a finite volume discretization technique and to compute the numerical fluxes across cells interfaces, an approximate Riemann solver coupled with the Total Variation Diminishing (TVD) scheme proposed by Harten and Yee is utilized. The eigensystem introduced by Powell and the eigenvectors normalization by Zarachay et al. have also been used. To verify its accuracy, the MGD code has been applied to the simulations of a magnetogasdynamics Riemann problem and of the Hartmann flow. The results obtained show good agreement with those reported by other authors. In the second code, a TVD scheme has been implemented on a non structured 3D finite volume formulation for solving the Euler equations. To simultaneously, achieve adequate accuracy in smooth flows, high resolution at flow discontinuities and to avoid spurious oscillations, different flux limiter functions are applied in a wave-to-wave basis. In this paper are analyzed the numerical viscosity reduction resulting after using compressive limiter functions in waves from the families two to four, and the ability of diffusive limiter functions for the family waves one and five to capture pressure discontinuities whereas preserving the robustness of the TVD scheme. This sort of adaptive scheme has satisfactorily been applied to the slip interface between two parallel flows, and to supersonic flows over and airfoil, a wedge and a blunted bi-conic body.*

Keywords*: Finite volume, Magnetogasdynamics, Gas dynamics, minimod, superbee*

PAC0380: NEW REINJECTION PROBABILITY FUNCTION FOR INTERMITTENCY TYPE II AND III

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Abstract. *Intermittency is characterized by the successive occurrence of a signal that alternates chaotic burst between quasi-regular periods (laminar phases). It has been studied that number of chaotic burst increases with an external parameter, then intermittency phenomenon is a continuous route from regular to chaotic motions. The intermittency phenomenon is classified into three types in function of the local Poincaré map and the value of the respective Floquet multiplier (local property): type I, type II and type III. To determine the intermittency behavior and characteristic parameters such as the average laminar length it is necessary to know the reinjection probability function, RPF (global property). At the present several books and papers consider that the RPF is constant, a fixed point or some artificial function. However there are some tests in which theses conditions are not satisfy. In this paper is introduced a new reinjection probability function for intermittency type II and III, together a technique to obtain the new function. The new RPF is more general and it includes the constant RPF as a particular case. The proposed technique to obtain the new RPF shows advantages because it reduces the noise in experimental and numerical data. Finally, two maps are analyzed to prove the accuracy of the new RPF function and the viability of the proposed technique to obtain it*

Keywords*: intermittency, chaos, reinjection*

PAC0417: ALTERNATIVES OF LONG TERM BEHAVIOR OF A GYROSCOPE CONSIDERING DAMPING

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Abstract. *In this work a mathematical model of a gyroscope is generated, including existing frictions between the components of the mechanical system (besides considering the inertias of rotor and gimbals). Newton-Euler laws were used to obtain the equations of movement, with a procedure of normalization for reduction of a parameter in the equation and a dimensionless model of a gyroscope is obtained. Dimensionless equations are an useful tool of non linear dynamics as well as the definition of basins of attraction by means of the cardanic angles. Since there will be no limitations on these angles, this maping will not be restricted to* $-\pi$ *to* π*. It is obtained a numerical value of the minimal energy needed for the motion to change between the basins of attraction. Curiosly, if the initial energy is enough for a change, the movement does not remain inside any basin of attraction, since it continues changing basin of attraction without regard to the kinetic energy becoming lesser due to friction. This work studies and interprets this physical phenomenon. Long term behavior of a gyroscope with unbounded motion possibility considering the loss of kinetic energy due to friction is investigated. It is shown how the friction due to the motion between the suporting gimbal components influences the dynamic behavior of the gyroscope. The contribution of this work besides showing effect of friction and inertias on a cardanically suspended body, will be relevant for the analysis of tumbling bodies in space.*

Keywords*: Nonlinear Dynamics, Limits of Stability, Damping, Orientation in the space*

PAC0525: NON LINEAR EXTENDED HILL'S EQUATION AND CHAOS: CONTROLLING THE INTERVALS OF INSTABILITY

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Abstract. *The Hill's equations - even in the linear original version - are a describer of phenomenon having chaotic flavor, showing sometimes very unusual situations when acting. The theory of the so called intervals of instability in the equation, provides the precise description for the most of these phenomenons. The consideration of nonlinearities into the Hill's equation it is a quite recent task, but the linearization for almost of these systems it reduces to the Hill's classical linear one. In this paper, we present some indicative facts about the possibility in to have the linear system stabilizable and/or exactly controllable. As consequence of such approach we get results having strong classical aspects, like the one talking about location of parameters in intervals of stability. A proper result for nonlinear controlled Hill's equations, with periodic forcings it is considered too.*

Keywords*: Hill's equation, controllability, stabilizability, nonlinearities, periodic solution*

H. NUMERICAL SIMULATION OF COMPLEX FLOWS

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NOTES

PAC0130: VISCOELASTICITY IN INKJET PRINTING

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Abstract. *We investigate the effects of viscoelasticity on drop generation in inkjet printing. In drop-on-demand printing, individual ink `drops' are ejected from a nozzle by imposed pressure pulses. Upon exiting the nozzle, the shape of each `drop' is that of a nearly spherical bead with a long thin trailing ligament. This ligament subsequently breaks up under the Rayleigh instability, typically into several small droplets (known as satellite drops). These satellite drops can create unwanted splash on the target substrate, and a reduction in printing quality. Satellite drops can potentially be eliminated by adding polymer to the ink; elastic stresses can act to contract the trailing ligament into the main drop before capillary breakup occurs. However, elasticity can also reduce the drop velocity, and can delay or even prevent the break-off of the drop from the ink reservoir within the nozzle. To achieve optimal drop shape and speed, non-Newtonian parameters such as the polymer concentration and molecular weight must be chosen correctly. We explore this parameter space via numerical simulations, using a split Lagrangian-Eulerian finite-element method. Results are compared with experimental observations taken from real printheads.*

