PROGRAM
Second European-Latin-American Conference of Theoretical and Applied Mechanics
University of Havana, February 11-13, 2019

Web-site: http://www.elactamcuba.com

Note: The talks are 30 min: 25 minutes + 5 min for questions.

Place	Time	Monday 11.02.18	Tuesday 12.02.18	Wednesday 13.02.18
Classroom 5	8:30-9:00	**Registration** Faculty of Mathematics (Building Felipe Poey, 1st floor) and Opening Ceremony (Aula Magna)	T13	T31
	9:00-9:30		T14	T32
	9:30-10:00		T15	T33
	10:00-10:30	T1	T16	T34
	10:30-11:00	T2	T17	T35
	11:00-11:30	**Coffee break**		
	11:30-12:00	T3	T18	T46
	12:00-12:30	T4	T19	T37
	12:30-13:00	T5	T20	T38
	13:00-13:30	T6	T21	T39
	13:30-15:30	**Lunch**		
Classroom 6	8:30-9:00	**Registration** Faculty of Mathematics (Building Felipe Poey, 1st floor) and Opening Ceremony (Aula Magna)	T22	T40
	9:00-9:30		T23	T41
	9:30-10:00		T24	T42
	10:00-10:30	T7	T25	T43
	10:30-11:00	T8	T26	T44
	11:00-11:30	**Coffee break**		
	11:30-12:00	T9	T27	T45
	12:00-12:30	T10	T28	T46
	12:30-13:00	T11	T29	T47
	13:00-13:30	T12	T30	T48
	13:30-15:30	**Lunch**		
	17:30-19:30	***Welcome Cocktail***		

Participants

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NONLINEAR VISCOELASTIC EFFECTS IN PRESSURIZED FIBER REINFORCED TUBES

Abstract: Consider a circular cylinder composed of a nonlinear fiber reinforced material in which the fibers are symmetrically and helically wound. The ends are closed and pressure is uniformly applied over the inner surface. The cylinder is assumed to undergo uniform length and radial change as it deforms. The relative length and radial changes depend on the fiber winding angle in the reference configuration and the properties of the fibers relative to the matrix. When the matrix and fibers are nonlinearly elastic, depending on fiber angle and the properties of the fibers relative to the matrix, the cylinder may increase in length and decrease in radius or vice versa. Nonlinear viscoelastic response connects with nonlinear elastic response in two limits: (1) the initial response and (2) the equilibrium response in the limit as time increases. In these limits, the equations governing the deformation of the tube have the same form as for nonlinear elastic matrix and fibers. However, the properties of the fibers relative to the matrix at equilibrium may have changed significantly compared to that in the initial case. There may be an increase in length and decrease in radius for these relative properties at small times and then a transition to a reversal for them at large time. In general, differing relative properties of the matrix and fiber in these

limits as well as different characteristic times for stress relaxation can lead to unusual deformation histories connecting these limits. The influence of these relative time dependent properties is investigated using the nonlinear single integral Pipkin-Rogers constitutive equation for viscoelastic response. This constitutive equation exhibits the essential feature of nonlinear viscoelasticity, i.e. strain-dependent stress relaxation. Further, with this formulation it is straightforward to obtain the representation of the strain-dependent stress relaxation properties due to the material symmetry associated with the fiber reinforcement. In this representation the matrix material and fibers have different nonlinearly viscoelastic properties. Here, material properties are assumed such the initial and equilibrium limits have the same form as for the standard nonlinear elastic reinforcing model, but the stiffness and relaxation time of the fiber differs relative to those of the matrix. This formulation leads to nonlinear Volterra integral equations governing the deformation of the cylinder. Numerical examples are presented that illustrate the phenomena that can occur.

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TOWARDS MICROSTRUCTURALLY MOTIVATED CONSTITUTIVE MODELING OF BRAIN TISSUE
Abstract: The brain is one of the most complex and fascinating organs in the human body. While initially brain research had mostly been focused on biochemical and electrophysiological processes, more and more evidence suggests that mechanics play an important role in modulating brain form and function. On the one hand, the impact of external mechanical forces may cause serious injuries and brain damage. On the other hand, mechanics control cortical folding during brain development and the migration of neurons and tumor cells, as well as tissue adaptation, de- and regeneration through mechanosensing. Computational mechanics are a powerful tool to predict the behavior of brain tissue in health and disease. However, the success of in silico simulations critically depends on the development of accurate constitutive models and reliable identification of the corresponding material parameters. This has proven difficult due to the extremely compliant nature of brain tissue: its mechanical response is nonlinear, hysteretic, conditioning, strain-rate-dependent, loading-mode-specific, region-dependent, and compression-tension asymmetric. Furthermore, controversial experimental findings have hindered expeditious progress in constitutive modeling of brain tissue. To date, a comprehensive model that reliably captures the wide range of loading conditions occurring in vivo and the high regional variations is still missing. Here, we carefully analyze the microstructure of brain specimens from different anatomical regions (cortex, basal ganglia, corona radiata, and corpus callosum) tested under multiple loading modes-simple shear in two orthogonal directions, compression, and tension – to gain insights into the correlations between individual (cellular and extracellular) microstructural components and the macroscopic mechanical response. Interestingly, neurons together with their axons - the functionally most important elements of brain tissue - seem to play a minor role in tissue mechanics. Although nerve fibers are highly aligned in certain brain regions (leading to a rather anisotropic microstructure), the continuum-level-response appears to be isotropic. Our simultaneous analysis of the large-strain response of brain tissue and the underlying microstructure provides a first step towards microstructurally motivated constitutive models that inherently capture regional variations in brain tissue properties arising from local differences in functional demands and thus, in the tissue's microstructure. These new insights in the correlation between mechanics and microstructure valuably advance our understanding of brain mechanics and open new pathways in region- and disease-specific constitutive modeling. Microstructurally motivated models are not only able to predict regionally varying properties, but also foresee the effects of pathological degradation of certain components on the mechanical properties of the tissue. The latter become especially important as cells react to their mechanical environment through mechanosensing, in the worst case leading to apoptosis.

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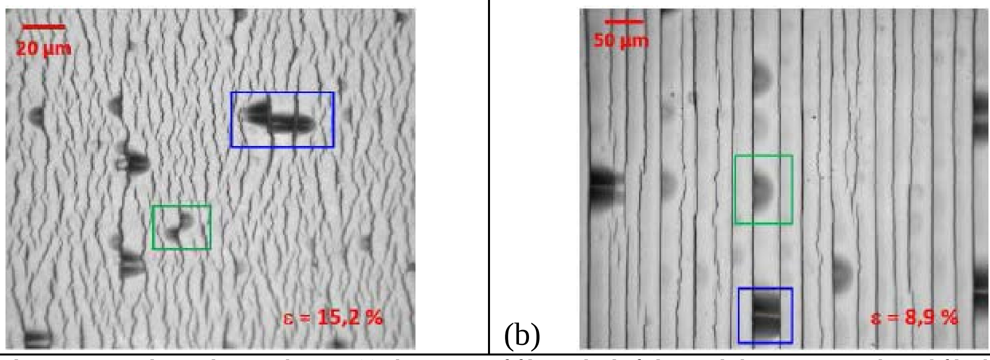
EXPERIMENTAL STUDY AND MODELLING FOR THE PREDICTION OF THE MECHANICAL INTEGRITY OF METAL FILM ON POLYMER SUBSTRATE FOR FLEXIBLE ELECTRONICS

Abstract: Over the past 20 years, new improvements in materials and processes led to the development of printed flexible electronics. Flexible electronics devices subjected to bending, twisting, or stretching during their lifetime, the development of device with high reliability is therefore of great importance for the efficiency of electrical connection. This work investigates the mechanical reliability of inkjet or screen-printed Ag thin films on polyimide substrates dedicated to the electrical interconnection of active components. Expected mechanical failure modes are film cracking and buckling delamination. First of all in order to characterized the two mechanisms, tensile tests are performed under an optical microscope to follow cracks and under an optical interferometer to follow buckles. In order to obtain crack spacing evolution during deformation, an image processing is realized. Two types of cracks are observed: long and straight cracking for thick films and small and zigzag shape cracking for thin films. The evolution of buckles shape with imposed tensile deformation is characterized. In a second step, in order to understand experimental observations, mechanical failure modes are analyzed with finite elements models. The origin of the two types of cracking are interpreted by a geometrical effect of film thickness. An elastoplastic shear lag bidimensional model gives upper and lower bonds of crack spacing during deformation. A three-dimensional model allows identification of cohesive zone model parameters at the film/substrate interface, from experimental buckles. An adhesion energy of 2 J.m-2, a critical strength of 20 MPa and a mode mixity parameter of 0.4 are identified from the comparison between the predicted and measured buckle's profile. Once these failure mechanisms identified and described, the optimal design of metal on polymer substrate system is accessible, and will be exemplified for a simple system.



(a) (b)

Figure 1: tensile test son metal on polymer substrate, (a) observation of film multiple failure and short zigzag cracks and film bucking at a axial strain of 1(% and above, film thickness is 0.4 micron, substrate thickness is 75 micron , (b) long and straight crack and buckling from 8% axial strain, the substrate thickness is identical, 75 microns

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MODELING THE MECHANICAL BEHAVIOR OF MULTICELLULAR AGGREGATES
Abstract: The mechanical properties of cells and biological tissues are key factors in many physiological and pathological processes. Therefore, we study the mechanical behavior of multicellular aggregates, treated as porous materials, composed of cells and filled with water, to derive an elasto-visco-plastic model [1-4]. The cellular constituent is responsible for the elastic and the plastic behavior (due to the rearrangement of adhesive bonds between cells), while the liquid constituent is responsible of the viscous-like response. The possible process of growth is modeled as the mass uptake of the solid-phase from the fluid-phase and it implies a continuum change of tissue geometry and internal structure. In order to incorporate the capability of cells to reorganize when submitted to stresses and to eventually grow, we use the notion of evolving natural configurations. The model is used to describe the uniaxial homogeneous compression when a fixed deformation is imposed and subsequently released. Results are compared with the dynamics observed in mechanical experiments found in literature [5].
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PERIODIC SOLUTIONS OF THE MONO-DOMAIN MODEL FOR THE ELECTRICAL ACTIVITY OF HEART
Abstract: The mono-domian model it is obtained, as a simplification, from the bi-domain which is one of the most used models to simulate the electrical activity of the heart. From a mathematical point of view, this model is conformed by a system of equations formed by one nonlinear parabolic equation for the potential of membrane and a system of ordinary equations for the activation variables. In this talk, we will be presented results obtained for the mono-domain model in a isolated region of the heart, (a ventricle), in where the activation is given in the endocardium, with a period of activation T, considering a ionic model of Roger-McCulloch type. In this case, we obtain the variational formulation of the boundary problem and give two notions of solution: “strong” and “weak”. The difference between weak solution and strong solution in this work lies in that for the first is not necessary to have a notion of derivative with respect to time, however, the strong solution must has derivative in a distributional sense. Also, this satisfies an abstract evolution equation (in a weak sense) where the linear part does not depend on $t.$ This last will allows us, in future works, to give a definition of strong solution as a solution of an abstract evolution equation in a strong sense, being possible to apply results associated to this type of equation. Then, we prove the existence of a weak T-periodic solution and we prove that this solutions also is strong. Finally, we give a sufficient restriction over the parameters of the model so that there is such T-periodic solution, which can be interpreted in a physiological sense.

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THE SLIDING CONDITION IN A SIMPLIFIED MODEL OF SEISMIC ACTIVITY AND ITS EFFECT ON THE DESTABILIZATION OF THE TECTONIC PLATES
Abstract: In this paper we analyze a simplified model of concentric elastic spheres that imitate the tectonic plates placed around a central sphere that simulates the terrestrial viscous fluid mantle and that allows the movement of said plates. Contact conditions between the plates and one of the plates with the fluid mantle including a dynamic condition of sliding between the two elastic plates are considered. The stability conditions for the sliding of the plates with a constant speed are studied, stating that the destabilization of this movement corresponds to the so-called plate breakage that corresponds to the beginning of the appearance of an earthquake. For this reason the determination of the stability threshold of the relative slip with constant velocity allows defining a risk index for a certain region to be more prone to the occurrence of earthquakes due to a small disturbance of the convective activity produced in the mantle. Some inverse problems of identification of parameters that could allow to determine the parameters involved in the definition of the risk index, from the knowledge of Surface measurements of seismic activity will be considered.

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MACROSCOPIC SIMULATION OF SELECTIVE BEAM MELTING PROCESSES BY MEANS OF ADAPTIVITY AND MULTI-RATE-INTEGRATORS
Abstract: The manufacturing of complex part geometries can by realised by utilising additive manufacturing (AM) techniques such as selective electron beam melting (SEBM) or selective laser sintering (SLS). The manufacturing of a part is accomplished in a layer-wise manner by fusing powdered material in locally defined regions, i.e. the current cross-section, using the energy provided by an electron or laser beam. Thereafter the building platform is lowered and the next cross section is manufactured as depicted in figure 1. The continuous improvement of such processes can be supported by considering numerical tools. Yet, the simulation of such processes is quite challenging, considering the different

involved time and length scales, nonlinear material behaviour and the continuous growth of the computational domain. Hence, multiple numerical techniques are combined to allow for a detailed simulation with moderate numerical cost. In the present contribution we make use of adaptivity for both, the spatial and temporal discreti- sation, employing suitable error estimates [1, 2]. Further, multi-rate-integrators are considered [3, 4] which allow to discretise the problem in time with heterogeneous time step sizes throughout the com- putational domain. Hence, as illustrated in figure 2, areas that are close to the laser or electron beam spot are resolved with a smaller time step size, while the remaining part of the domain is solved with a larger time step size.