Keywords*: viscoelasticity, breakup, FENE, simulation, inkjet*

PAC0356: FINDING THE COEFFICIENTS FOR AN ALGEBRAIC EXPLICIT STRESS MODEL FOR THE CLOSURE PROBLEM IN TURBULENCE FROM DNS RESULTS OF THE SQUARE DUCT

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Abstract. *Turbulent models provide closure equations that relate the Reynolds stress with kinematic tensors. In this study, we have developed a methodology to quantify the dependence of the Reynolds stress tensor on mean kinematic tensor basis. The analysis is conducted in three steps. In the first approach, one extracts from the anisotropic Reynolds stress tensor, the part that is proportional to the strain rate tensor. The second approach extracts from the anisotropic Reynolds stress tensor the part that is in-phase (coaxial) with the strain rate. The third one, expresses the out-of-phase part as a function of a persistence-of-straining tensor (Thompson and de Souza Mendes, 2005). The study is conducted for the turbulent flow through a square duct using DNS (direct numerical simulation) data. As expected for this anisotropic complex flow, the results have shown that the tensorial form of the Boussinesq hypothesis is not a good assumption even for the region far from the wall. We then show that the set of tensor basis composed by the rate-of -strain tensor, its square, and the persistence-of-straining tensor is able to describe well the anisotropic Reynolds stress (up to 90% of it). With the proposed methodology, the scalar coefficients of nonlinear algebraic turbulent models can be determined.*

Keywords*: AESM models, Tensor decomposition, DNS square duct*

PAC0363: MODELING TURBULENT NEWTONIAN SHEAR USING NON-NEWTONIAN BACKBONE

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Abstract*. Non-Newtonian fluids are known to display distinct differences from Newtonian fluids in many kinds of geophysical and engineering flow situations. Rivlin (1957) was perhaps the first to investigate the relation between the laminar flows of non-Newtonian fluids and the turbulent flows of Newtonian fluids qualitatively. He noted that there is some intrinsic similarity between their constitutive equations. Speziale (1996) used a CEF (Bird et al., 1987) constitutive equation to propose a closure model for the Reynolds stress tensor as a function of the basis constituted by the rate-of-strain tensor, its square, and its contravariant convected time derivative. For steady-state problems this assumption leads to the three-basis tensor explored in Jongen and Gatski (1998), Schmitt and Hirsh (2000) and Schmitt (2007a,b). This model is used to fit DNS data for the channel flow. The results are given as function of entities that are defined in a non-Newtonian viscoelastic context. The turbulent viscosity exhibiting a shear-thinning behavior, is fitted with a Carreau-type model. First and second normal Reynolds stress differences in shear and a Turbulent Weissenberg number, based on a characteristic turbulent time, the relation between first normal stress difference and apparent kinematic viscosity, are given for different Reynolds numbers. The results give another way of understanding and interpreting turbulence results and new insights are in order.*

Keywords*: Closure turbulent model, turbulent Weissenberg number, DNS channel flow*

PAC0365: Constitutive modeling for three-dimensional time-dependent viscoelastic FREE-SURFACE FLOWS

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Abstract. *Free surface flows of viscoelastic liquids is a research topic of growing interest within the non-Newtonian fluid mechanics community. Viscoelastic fluids are largely employed in industrial processes, and they are frequently*

*flowing in or around three-dimensional (3D) complex geometries. For specific applications of extrusion, the modeling of viscoelastic materials and the free surface shape prediction are still challenges for the Computational Fluid Dynamics (CFD) community. The difficulties can be related with the constitutive equation, the numerical method, and the very large number of degrees of freedom of the system. The aim of the present work is to present results of numerical simulations for two complex flows of viscoelastic fluids, the die swell and jet buckling problems, using a new algebraic viscoelastic constitutive equation. This new model is based on an explicit algebraic representation of the non-Newtonian extra-stress through a kinematic tensor formed by the scaled dyadic product of the velocity field by itself. The elasticity of the fluid is taken into account through a single differential transport equation for a scalar quantity characterizing the strain rate of the flow. The model is characterized by a positive first normal stress difference and a bounded extensional viscosity for viscometric flows. The free surface flow is modeled using a mark**er**-and-cell approach embedded in a three-dimensional time-dependent numerical finite difference code that was applied to simulate the transient extrudate swell and jet buckling flows. The results showed stable flows with very large extrudate growths beyond die swell ratios usually observed with standard differential viscoelastic models and converged jet buckling results. The main advantage of this approach, in comparison with classical constitutive equations, is the economy in memory storage and CPU time when modeling unsteady three-dimensional viscoelastic flows. The reduction in computing time of course grows with mesh size, which in some instances might render possible an otherwise unfeasible computation, especially for flows involving complex geometries.*

***Keywords**: algebraic constitutive equation, three-dimensional free surface flows, viscoelastic fluids, extrudate swell, jet buckling*