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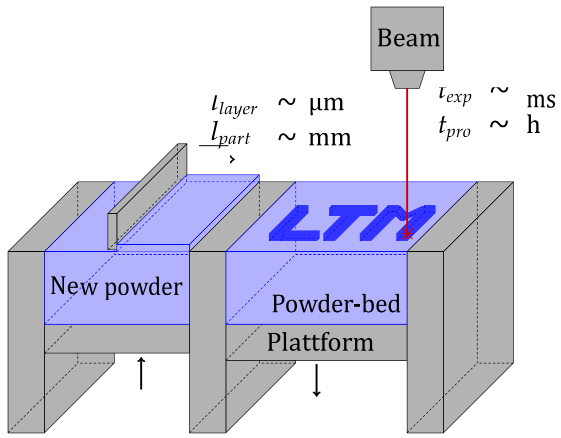

Fig. 1: Principle steps of powder bed-based AM processes

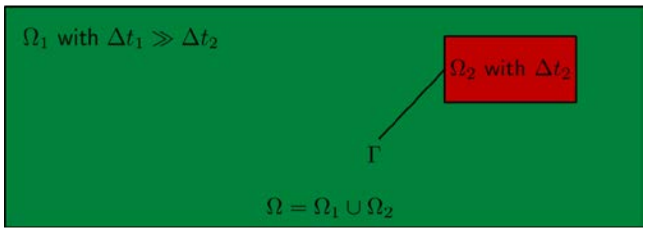

Fig. 2: Domain decomposition with heterogeneous time step size

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PHYSICALLY BASED MODELING OF MECHANOLUMINESCENCE IN ELASTOMERS

Abstract: Mechanoluminescence is a phenomenon where broken chemical bonds send out visible light upon stress application. The intensity of the emitted light correlates with the underlying evolution of chain scission in polymers. In this contribution, an anisotropic analytical network-averaging concept is uti-lized to model mechanoluminescence, Mullins effect, hysteresis and induced anisotropy in mechano-chemically responsive polymeric materials. The network damage and recovery alter the distribution of molecules in space and consequently change the mean field deformation measures (mesoscopic stretch and tube contraction). The mechanoluminescence is elucidated on the basis of microvoid growth. By this means, its characteristics such as the irreversibility and the anisotropy can be cap-tured. Model predictions demonstrate good agreement with experimental data of dioxetane cross-linked and filled elastomers.

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A GENERALIZED FRAMEWORK TOWARDS STRUCTURAL MECHANICS OF THREE-LAYERED COMPOSITE STRUCTURES

Abstract: Three-layered composite structures find a broad application. Increasingly, composites are being used whose layer thicknesses and material properties diverge strongly. In the perspective of structural mechanics, classical approaches to analysis fail at such extraordinary composites [1]. Therefore, emphasis of the present approach is on arbitrary transverse shear rigidities and structural thicknesses of the individual layers. Therewith we employ a layer-wise approach for multiple (quasi-)homogeneous layers [2]. Every layer is considered separately whereby this disquisition is based on the direct approach for deformable directed surfaces [3]. We limit our considerations to geometrical and physical linearity. In this simple and familiar setting we furnish a layer-wise theory by introducing constraints at interfaces to couple the layers. Hereby we restrict our concern to surfaces where all material points per surface are coplanar and all surfaces are plane parallel. Closed-form solutions of the governing equations enforce a narrow frame since they are strongly restrictive in the context of available boundary conditions, a computational solution approach is introduced using the finite element method [5]. In order to determine the required spatially approximated equation of motion, the principle of virtual work is exploited. The discretization is realized via quadrilateral elements with quadratic shape functions. Hereby we introduce an approach where nine degrees of freedom per node are used. Different integration schemes are applied to counter locking effects. In combination with the numerical solution approach, this layer-wise theory has emerged as a powerful tool to analyze composite structures [6]. In present treatise the capability of the proposed method is demonstrated for an anti-sandwich. This structure is geometrically contrary to a classical sandwich. Thereby the excellent convergence properties and the broad ranges of application are discussed. The solution methodology proves itself to be particularly efficient.

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MULTISCALE MODELING OF SHEET-LAYERED LAMINATION STACKS WITH DIFFERENT CONSTITUTIVE CONTACT LAWS

Abstract: In electrical machines, components like rotor and stator exhibit a complicated structural behavior due to their special layered design. The individual sheet interactions on the microscale, which is often characterized by frictional contact between rough surfaces, are mainly responsible for the difficulties arising in the simulation of these components. Here, it is shown in Fig. 1 that the contact situation can be approximated very well by a Finite-Element simulation with Zero-Thickness elements, cf. [1], revealing a very good agreement to experimental tests carried out in [2] and [3]. After verifying the capability of modeling this contact situation by a penalty formulation, a transversely isotropic material

model, which can be expressed in terms of basic invariants [4], is identified by homogenization techniques, cf. for example [5]. For a linear penalty law, the stress-strain relation of the considered representative volume element can be derived analytically, cf. [6] and [7], while for nonlinear contact laws a linearization is necessary. In Fig 2, the results of a numerical homogenization [8] is compared to the presented material model for different normal contact laws showing a perfect accordance.

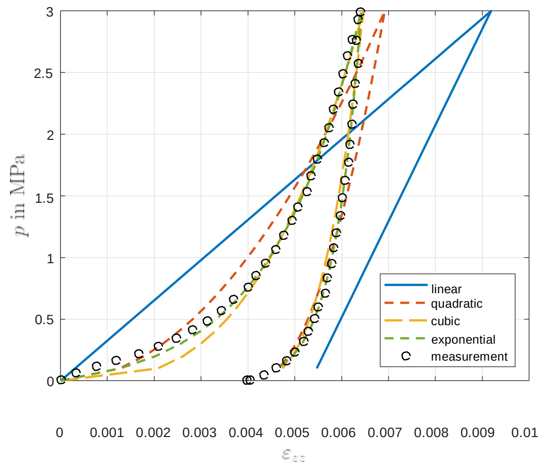

Fig. 1: Comparison of FE-simulations with different normal contact laws to experiments in [2] and [3] for compression tests of three stacked sheets.

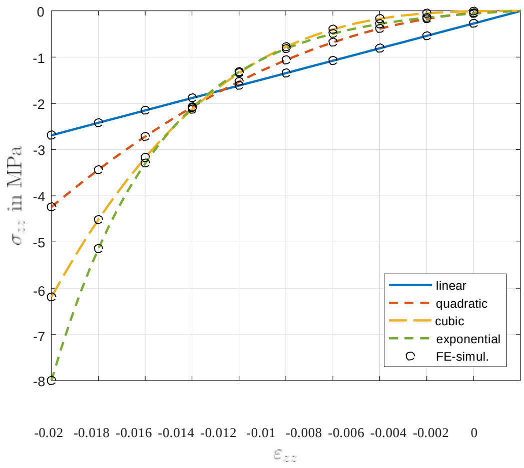

Fig. 2: Stress-strain curve of a representative volume element consisting of two half-sheets in contact for a numerical homogenization and the identified material mode.