PAC0371: ELASTICITY IN VISCOPLASTIC FLOWS THROUGH AN AXISYMMETRIC EXPANSION FOLLOWED BY A CONTRACTION

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***Abstract.** In this work, we use a new constitutive model that address the elastic behavior of viscoplastic liquids, in the limit of low strain rates. We test the equation in an expansion-contraction axisymmetric flow, and compare the results with some experimental data obtained previously de Souza Mendes et al. (2007). Steady, inertialess numerical solutions are obtained by solving the conservation equations of mass and momentum via the finite element method, using the Polyflow software (Ansys Inc.). We obtain the velocity and stress fields for different combinations of the governing parameters, and observe that elasticity leads to a non symmetric flow field, and affect the pressure drop and the volume of displaced fluid through the cavity.*

***Keywords**: elasticity, viscoplastic liquids, yield stress, expansion/contraction flows*

PAC0442: NUMERICAL INVESTIGATION OF DIRECTOR ORIENTATION AND FLOW OF NEMATIC LIQUID CRYSTAL IN A PLANAR 1:4 EXPANSION

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***Abstract.** In this paper, numerical solutions to the equations for the Ericksen-Leslie dynamic theory are obtained for two-dimensional nematic liquid crystal flows subject to a magnetic field. A numerical method for solving the*

governing equations for 2D flows has been formulated. The governing equations are solved by a finite difference technique based on the GENSMAC methodology introduced by Tomé and McKee (1994), Tomé et al. (2002). To demonstrate the capabilities of the numerical method the flow of a nematic liquid crystal in a planar 1:4 expansion was simulated. Calculations were simulated for various values of the Ericksen number (the ratio of viscous to elastic stress).

***Keywords**: Nematic liquid crystal, Ericksen-Leslie equations, Two-dimensional flow, Finite difference*

PAC0484: THE MOTION OF AN OSCILLATING SPHERICAL BUBBLE IN A COMPLEX FLUID

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***Abstract.** The motion of an oscillating bubble in a complex fluid is investigated. The bubble is immersed in a substance composed of a Newtonian liquid and a dilute volume fraction of anisotropic additives as long fibers or few ppm of macromolecules. The constitutive equation for the fluid has been based on a Maxwell model with an extensional viscosity for the viscous contribution. This approach results in a modified version of the classical Rayleigh-Plessetequation of bubble dynamics that might be integrated by using a fifth order Runge-Kutta scheme with appropriated time steps. The numerical computation solves three first order ordinary differential equations, including the one associated with the solution of the convolution integral. The orientation of the particles is considered. The angular probability density function is based on the normal distribution. The results show that the model based on the fully aligned additives with the radial direction overestimates the tendency of the additives to stabilize the bubble motion, since the effect of extensional viscosity occurs due to the particles resistance to the movement throughout its longitudinal direction.*

***Keywords**: bubble dynamics, elasticity, convolution integral, fiber orientation, viscoelasticity*

PAC0486: FROM DROP SHAPE TO A CONTINUUM DESCRIPTION OF HIGH VISCOSITY EMULSION FLOWS

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***Abstract.** This theoretical work shows how the knowledge of the emulsion micro-scale, including drop stretching and orientation leads to a continuum description of emulsion flows. A first order small deformation theory is explored for describing the rheology of an emulsion of high viscosity drops undergoing unsteady shear flows. The stationary shape and the interfacial velocity of a drop are used in order to obtain the contribution of the drop to the effective stress tensor of the emulsion. A complex rheology including the nonlinear frequency response of the emulsion under oscillatory shear at arbitrary frequency forcing and strain amplitude is identified.*

***Keywords**: emulsion, viscous drop, rheology, shear flows, viscoelasticity*

PAC 0488: A THEOTERICAL INVESTIGATION OF CONCENTRATION WAVES IN FLUIDIZED BEDS

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Abstract. *In this work, the problem of bubble formation in a fluidized bed is investigated theoretically. A modal analysis is carried out after linearizing the set of governing equations for the two-fluid problem. The particle pressure is expressed in terms of two mechanisms: at low Reynolds numbers, the particle pressure is defined by particle velocity fluctuations due to viscous hydrodynamic interactions, whereas at high Reynolds number regimes particle pressure is associated with velocity fluctuations due to inertial effects. The influence of the particle pressure on the stabilization of the bed is examined separately. The linear stability regime is used as a base state for the non-linear stability analysis problem. The set of the nonlinear governing equations is solved numerically by the characteristic method for the unidimensional regime. The results show the spatiotemporal evolution of a small disturbance and the appearance of flow discontinuities similar to a shock wave in gases. We also investigate how the physical parameters of the problem can attenuate or stimulate shock formation (that we associate to bubble formation). In addition, based on both linear stability analysis and the numerical solution of the problem, the particle pressure function is explored in terms of the flow parameters such as particle volume fraction, Reynolds number and Froude number, at critical wave lengths.*

Keywords*: Fluidized Beds, Instabilities, Numerical Characteristic Method, Shock Waves*

NOTES

I. FATIGUE AND FRACTURE MECHANICS OF STRUCTURAL AND ADVANCED MATERIALS

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NOTES

PAC0109: FATIGUE CRACK PROPAGATION ANALYSIS AND CHARACTERIZATION OF SURFACE CRACKS IN STRUCTURAL STEEL PLATES AND WELDED JOINTS