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LARGE SCALE MODELLING OF DYNAMIC SHEAR LOCALIZATION AND MICRO-VOIDING ASSISTED FAILURE OF VISCOPLASTIC STRUCTURES

Abstract: Under high loading rate involving quasi adiabatic conditions, shear localization bands (adiabatic shear bands) may form in engineering structures made of high strength metals and alloys leading to their premature failure. Dealing numerically with this local softening phenomenon, resulting from a competition between material hardening and softening mechanisms and which has severe irreversible consequences at the structural level, still remains a challenging task. Indeed, the aim is to control the evolution of this material instability all along its progress and accordingly overcome the

numerical instability the finite element computation code is subject to in the softening regime (and subsequent meshing dependence of the numerical results). To that purpose, the band (or the band cluster) needs to be considered as a full entity to be embedded within the representative volume element (RVE) – i.e. the band is entirely contained in the RVE –, and its consequences need to be described in a consistent way. In this context, the finite strain, three-dimensional constitutive model presented in this work accounts for the material and kinematic consequences of the ongoing shear banding via an anisotropic damage like variable acting on both elastic and plastic moduli and a specific velocity gradient which progressively becomes predominant in the RVE kinematics. Micro-damage (in the form of micro-voiding or/and micro-cracking) in the band wake is also described as a second step toward the ultimate failure. The large scale constitutive model aiming at reproducing the dynamic shear localization and micro-damage-assisted failure of viscoplastic structures is implemented as user material into the commercial finite element computational codes LS-DYNA. Its performances are evaluated considering initial-boundary value problems with increasing complexity, viz. hat shaped structures under high strain rate shear-compression loading.

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ELASTIC INSTABILITIES IN HYPERELASTIC COMPOSITE

Abstract: We investigate the mechanical stability of soft microstructured materials subjected to finite deformations. The periodically structured materials exhibit the so-called buckling phenomenon when compressed to a critical level. For example, wavy patterns develop in layered materials upon achieving the critical compressive strain level. In this work, we perform a detailed study of the dependence of pattern formations on material properties and geometrical parameters of soft composites such as hyperelastic laminates [1], 3D fiber composites [2,3], and void-matrix-particles soft periodic systems [4]. The composite samples with various materials for the stiffer phase and matrix were manufactured by means of 3D printing. These 3D printed samples were mechanically deformed, and the critical buckling strain and post-bifurcation geometry were determined experimentally [1,3,4]. The experimental findings are in a good agreement with the predictions obtained from the numerical simulations. Moreover, we show that the buckled shapes in the laminates with rate dependent constituents can be tuned and controlled by the applied strain-rate [1]. In laminates, the critical wave-length of the instability induced wavy patterns varies with the applied strain-rate. It is possible, however, to design composites, in which the critical wavelength remains the same independent of the applied strain rate, while the critical strain varies with a change in the strain-rate. Thus, a wider range of wavy patterns with various wavelengths and amplitudes can be archived through the combination of the instability and viscoelastic phenomena [1]. Finally, we illustrate that, on the example of void-matrix-inclusion periodic system [4], that that instability induced pattern transformation can be used induced elastic wave band gaps through applied deformation [4].

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ON THE MECHANICAL BEHAVIOR OF POWER PLANT COMPONENTS

Abstract: The worldwide energy demand continues to increase as the global population grows and the developing world economies expand. Although renewable sources of energy are on the rise, the majority of global energy production is still based on conventional sources of energy, such as liquid fuels, natural gas, coal, and nuclear technology. A large part of the global electricity demand is generated in modern power plants with gas or steam turbines. In order to increase the efficiency of these turbines, elevated

temperatures are favorable, and consequently power plant components have to withstand high temperatures. Furthermore, the energy generation based on renewable sources, such as solar or wind power, is often unpredictable due to ambient conditions, in contrast to the steady and predictable output of a conventional power plant. In case of higher or lower energy generation by renewable sources, conventional power plants close this gap by shutting-down or starting-up, respectively. This procedure induces additional cyclic loads on the power plant components [1]. Usually, high chromium steels are used for power plant components since they offer excellent mechanical and thermal properties [2]. However, these alloys suffer from softening effects under constant and cyclic loads [3, 4]. In order to model the mechanical behavior of high chromium steels, the contribution at hand presents a unified model, which takes elasticity, rate-dependent inelasticity, hardening, as well as softening into account. For the modelling of hardening and softening processes, two internal variables, i.e. a back-stress tensor of Armstrong-Frederick-type [5] and a dimensionless softening variable, are introduced. To allow for the analysis of complex power plant components under various boundary conditions, the constitutive model is implemented into the commercial finite element code ABAQUS. In a next step, the mechanical behavior of an idealized steam turbine rotor is simulated. During a thermo-mechanical finite element analysis, the influence of a cold start and a subsequent hot start on the mechanical behavior of the rotor is studied, i.e. the rotor is started at lower temperatures (cold start), the mechanical and thermal loads are held constant during a holding stage over several hours, the rotor is cooled down to an intermediate temperature level before it is started again at higher temperatures (hot start), which is followed by a second holding stage and the final cooldown. Within the preceding heat transfer analysis, the nonstationary steam temperature and the heat transfer coefficients are prescribed, and the nonstationary temperature distribution in the rotor is computed. The obtained temperature field serves as input for the subsequent structural analysis based on the implemented constitutive model, providing the stress and strain tensors. For future applications, these results could lay the foundation for the estimation of creep and fatigue damage, thus allowing for a precise prediction of the lifetime of power plant components in use.

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A MATHEMATICAL JUSTIFICATION OF THE REISSNER-MINDLIN PLATE MODEL

Abstract: Due to its ability to account for shear effects, the Reissner–Mindlin plate model is often preferred in the engineering literature over the Kirchhoff–Love plate model. So, as already done for the Kirchhoff–Love plate model, it is challenging to proceed with a rigorous mathematical derivation of the Reissner–Mindlin plate model by studying the asymptotic behavior of a thin 3-dimensional elastic body when its thickness goes to zero. This was done in a simplified framework by using a second gradient or Cosserat continuum for the body, jointly with constitutive symmetry assumptions; here – being aware of results on the bonding of thin plates – we prefer to consider a strongly heterogeneous classical linearly elastic body made of a periodic distribution of thin anisotropic plates abutted together. The mathematical study via variational convergence shows that it is not necessary to use a different continuum model nor to make constitutive symmetry hypothesis as starting points to deduce the Reissner–Mindlin plate model.

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NON-CONVENTIONAL DYNAMICS OF HIGHLY CONTRASTED PLATES

Abstract: This paper focus on the effective description of two types of highly contrasted structured plates that exhibit non-conventional dynamic behaviour. The first type corresponds to stratified (HCS) plates in which the mechanical properties of the layers are highly contrasted. The second type corresponds to plates stiffened by a periodic mono- or bi-dimensional array of beams clamped on it. The effective HCS plate behaviour is derived from (i) the 3D constitutive law of the materials combined with (ii) an asymptotic expansion formulation and (iii) the appropriate scaling of the stiffness contrast. The different regimes of behaviour are specified, according to the mechanical and geometrical parameters of the layers, and to the loading. The analysis clearly evidences the enriched kinematics of such HCS plate and yields to a synthetic and analytic bi-torsor representation that encompasses the shear and the two types of bending mechanisms. It results in a tri-Laplacian plate formulation that provides a simple understanding of the behaviour and enables to derive analytical solutions under basic loadings. The theory is easily extended to viscoelastic constituents and has been validated experimentally on laminated glass made of two glass layers pasted with a soft viscoelastic interlayer. The dynamic behaviour of periodically stiffened plates is established by up-scaling the linear local description of the stiffening beams coupled to the plate, through multi-scale asymptotic method. The study focus on situations of inner resonance reached for specific mechanical contrasts between the beam and plate. In the case of mono-axial stiffening, an effective hybrid beam/plate model is obtained. The latter discloses two dynamic regimes, one with active beams (and locally resonant plate), the other with passive beams and guided waves in plates. The case of bi-axial stiffening yields a non-conventional plate model with frequency dependent apparent mass. These results allow investigating the atypical wave dispersion with respect to the geometrical and mechanical contrasts of the structural components. The validity of the model and its practical feasibility are also verified by comparing theoretical predictions with numerical FEM simulations and with experimental data gained in laboratory on several prototypes.