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Abstract. . *This work is concerned with the analysis and characterization of the fatigue crack propagation of surface cracks in structural unwelded and welded steel plates. This analysis is done by using a dedicated experimental methodology that allows the detection and monitoring of the development of surface cracks by using a multi-strain gauges technique. Cracks are nucleated and propagated by fatigue from a small elliptical surface notch machined in the plate samples, or naturally nucleated from the toe of butt welded joints of the same plates. The methodology allows to characterize the fatigue crack propagation in the thickness directions of the plates and to obtain the corresponding material parameters of the Paris law. Then results allow to analyze and to compare the fatigue crack propagation from butt welded joints. The influence of different mechanical and geometrical parameters on the fatigue behavior of welded joint, as load ratio, thickness plate, reinforcement angle, etc., can be then study. Some preliminary results are presented for unwelded and welded ½ inch A36 steel plates*

Keywords*: Fatigue, Crack Propagation, Surface Cracks, Welded Joints*

PAC0237: THEORETICAL EFFECT OF CRACKS ON THE DYNAMIC BEHAVIOUR OF BEAMS

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Abstract. *This paper presents a theoretical methodology to analyze the damage on simple structures like beams, following Narkis (1994) developments. The main idea is to study the beam equation of motion taking into account the Euler-Bernoulli hypothesis. In the following, the differential equation of motion is solved with the presence of discontinuities due to cracks thus evaluating theoretical dynamic characteristics variations, such as, natural frequencies and mode shapes. As stated by Binici (2005), it is used a rotational spring between healthy parts of the beam to represent the discontinuities which is coupled into the equations of motion with the boundaries condition in the crack. Some experimental data regarding the flexibility of the spring are indicated by the literature (Ruotolo, 1997). The flexibility is function of crack patterns itself and fracture parameters such as CMOD (crack mouth opening displacement) as well as stress intensity factors. At the end of paper, some graphs are shown describing how the presence of the crack and its location may theoretically affect the modal characteristics of such structures.*

Keywords*: Damage Detection, Modal Analysis, Cracked Beams*

PAC0239: NUMERICAL ANALYSIS OF REINFORCED CONCRETE STRUCTURES USING DAMAGE MODELS

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Abstract. *This work presents one and two-dimensional numerical analyses using damage models for the concrete in order to discuss their applicabilities. Initially, it is shortly described the damage model proposed by Mazars. This constitutive model assumes the concrete as isotropic and elastic material, where locally the damage is due to extensions. On the other hand, the damage model proposed by Pituba the material is assumed as initial elastic isotropic medium presenting anisotropy, plastic strains and bimodular response (distinct elastic responses whether tension or compression stress states prevail) induced by the damage. To account for bimodularity two damage tensors governing the rigidity in tension and compression regimes, respectively, are introduced. Soon after, the models are used for analyzing the mechanical behavior of reinforced concrete structures. Accordingly with comparison of the obtained responses, considerations about the application of the constitutive models are presented. In particular, some difficulties related to strain localization are evidenced.*

Keywords: *damage mechanics, concrete structures, constitutive model*

PAC0284: FATIGUE LIFE OF NOTCHED SPECIMENS UNDER BENDING LOADING

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Abstract. *In this work, bending fatigue life of notched specimens with various notch geometries and dimensions is investigated by experiment and Manson-Caffin analytical method. In this analytical method, fatigue life of notched specimens is calculated using the fatigue life obtained from the experiments for plain specimens (without notch). Three notch geometries including u-shape, v-shape and* ц*-shape notches are considered in this investigation. The experiments are conducted on a rotary bending Moore machine. The specimens are made of a low carbon steel alloy which has wide application in industry. The stress- life curves are captured for all notched specimen by experiment. results indicate that Manson-Caffin analytical method can not adequately predict the fatigue life of notched specimen However, it seems that the difference between the experiments and Manson-Caffin predictions can be compensated by a proportional factor. The value of this factor needs more experiments to be conducted and more notch geometries to be considered. This remains to be accomplished in a more enhanced research program in future.*

Keywords. *Notched specimen; fatigue life; Mason-Caffin method; stress-life curve*

PAC0370: ORIENTATIONS AND CRACK CLOSURE EFFECTS ON FATIGUE CRACK GROWTH

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Abstract.*This study present fatigue behavior of aluminum alloy 2024 T351 SENT specimen where various parameters effects are studied such as load ratio, maximum load effec. The fatigue crack growth with constant amplitude is studied using the AFGROW code when NASGRO model is used. The effect of the load ratio is highlighted, where one notices a shift of the curves of crack growth. The comparative study between two orientations L-T and T-L on fatigue behavior are presented and shows the variation on the fatigue life.The results sown thant no crack closure*

phenomenon are present at higth stress intnrsity facotr.

***Keywords**: fatigue, aluminum alloy, load ratio, orientation, closure effect*

PAC0383: DEVELOPMENT OF FULLY-PLASTIC J SOLUTIONS FOR CIRCUMFERENTIALLY CRACKED PIPES UNDER COMBINED BENDING AND TENSION

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***Abstract.** Structural integrity assessments of pipe girth welds play a key role in design and safe operation of piping systems, including deep water steel catenary risers. More efficient and faster installation methods now employ the the pipe reeling process which allows welding and inspection to be conducted at onshore facilities. However, the reeling process subjects the pipe to large bending load and plastic deformation coupled with high tensile forces imposed on the pipeline with potential strong impact on unstable crack propagation of undetected flaws at girth welds. Fitness-for- service (FFS) assessments of reeled pipes rely heavily on accurate evaluation of elastic-plastic crack driving*
forces, such as the J-integral, for circumferential surface cracks. Such J solutions for these crack configurations remain rare and limited to few crack geometries. This work provides fully-plastic solutions for pipes with circumferential surface cracks subjected to bending and tensile load which enter directly in FFS procedures for such crack configurations