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REALIZABLE EFFECTIVE FRACTIONAL VISCOELASTICITY IN HETEROGENEOUS MATERIALS

Abstract: Fractional viscoelastic models have been introduced heuristically at the beginning of the twentieth century to represent experimental constitutive responses. For creep tests, for instance, the following time-dependence of the strain is observed in many materials (polymers, rocks, ice polycrystals, etc.)

$$\varepsilon(t) \propto \left(\frac{t}{\tau}\right)^{\alpha}, \quad 0<\alpha<1.$$

A first attempt to relate the fractional behaviour to the material's composition is the study of Bagley and Torvik [1] who showed that the molecular theory describing the polymer chain dynamics (Rouse model) was in fact a fractional viscoelastic model of order 1/2. Rheological models with a fractal arrangement of classical elastic and dashpot elements have also been proposed to obtain a fractional response without reference to a real material microstructure [2]. Studies have also focused on the possible link between the fractional response and the fractal scaling of the microstructure [3, 4]. However, the possible emergence of a fractional viscoelastic behaviour resulting from microstructural features of the material, in the rigorous framework of continuum micromechanics, remains an open question. This problem is addressed for two-phase composite materials made of elastic and viscous phases with various realizable microstructures. Besides, conditions to obtain an overall fractional response are discussed.

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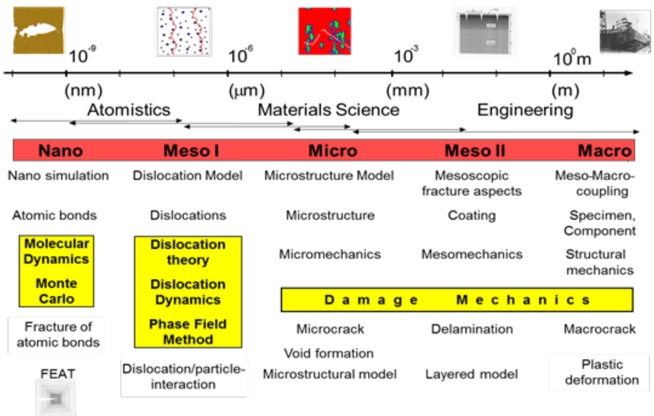
MULTISCALE MATERIALS MODELING: NEW DEVELOPMENTS WITH SPECIAL EMPHASIS ON FATIGUE SIMULATION

Abstract: In this overview it will be shown how the first successful example of real multiscaling for metals was achieved. Multiscale simulation in the present context comprises the involvement of all length scales from atomistics via micromechanical contributions to macroscopic materials behavior and further up to applications for components, frequently called multiscale materials modelling (MMM) (Fig. 1). The main focus of the presentation will be put on new developments with special emphasis on MD-simulations and other methods involved and how they interact within the present approach. It will be shown that each method is superior on the respective length scale. Furthermore, the parameters which transport the relevant information from one length scale to the next one are decisive for the success of physically based multiscale simulations [1]. While in the past, different methods were tried to be combined into one simulation, it is nowadays obvious in many fields of research that the only way to succeed in understanding the mechanical behavior of materials is to apply scale bridging techniques in sequential multiscale simulations (Fig. 2) in order to achieve physically based practical material solutions without adjustment to any experiment. This has opened the door to real virtual material design strategies. In a final step it will be shown that the approach is not limited to metals but can be extended to other material classes and can be also applied for composites [2] as well as to many aspects of material problems in modern technical applications where all disciplines meet, from physics to materials science and further on to engineering applications. A main focus will be put on the problem of fatigue of metals where multiscale materials modelling can provide the answer to numerous questions such as the influence of the lattice type or the relevance of materials properties.



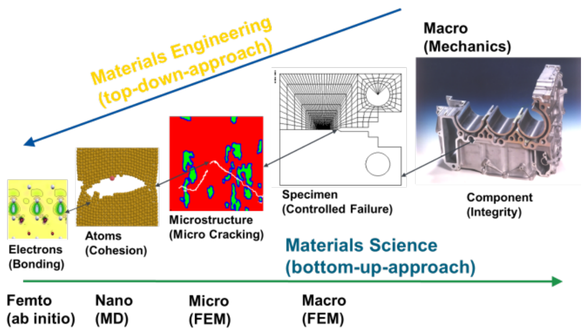


Figure 1. Multiscale Materials Modelling (MMM) Figure 2. Scale Bridging Technique

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MULTISCALE SIMULATION OF MULTIPHASE MATERIALS

Abstract: Many materials show a multiphase composition and have a distinct microscopic structure. Examples of multiphase materials are saturated or partly saturated porous material like soil, concrete but also steel and biological tissue like cartilage or bone. Their substructures are e.g. pores, fibres with different orientations or cells which can be influenced by bio-chemical reactions. The high complexity of those kind of material makes it reasonable to consider homogenization approaches and multiscale techniques in order to find an effective modeling access for the numerical simulation. This is even more the case since modern experimental methods as CT-scanning or MRI imaging give us the opportunity to get a deep insight into the microscale structure. Thus, we will present a combined multiphase-multiscale approach for the description of those kinds of materials. The method is based on the well-known Theory of porous media (TPM), a continuum mechanical homogenization approach founded on the mixture theory in combination with the concept of volume fraction, cf. de Boer [1] and Ehlers [2]. Depending on the material, we will combine the TPM with reasonable multiscale techniques such as FE^2, POD-ODE, or the Phase Field method, cf. Moj et al. [3] and Ricken et al. [4].