***Keywords**: J-integral, HRR stress fields, fully plastic solutions, circumferential surface crack, pipeline*

PAC0403: 2D EVALUATION OF CRACK OPENINGS USING SMEARED AND EMBEDDED CRACK MODELS

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***Abstract.** This work deals with the determination of crack openings in 2D reinforced concrete structures using the Finite Element Model with a smeared rotating crack model or an embedded crack model. In the smeared crack models, the strong discontinuity associated with the crack is spread throughout the finite element. As it is well known, the continuity of the displacement field assumed for these models is not compatible with the real discontinuity. In spite of this, this type of model has been extensively used due to its relative computational simplicity provided by treating cracks in a continuum framework, as well as to reported good predictions of the structural behavior of reinforced concrete members. On the other hand, the embedded crack model is able to*

describe the effects of actual discontinuities (cracks), by enriching the displacement field in the interior of each finite element crossed by the crack paths. This paper presents a comparative study between the abilities of these two models in 2D computational modeling to predict the mechanical behavior of reinforced concrete structures. Structural responses, crack patterns, crack openings, rebar stresses and concrete stresses predicted by both models are compared with experimental results from literature.

***Keywords**: Finite Element Method, Smeared Crack Model, Embedded Crack Model, 2D Computational Modeling*

PAC0476: MICROMECHANICAL MODELING OF MECANICAL BEHAVIOR OF IMPACT MODIFIED POLYPROPYLENE

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***Abstract.** Polypropylene (PP), a member of polyolefin plastics family, has various applications ranging from biaxially blown film for packaging to various structural components such as instrument panels, the front and middle pillars and bumper fascia in automotive, consumer housing, appliances etc. Impact modification of PP as well as many other thermoplastic polyolefins (TPO) is commonly used for applications with certain impact resistant requirements. Impact modified PP is a blend of polypropylene with an impact modifier such as ethylene propylene rubber, ethylene alpha olefin elastomers or styrenic based rubber. The advantage of using these types of impact modifiers for PP is that they are well compatible with PP. It is well known that the rubber particle shape, size distribution, and basic mechanical properties play an important role in the impact toughness of impact modified TPO. Crazing is a source of inelastic deformation additional to the elastic one up to the necking process or brittle fracture. In this study we present a quantitative modeling of macroscopical behavior (stress-strain curve) of impact modified PP based on a micromechanical model of crazing initiated from rubber particles. The effective compliance increases with stress (strain). The observed relations between the effective compliance and the stress allow one to separate the craze formation and craze growth effects. The total number of crazes for a given rubber volume fraction is evaluated and an adequate stress-strain relationship is proposed.*

***Keywords**: Crazing, Impact modified PP, Thermoplastic polyolefins*

PAC0487: INVESTIGATION OF THE DEPENDENCY OF THE STRESS CONCENTRATION FACTOR ON PLATE LENGTH IN NOTCHED PLATES UNDER BENDING

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Abstract. *In this paper the dependency of the stress concentration factor on plate length, in plates with opposite elliptic notches (see figure 1) subjected to in- plane bending is studied. To accomplish this goal, a FE code has been developed. Due to symmetric geometry, only one half of the plate considering geometric boundary condition, as illustrated in figure, 2 is analyzed. The achieved results in special cases that elliptic notches convert to circular ones are compared to that of reported results [1].*

Keywords*: Stress concentration factor, transition length, bending, plate*

PAC0498: CRACK INITIATION IN HIGH DENSITY POLYETHYLENE PIPE RESULTING FROM CHEMICAL DEGRADATION

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Abstract. *The fracture phenomena in engineering thermoplastics such as high density polyethylene (HDPE) resulting from chemical degradation is usually observed in the form of a microcrack network within a surface layer of degraded polymer exposed to a combined action of mechanical stresses and chemically aggressive environment. Degradation of polymers is usually manifested in a reduction of molecular weight, increase of crystallinity in semi crystalline polymers, increase of material density, a subtle increase in yield strength, and a dramatic reduction in toughness. The critical level of degradation for fracture initiation depends on the rates of toughness deterioration and build-up of the degradation related stresses as well as on the manufacturing and service stresses. In this paper, the evaluation of chemical degradation induced stresses and modeling of fracture initiation in HDPE pipes is presented. The probability of the crack initiation is formulated using the formalism of statistical fracture mechanics (SFM) and chemical degradation induced stresses. The critical level of degradation is determined by using point-wise Weibull distribution of material toughness parameter. Experimental observations obtained from accelerated tests of HDPE pipe at an elevated temperature and chemically aggressive environment are compared with the results of the mathematical model of the described above processes.*

Keywords*: High density polyethylene, Fracture, Mechano-chemical degradation, Statistical fracture mechanics*