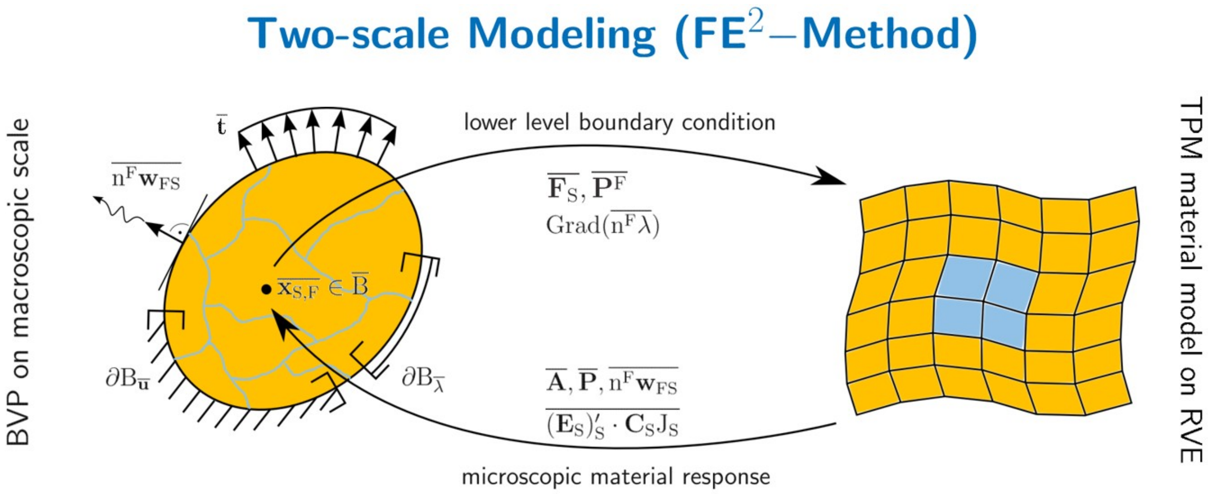

Fig. 1. Basic concept of TPM^2 approach

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ASYMPTOTIC TH*EORY FOR SURFACE WAVES ON COATED SOLIDS*

Abstracts: The asymptotic hyperbolic-elliptic formulation for the Rayleigh elastic wave induced by prescribed surface stresses was originally established in [1], see also [2] summarizing the peculiarities of the developed methodology. It reflects a dual physical nature of surface waves, for which the decay over the interior is described by a “pseudo-static” elliptic equation, whereas the wave propagation along the boundary is governed by a hyperbolic equation. It is worth noting that both elliptic and hyperbolic equations are scalar, with the overall near-surface field restored in terms of a single harmonic function, according to [3, 4]. The consideration in [1] has been extended to a coated half-space in [5], resulting in a singularly perturbed hyperbolic equation for the surface wave with the perturbation in the form of a pseudo-differential operator. In this case the effect of a coating has been reduced to effective boundary conditions, derived as the long wave approximation of the related 3D problem in linear elasticity for a thin layer. Further details on the effective boundary conditions may be found in [6], confirming at leading order the physically motivated conditions in [7] and comparing higher order ones with the results in [8]. The present study aims at further development of the framework of [5] along two directions. First, the

effect of anisotropy of the coating is incorporated. As might be expected, the analysis results in a hyperbolic equation, singularly perturbed by a pseudo-differential operator, involving a more sophisticated constant coefficient. In addition, we consider several types of boundary conditions along the surface of the coating, including a clamped surface, as well as a sliding one. In contrast to a homogeneous elastic half-space supporting a surface wave only for a traction-free surface, a layered half-space generally does not exclude the existence of surface waves, as follows from the rigorous analysis in [9]. In the latter case, for a soft coating similar singularly perturbed hyperbolic equations are derived. The established asymptotic formulations are tested by comparison with the exact solutions of the original equations in linear elasticity. The developed methodology is also implemented to approximate treatment of rather technical problems in elastodynamics, including, in particular, a 3D moving load problem for a coated half-space [10].

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NODE-BASED FORM FINDING WITH ALTERNATING NUMBER OF NODES CAUSED BY REMESHING

Abstract: The inverse, non-invasive form finding [1] aims to determine the optimal material configuration of a predefined forming process. The node-based algorithm iteratively minimizes the difference between the spatial and the desired target configuration. The objective function, composed by the squared error sum of the differences at the design nodes, is minimized using Taylor approximation. Modified Gauss-Newton methods [2] are applied to project the computed differences onto the material configuration in order to update these. The algorithm works in a non-invasive way, which implies a strict separation of the FE-solver from the optimization. Thus, the mechanical formulation remains entirely unaffected. In [3] a possibility was presented to generate the mesh of the target configuration independent of the structural analysis. This improvement paved the way for changing the node number during the simulation despite the node-based approach. Now, for the first time, the node-based form finding approach is presented in combination with remeshing. Remeshing is essential for forming simulations, since high degree of deformation must be modeled. This novelty opens up a further range of application.

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MODAL CHARACTERISTICS OF GYROSCOPIC SY*STEMS IN ALE FORMULATION*

Abstract: Modal characteristics govern the vibratory behaviour of mechanical systems. When subjected to rotation, they may be heavily influenced by gyroscopic effects – altering range and nature of common quantities such as eigenfrequencies and eigenmodes. This work gives an overview over these impacts with the help of numerical and experimental modal analyses. The numerical computations employ the Arbitrary-Lagrangian-Eulerian (ALE) finite element formulation, decomposing rotational and vibrational particle motions in separate deformation maps. The presented experimental set-up with a rotating test rig mimics this theoretic approach in practice. An overall comparison of numerical and experimental results with analytic solutions concludes the insights into the structural dynamics of gyroscopic systems.

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TWO-DIMENSIONAL FIRST INTEGRAL OF VISCORESISTIVE MAGNETOHYDRODYNAMICS

Abstract: The purpose of this article is to study some question related to the visco-resistive complex two-dimensional first integral equations of magnetohydrodynamics. In this work the authors found a way to write a first integral, for visco-resistive magnetohydrodynamics, which generalizes Bernoulli’s equation and which depends on a real-valued potentials. Upon inserting the streaming-function representation of the flow, the first integral amounts to the two second order complex equations for four realvalued fields, i.e., the velocity and magnetic potential and streaming function for the flow and flux function for the magnetic field. Most of the questions that we investigated are related to the transformations of differential magnetohydrodynamics operators from the real plane (R) to the complex plane (C). A new type of complete set of field equations appears: the first integral complex magnetohydrodynamics equations. We also calculated a special case of complex solution for these magnetohydrodynamics equations. In this family, with many members of coupling solutions the magnetic field appears with the same structure as the velocity field.

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PROTEIN GEOMETRIC CONSTRAINT NETWORKS UNCOVER SHIFTING CONFORMATIONAL DYNAMICS

Abstract: Proteins perform an enormous variety of biological functions on a broad range of spatial and temporal scales. While Molecular Dynamics (MD) simulations can offer insights into atomically detailed trajectories, complex underlying force-fields and long simulation times often complicate interpretation of localized events and their immediate effect on large-scale conformational changes. Here, we demonstrate the potential of geometric constraint nework models to efficiently study the effect of small perturbations like energy fluctuations on protein conformational dynamics. We represent a macromolecule as a kinematic chain, with dihedral angles of single covalent bonds as torsional degrees of freedom and non-covalent interactions such as hydrogen bonds and hydrophobics as holonomic constraints. A singular value decomposition of the constraint Jacobian matrix ranks a spectral distribution of orthogonal protein motion modes by increasing perturbation of the constraint network. These motion modes are foldspecific, but remarkably conserved in the protein universe. Using information theory based expressions for the collectivity and free energy of motion modes, we analyze the effects of local changes in the constraint network to local and global protein dynamics. In the case of isocyanide hydratase (ICH), an enzyme of the DJ-1 superfamily, we reveal how disrupting a single hydrogen bond involving the reactive cysteine in the active site affects motion modes, and alters how the protein accesses collective motions critical in the catalytic cycle. Disruption of the bond leads to a set of correlated conformational changes that remodel the ICH active site and propagate across the protein. Experimentally, these motions can be observed from photo-oxidation induced cysteinemodification in high-resolution crystallography data. The near-instantaneous nature of our analysis can provide fast insight into shifting protein conformational ensembles from local changes in the network. Importantly, it can analyze changes to protein conformational dynamics across a large set of network topologies within minutes and help interpret the effect of disease-related mutations, or guide ligand design and protein engineering. The software (KGS) is available from http://github.com/ExcitedStates.