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FEDALTO, L.	BRASIL	PAC0387
FERREIRA, J.A.F.	PORTUGAL	PAC0120
FILIPPIN, C.G.	BRASIL	PAC0387
FINZI NETO, R. M.	BRAZIL	PAC0376
FRANKL, J.	CZECH REPUBLIC	PAC0396
GALLO, C.A.	BRAZIL	PAC0376
GOMES, A.	BRASIL	PAC0179
GOMES, R.C.	BRASIL	PAC0280
GONÇALVES	BRASIL	PAC0195
GONZÁLES, A.	REPÚBLICA BOLIVARIANA DE VENEZUELA	PAC0174
HERNANDES, J.A.	BRASIL	PAC0415
HOU, Y.M.	CHINA	PAC0315
JASENEVICIUS, R.G.	BRAZIL	PAC0124
JAVAREZ LAERCIO, JR.	BRAZIL	PAC0124
KHATCHATOURIAN, O.	BRASIL	PAC0213, PAC0230
KLOIBER, M.	CZECH REPUBLIC	PAC0396
LACAVA, P.T.	BRAZIL	PAC0436
LEITE, E.	BRASIL	PAC0179
LI, Y.L.	CHINA	PAC0315
LINDENBERG, H.N.	BRAZIL	PAC0313
MASSUDA, A.I.	BRASIL	PAC0254
MENDES, M.F.	BRAZIL	PAC0326
MONTANARI, L.	BRAZIL	PAC0124
NETO DA SILVA, F.J.	PORTUGAL	PAC0120
OKIMOTO, P.C.	BRASIL	PAC0387
OLIVEIRA, F.A.	BRAZIL	PAC0166
OLIVEIRA, F.A. DE	BRAZI	PAC0230
PARDINI, L.C.	BRASIL	PAC0254
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PONCIANO, W.M.	BRASIL	PAC0415
PORTELLA, K.F.	BRASIL	PAC0387
RADE, D.A.	BRAZIL	PAC0376
RAMIREZ R E.	BRAZIL	PAC0413
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SCHWER, L.	USA	PAC0062, PAC0554
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SILVA, R.E.P.	BRAZIL	PAC0436
STEFFEN JÚNIOR, V.	BRAZIL	PAC0376
TIPPNER, J.	CZECH REPUBLIC	PAC0396
VIELMO, H.A.	BRAZIL	PAC0230
VIVEROS, H.P.	BRAZIL	PAC0262
WANG, J.H.	CHINA	PAC0315
XU, A.J.	CHINA	PAC0315

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AGRAWAL, R.	USA	PAC0112, PAC0113
BASAGLIA, C.	PORTUGAL	PAC0102
BATRA, R.C.	USA	PAC0373
BURGOS, R.B.	BRASIL	PAC0440
CAMOTIM, D.	PORTUGAL	PAC0102
CETALE SANTOS, M.A.	BRASIL	PAC0440
CHEN, Z.	CHINA	PAC0532
DEL PRADO, Z.J.G.N.	BRAZIL	PAC0216
DUARTE, H.	BRASIL	PAC0463
ESPINOSA, H.D.	USA	PAC0112, PAC0113
FAFITIS, A.	USA	PAC0532
FEDOTOV, A.A.	RUSSIAN FEDERATION	PAC0353
FUINA, J.S.	BRASIL	PAC0168
GDOUTOS, E.E.	USA	PAC0112
GODOY, L.	ARGENTINA	PAC0329
GONÇALVES, P.B.	BRAZIL	PAC0216, PAC0305
GRISTCHAK, V.Z.	UKRAINE	PAC0304
HALPHEN, B.	FRANCE	PAC0301
JACA, R.	ARGENTINA	PAC0329
KAUSHIK	USA	PAC0373
LENCI, S.	ITALY	PAC0305
LUONG, M.P.	FRANCE	PAC0301
LUONGO, A.	ITALY	PAC0095
MARCHEGGIANI, L.	ITALY	PAC0520
MAZZILLI, C.E.N.	BRAZIL	PAC0075
MISCHENKO, A.A.	RUSSIAN FEDERATION	PAC0353
ORLANDO, D.	BRAZIL	PAC0305
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PENG, B.	USA	PAC0112
PITANGUEIRA, R.L.S	BRASIL	PAC0168
REGA, G.	ITALY	PAC0305
REQUENA, J.A.V.	BRAZIL	PAC0279
RONG, B.	USA	PAC0532
SALGANIK, R.L.	RUSSIAN FEDERATION	PAC0353
SANCHES, C.T.	BRAZIL	PAC0075
SHRIVASTAVA, S.	CANADA	PAC0201

SILVA, F.M.A.	BRAZIL	PAC0216
SILVA, R.R.	BRASIL	PAC0440
SILVESTRE, N.	PORTUGAL	PAC0102
VIEIRA, R.F.	BRAZIL	PAC0279
ZHANG, J.	CANADA	PAC0201
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ABOU-KANDIL, H.	FRANCE	PAC0107
AUBOUET, S.	FRANCE	PAC0546
BARA, G.I.	FRANCE	PAC0340
BARASUOL, V.	BRASIL	PAC0362
BERTOL, D.W.	BRAZIL	PAC0410
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CHEMORI, A.	FRANCE	PAC0321
COMPANY, O.	FRANCE	PAC0321
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DAAFOUZ, J.	FRANCE	PAC0204
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GALVEZ, J.M.	BRAZIL	PAC0510
GODOY, E.P.	BRAZIL	PAC0176
GÓES, L.C.S.	BRAZIL	PAC0261
HALALCHI, H.	FRANCE	PAC0340
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IUNG, C.	FRANCE	PAC0204
JABBOUR, Z.	FRANCE	PAC0079
JESUS, G.A.R.	BRAZIL	PAC0510
JUNGERS, M.	FRANCE	PAC0410
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LAROCHE, L..	FRANCE	PAC0340
MALLOCI, I.	FRANCE	PAC0204
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MARTINS, N.A.	BRAZIL	PAC0410
MATHELIN, L.	FRANCE	PAC0107
MOREAU, S.	FRANCE	PAC0079
PALLUAT, N.	BRAZIL	PAC0467
PASTUR, L.	FRANCE	PAC0107
PIERROT, F.	FRANCE	PAC0321
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RAMIREZ, R.	MEXICO	PAC0546
RAMOS, R.L.C.B.	BRAZIL	PAC0261
RIWAN, A.	FRANCE	PAC0079
ROSARIO, J.M.	BRAZIL	PAC0125
SARTORI NATAL, G.	FRANCE	PAC0321
SAVI, M.A.	BRAZIL	PAC0499
SENAME, O.	FRANCE	PAC0546
SILVA, F.C.G.	BRAZIL	PAC0467