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MODEL,SIMULATION AND ANALYSIS OF AN ALKALINE ELECTROLYZER FOR REDUCING EMISSIONS IN INTERNAL COMBUSTION ENGINES

Abstract: In order to reduce the polluting emissions of an internal combustion engine, the use of an alkaline electrolyzer is proposed to replace part of the gasoline in the engine for hydrogen. The mathematical model, simulation and analysis of the proposed system are presented in this article. The model of the electrolyzer is based on existing models; it was simulated using a block diagram and validated through experimentation. With the validated model and based on an analysis of the energy needs of an engine, it was obtained, under different operating conditions, the extent to which the polluting emissions of an engine can be reduced using the proposed system.

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COUPLING OF HYDRODYNAMIC AND ELASTIC MODES IN LIQUID CRYSTALS SIMULATED BY MULTI-PARTICLE COLLISION DYNAMICS

Abstract: Liquid crystals (LCs) have been subject of continuous interest through decades since they exhibit anisotropic optical properties that can be manipulated by small energies of electromagnetic or surface-liquid interaction origin. Modern LC technologies have promising applications in, e.g., biosensing and medical diagnose. Simulations could play an important role in helping developers to test models for these emerging technologies. However, Molecular Dynamics (MD) is not able to reproduce all the relevant effects occurring in novel LC devices. The reason is that MD is restricted to microscopic systems and simulation times. In contrast, phenomena in LCs occur not only at the microscopic scale but cross over the mesoscopic and hydrodynamic scales too. Examples include elastic distortions, topological defects, and hydrodynamic fluctuations. These effects are closely related, although they evolve over widely separated scales, e.g., topological defects are essential part of the structure and macroscopic order might affect molecular vibration. Therefore, the proper numerical tools intended to simulate LCs should be able to reproduce, under a unified scheme, the behavior of these widely separated phenomena. In this context, simulation techniques with a multi-scale character could be very useful. Multi-Particle Collision Dynamics (MPCD) is an appealing technique that serves this purpose. It was originally introduced for the simulation of isotropic fluids at the mesoscopic scale. In MPCD, fluids are simulated by particles

interacting through coarse-grained defined rules that preserve momentum and energy. Algorithms for simulating LCs by extending the rules of MPCD have been proposed recently [1]. Here, the implementation of MPCD for nematics (MPCD-N) is reviewed. The algorithm consists, basically, of the succession of streaming and stochastic collision events where clusters of particles exchange momentum and orientation, thus giving rise to hydrodynamic fluctuations. In addition, the algorithm incorporates procedures that cover two fundamental issues, namely: velocity gradients produce torques that reorient particles, and reorientation induce backflow. The reliability of the technique is illustrated through the analysis of the relaxation of fluctuations towards equilibrium. Results show that fluctuations in MPCD-N can be described by a linearized model where viscosity and elastic effects are isotropic. If simulation parameters are kept within the ranges suggested in the original proposal of the method [1], velocity and orientation fluctuations can be considered to be only one-way coupled. Namely: while flow affects orientation, backflow effects can be neglected [2]. In such case, the orientation-velocity correlation function in Fourier domain, (k,w), is given by

$$G_{n1,V3} = \mathrm{Re}\{<\delta n(k,w)\delta v^*(k,w)>\} = \chi_{HI}(\lambda-1)\nu k^3 \omega / [2\rho_0(\omega^2+\nu^2 k^4)(\omega^2+D_n^2 k^4)], \quad (1)$$

where ρ_0 is the mass density, λ the tumbling parameter, χ_{HI} the strength of flow alignment, ν the kinematic viscosity, and D_n the relaxation rate for orientation fluctuations. Figure 1 shows the good agreement existing between this model and simulation results.

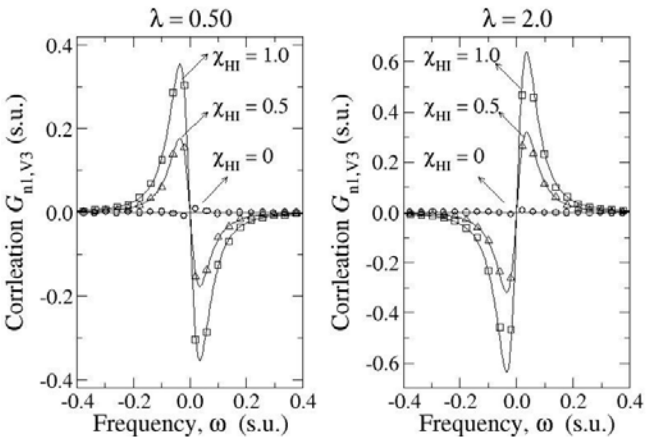

Figure 1. Symbols: simulation results. Continuous curves: model given by Eq. (1).

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PHASE-FIELD MODELLING OF FRACTURE BASED ON STRAIN GRADIENT THEORIES

Abstract: The simulation of crack propagation has always been a challenging task from a computational point of view. In the past, many mathematical and mechanical assumptions had to be taken into account to successfully simulate this process. The problem of tracking the sharp crack surface was among the first issues which was alleviated by the introduction of phase-field models. The appearance of stress singularities near the crack tip in the classical continuum mechanics theory is considered to be another source of problem which makes the selection of proper mesh sizes for numerical models very cumbersome, and leads to unphysical results. In the presence of a singularity, the crack propagation starts earlier in problems with a finer discretization which is only natural considering that the strain energy density is higher and increases faster for smaller mesh sizes. Likewise, a loading which normally could not cause a crack to nucleate or propagate inside a structure, will do so in the numerical simulation due to over-estimated stresses. Therefore, it stands to reason that removing this singular field from the results is a very crucial step in achieving physically meaningful results. The goal of the current contribution is twofold: first, existing models are shown to exhibit a singular stress behavior, and second, a possible remedy is proposed based on the application of higher-order strain gradients.