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CERROLAZA, M.	VENEZUELA	PAC0511
CISILINO, A.P.	ARGENTINA	PAC0171, PAC0083
CODA, H.B.	BRAZIL	PAC0245
D'AZEVEDO, E.F.	USA	PAC0074
DENDA, M.	UNITED STATES OF AMERICA	PAC0511
DENIPOTTI, G.J.	BRASIL	PAC0224
DONDERO, M.	ARGENTINA	PAC0171
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FERREIRA, L.O.S.	BRAZIL	PAC0252
FIGUEIREDO, L.G.	BRAZIL	PAC0544
FONTES, E.F.	BRASIL	PAC0115
GRAY, L.J.	USA	PAC0074
JORGE, A.B.	BRAZIL	PAC0348
KONDA, D. H.	BRASIL	PAC0222, PAC0224
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LABAKI, J.	BRAZIL	PAC0252
LANGER, S.	GERMANY	PAC0556
LARROSA, N.O.	ARGENTINA	PAC0083
MANZOLI, O. L.	BRAZIL	PAC0220
MARCZAK, R.J.	BRAZIL	PAC0167, PAC0170
MESQUITA, E.	BRAZIL	PAC0252
OBERLAENDER, D.T.	BRAZIL	PAC0528

ORTIZ TÁVARA, J.E.	ESPAÑA	PAC0083
PALERMO JR., L.	BRAZIL	PAC0544
PESSOLANI, R.B.V.	BRAZIL	PAC0528
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SENSALE, B.	URUGUAY	PAC0159
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SILVEIRA, O.A.A.	BRAZIL	PAC0167, PAC0170
TELLES, J.C.F.	BRASIL	PAC0115
THÖNI, K.	AUSTRIA	PAC0511
URQUIZA, S.	ARGENTINA	PAC0171
VENTURINI, W.S.	BRAZIL	PAC0308, PAC0245
VERA-TUDELA, C.A.R.	BRASIL	PAC0115
WAIDEMAM, L.	BRAZIL	PAC0308
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AKHRAS, G.	CANADA	PAC0453
ALSHITS, V.I.	RUSSIA	PAC0539
BEAUMONT, P.W.R.	ENGLAND	PAC0550
BERGER, H.	GERMANY	PAC0121
BOUTIN, C.	FRANCE	PAC0401
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BRAVO-CASTILLERO, J.	CUBA	PAC0071, AC0121, PAC0236, AC0244, PAC0263, PAC0398
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CAMPOS FILHO, A.	BRAZIL	PAC0211
CISILINO, A.P.	ARGENTINA	PAC0111
DEGISCHER, H.P.	AUSTRIA	PAC0408
DUDZIAK, M.	POLAND	PAC0506
DUMONT, N.A.	BRAZIL	PAC0471
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FEDOTOVA, T.	SOUTH AFRICA	PAC0295
GABBERT, U.	GERMANY	PAC0121
GOLDSZTEIN, G.H.	USA	PAC0334, PAC0335
GUINOVART-DIAZ, R.	CUBA	PAC0121, AC0236, PAC0244
HUAMÁN MOSQUEIRA, D.	BRAZIL	PAC0471
IBARRA PINO, A.	ARGENTINA	PAC0111
LAUKE, B.	GERMANY	PAC0369
LI, W.	CANADA	PAC0453
LOPEZ-REALPOZO, J.C.	CUBA	PAC0236
MAGHOUS, S.	BRAZIL	PAC0211
MALUJDA, I.	POLAND	PAC0491, PAC0506
MARKS, E.D.	AUSTRIA	PAC0408
MARQUES, F.D.	BRAZIL	PAC0207
MIELNICZUK, J.	POLAND	PAC0506
MONSIVAIS, G.	MÉXICO	PAC0398
MORENO, M.E.	BRAZIL	PAC0207
MURRALI, A.	ITALY	PAC0154
NOWACKI, J.P.	POLAND	PAC0539
OTERO, J.A.	CUBA	PAC0398
PACHECO, A.R.	BRAZIL	PAC0211
PASA DUTRA, V.F.	BRAZIL	PAC0211
PEÑATE-RODRÍGUEZ, C.	CUBA	PAC0071
PÉREZ-FERNÁNDEZ, L.D.	CUBA	PAC0263, PAC0244
PIETRZAKOWSKI, M.	POLAND	PAC0502
RADOWICZ, A.	POLAND	PAC0539
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RODRIGUEZ-RAMOS, R.	CUBA	PAC0071, AC0121, PAC0398, AC0236, PAC0244, PAC0263
RODRÍGUEZ-RAMOS,R.	CUBA	
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SABINA-CÍSCAR, F.	MEXICO	PAC0236
SEVOSTIANOV, I.	USA	PAC0267
SHATALOV, M.	SOUTH AFRICA	PAC0295
SOUBESTRE, J.	FRANCE	PAC0401
TENKAM, H.M.	SOUTH AFRICA	PAC0295
TIPPUR, H.	USA	PAC0296
TITA, V.	BRAZIL	PAC0207
TROVALUSCI, P.	ITALY	PAC0154
VARANO, V.	ITALY	PAC0154

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AHMADI, R.	CANADA	PAC0497
ASHEGHIAN, L.	USA	PAC0534
BORAEY, M.	CANADA	PAC0184
CHIANG, F.P.	USA	PAC0093
DARGAHI, J.	CANADA	PAC0497
EPSTEIN, M.	CANADA	PAC0184
GANDHI, F.	USA	PAC0534
GONÇALVES, P.B.	BRAZIL	PAC0217
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HUČKO, B.	SLOVAKIA	PAC0103
KALANTARI, M.	CANADA	PAC0497
KÖVECSES, J.	CANADA	PAC0497
KUDVA, J.	USA	PAC0534
OLYMPIO, K.R.	USA	PAC0534
PACKIRI, M.	CANADA	PAC0497
PAMPLONA, D.	BRAZIL	PAC0217
PAMPLONA, D. C.	BRAZIL	PAC0223
SELVADURAI, A.P.S.	CANADA	PAC0228
SOARES, R.M.	BRAZIL	PAC0217
STREET, J.	USA	PAC0534

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AVILA DA SILVA JR	BRAZIL	PAC0242, AC0247
BECK, A.T.	BRAZIL	PAC0072, AC0073, PAC0242, AC0247
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BRASIL JR., A.C.P.	BRASIL	PAC0322
CATALDO, E.	BRAZIL	PAC0177
CURSI, E.S. DE	FRANCE	PAC0219
DINIZ, A.C.G.C.	BRASIL	PAC0322
DINIZ, S.M.C.	BRAZIL	PAC0226
FABRO, A.T.	BRAZIL	PAC0082
FREITAS, M.S.R.	BRASIL	PAC0433
GEUBELLE, P.H.	USA	PAC0187
GOMES, W.J.	BRAZIL	PAC0072
JENSEN, H.	CHILE	PAC0288
KIM, I.H.	USA	PAC0187
LEONEL, E.D.	BRAZIL	PAC0073
LEPAGE, S.	USA	PAC0187
LOPEZ, R.H.	FRANCE	PAC0219
MAUPRIVEZ, J.	BRAZIL	PAC0177
MORAIS, M.V.G.	BRASIL	PAC0322
OLIVEIRA, A.L.	BRASIL	PAC0433
PIMENTA, R.	BRAZIL	PAC0226
RITTO, T.G.	BRAZIL	PAC0080, AC0082, PAC0219
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SOIZE, C.	FRANCE	PAC0080
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SOUSA, F.O.S.	BRASIL	PAC0322
STUMP, F.V.	USA	PAC0187
TYLIKOWSKI, A.	POLAND	PAC0536
VENTURINI, W.S.	BRAZIL	PAC0073
Sampaio, R.	Brazil	PAC0080
Sampaio, R.	Brazil	PAC0082
Sampaio, R.	Brazil	PAC0219
Sergio Bellizzi	France	PAC0101
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SoUSA Jr, J.B.M.	Brazil	PAC0433
SoUSA, F. O. S.	Brazil	PAC0322
Stump, F.V.	USA	PAC0187
Tylikowski, A.	Poland	PAC0536
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ALAZARD, D.	FRANCE	PAC0152
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BARROS, F.B.	BRAZIL	PAC0175
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CARVALHO, E.	BRAZIL	PAC0330
CODA, H.B.	BRAZIL	PAC0317
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DAMASCENO, B.C.	BRAZIL	PAC0525
DANNY HERNÁN, Z.C.	BRAZIL	PAC0417
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ELASKAR, S.	ARGENTINA	PAC0347, PAC0380
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GOES, L.C.S.	BRAZIL	PAC0127
GONÇALVES, P.	BRAZIL	PAC0330
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KAPITANIAK, T.	POLAND	PAC0091
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OSTOJA-STARZEWSKI, M.	**USA**	**PAC0206**
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PICCIRILLO, V.	**BRAZIL**	**PAC0127**
PRADO, Z.	**BRAZIL**	**PAC0330**
RAMOS, R L.C.B.	**BRAZIL**	**PAC0127**
SANCHES, L.	**FRANCE**	**PAC0152**
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LAURENT, T.	FRANCE	PAC0356
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MORRISON, N.F.	ENGLAND	PAC0130
NACCACHE, M.F.	BRAZIL	PAC0371
NASSAR, B.	BRAZIL	PAC0371
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QIU, X.	FRANCE	PAC0363
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SCHMITT, F.	FRANCE	PAC0363
SOBRAL, Y.D.	BRAZIL	PAC0488
SOUZA MENDES, P.R.	BRAZIL	PAC0371
THAIS, L.	FRANCE	PAC0365
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GAMINO, A.L.	BRASIL	PAC0403
GUSTAVO	BRASIL	PAC0237
HADJOUI, A.	ALGERIA	PAC0370
HERBERT	BRASIL	PAC0237
HOSEINI, A.V.	IRAN	PAC0487
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SOUSA, J.L.A.O.	BRASIL	PAC0403

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