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A COUPLED PHASE FIELD/MECHANICAL/DIFFUSIONAL APPROACH FOR BAINITIC TRANSFORMATION
Abstract: The bainitic transformation is one of the most complex transformations in steel. The transformation from austenite to bainitic ferrite is assumed to be displacive [1] in contrast to the pearlitic growth which is highly dependent on the carbon movement and therefore is ranked as a diffusive transformation. However, regarding the whole microstructure named bainite, consisting of bainitic ferrite, carbides and (residual) austenite, the movement of the carbon is of major importance. The displacive and directed growth of the bainitic ferrite leads to a supersaturated phase. In lower bainite the carbon within the ferrite separates [2] and precipitates as carbides. In upper bainite the carbon leaves the supersaturated bainitic ferrite and diffuses across the interface into the austenite. This may lead to carbides close to the interface between ferrite and austenite but may also stop the transformation from austenite to bainitic ferrite and produce residual austenite. In this work the phase field method is utilized to simulate the phase transformations of upper and lower bainite, including the phase transition from austenite to bainitic ferrite and the precipitation of carbides [3]. The directed growth of the bainitic ferrite is modeled by coupling the phase field equations to the mechanical equations and considering eigenstrains. Furthermore the phase field equations are coupled to a diffusion equation governing the carbon concentration. The underlying system of partial differential equations is based on a thermodynamic framework of generalized stresses for a two phase Ginzburg-Landau system and a Cahn-Hilliard equation [4]. We extend this framework for multiphase field models coupled to a viscous Cahn-Hilliard equation with diffusion across the interface and mechanical contributions [5]. The numerical examples show the qualitative mechanism of the upper and the lower bainitic transformation unified in a model as discussed above.
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PREDICTING THE ELASTIC MODULUS OF NATURAL FIBER HYBRID COMPOSITE USING CLASSICAL LAMINATION THEORY
Abstract: Elastic modulus is the basic property which is required during design, optimization and modeling of composite laminate. Even though, the elastic modulus of uni-directional composite laminate is well developed using different approaches, the same models are not well suited for intralaminar natural hybrid composite laminate. In this paper, an analytical model is proposed to predict elastic modulus of natural fiber-reinforced hybrid composite based on classical lamination approach (CLT). Theoretically, the laminate elastic properties are predicted using classical lamination theory and rule of hybrid mixture model using the resin and fiber properties together with the volume fraction (micro-mechanics). In addition to that, Halpin-Tsai equation is used to calculate transverse modulus in order to offer the best suited model for prediction of elastic modulus under CLT approach. Different hybrid composites (i.e. Jute/Glass fiber, Jute/Sisal fiber, Jute/Curaua fiber are used. Predicted elastic modulus using different approach was compared with the experimental elastic modulus obtained through tensile tests of composites as per ASTM standard and a good agreement was found.
Keywords: Elastic modulus; Hybrid composite; Natural fiber; Composite lamination theory

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PROBABILITY BASED TOPOLOGY OPTIMIZATION OF STRUCTURES
Abstract: The aim of civil engineers is to design civil structures that optimally bear up the loads. The development in this direction was based on the experience of the old masters. Since the second half of

the last century, mathematical optimization methods have been used in connection with the introduction of computers in structural design. The problem of structural optimization was using different optimization methods for each type of mathematical function defining the objective function and constraints. The introducing of the genetic algorithm enabled to optimize arbitrary mathematical functions and to overcome the problem. The topology optimization of structures is a relatively new research area in mechanics. Topology optimization is shown as an efficient tool, whereas automatically generates structures with optimum shape and material distribution. The practice requires robust design of structures due to uncertainties of the loading. The paper combines recent advances of material-based topology optimization and design optimization under load and boundary condition uncertainties. The structural response is predicted by a finite element formulation. The probabilistic design compared to deterministic design requires including the uncertainties into problem definition and demands essentially a repetitive solution. The optimization procedures and probability calculations as well, generally use repeated numerical procedures with parameter changes. The idea of the contribution is instead of time consuming repetition of deterministic procedures, to use some partially results –images and the final topology result obtain as their weighted combination. The procedure of probability based topology optimization of structures works as follows: The topology is defined on the basis of the material distribution in elements of the structure with help of density variable. The structural model is created on the base of finite element method. The structural admitted area is chosen. The loading and the boundary conditions are defined. The initial design of the structure starts from the equable distributed mass in admitted area. The objective is the maximum structural stiffness. The constraints are subjected to densities, boundary conditions and loading. The optimal topology design is defined as an optimization problem. The optimization procedure applies the genetic algorithm. The uncertainties of loading and boundary condition are declared using the truncated Gaussian distribution as a statistical distribution function. The deterministic approach using selected input loading and boundary conditions results in the image of optimal topology distribution. The Monte Carlo simulation is applied. The contribution proposes topology optimization guided by the probability procedure. The probability procedure repeats the deterministic solutions and the results: the "deterministic" topology images are used. The results of simulations: the topology images are collected in the database. The combination of weighted images leads to the final topology. The weights are defined in dependence of the input uncertain distributions. The application of the images enables an analysis and overview of particular and resulting topology results. The method is numerically effective. Some results are verified with results in literature. Generally, the obtained results on the probability based topology optimization represent robust design structures and usable applications in practice.

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MAGNETOSTRICTION FOR HEALTH MONITORING AND STRESS SENSING USING NATURAL MATERIALS

Abstract: A wide range of reinforcements and morphologies can be employed to generate a magnetostrictive response in natural materials from carbonyl iron, nickel to rare-earth based metal alloys. A critical analysis of the various cellulose systems focusing on how the material selection influences the magnetorheological and magnetoelectric properties of materials. Various analysis methods can be employed including multiscale approaches, such as continuum micromechanics based theories and multi-physics approaches. Recognizing their unique properties, potential applications for natural materials incorporating electric current and stress sensing for health monitoring and biomedical fields are presented. This review of the literature points to new directions for fundamental research, interface studies and modeling improvements that can help in advancing this area of multi-modality mechanics.

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MACROSCOPIC BEHAVIOR OF 1-3 THERMOPIEZOEOLECTRIC PERFORATED STRUCTURES AND ENERGY HARVESTING APPLICATIONS

Abstract: This talk describes the homogenization process for a class of thermopiezoelectric structures perforated by unidirectional hollow cylinders. Based on the existence of links between local problem solutions, (exact) relationships are obtained between the effective coefficients without the need to solve them. These relationships allow to reduce the number of local problems that must be solved to obtain all the effective coefficients. The model applies to the particular case of transversely isotropic thermopiezoelectric media with cylindrical perforations of circular cross section and square periodic distribution. The formulas obtained for the effective coefficients have very simple expressions and compare well with results derived from the application of a numerical homogenization method based on the fast Fourier transform. Currently, comparisons are made with recently reported experiments in research related to the design of energy harvesting.

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HOMOGENIZATION OF THERMO-MAGNETO-ELECTRO-ELASTIC MULTILAMINATED COMPOSITES WITH IMPERFECT CONTACT

Abstract: The Asymptotic Homogenization Method is applied to a family of boundary value problems for linear thermomagneto-electro-elastic heterogeneous material with rapidly oscillating coefficients and magneto-electro-elastic imperfect contact between the phases. Using matrix notation we show the procedure for constructing a formal asymptotic solution that leads to the homogenized problem, the effective coefficients and the local problems. The effective coefficients are functions of the solutions of the local problems, which in the case of a laminate are systems of Ordinary Differential Equations. The methodology is illustrated with an example of a two-phase piezoelectric/piezomagnetic laminate formed by transversally isotropic phases. The analytical expressions of the effective moduli that were obtained work for any number of phases and any values of the magneto-electroelastic imperfect contact parameters. It is also shown that some moduli satisfy exact relations that allow us to compute any of them given any other. The numerical examples show the emergence of product properties such as the magneto-electric, pyromagnetic and pyroelectric effects.

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HOMOGENIZATION AND EFFECTIVE COEFFICIENTS OF PERIODIC TWO-PHASE FIBROUS COMPOUNDS WITH COMPLEX DIELECTRIC PROPERTIES

Abstract: In this talk, the main stages and results of my master's work will be given under the guidance of Dr. Julian Bravo Castillero. The work [1] was the main inspiration to carry out this project. The equations and conditions for a problem of biphasic periodic compounds with hexagonal arrangement and complex dielectric properties will be presented. The fundamental stages of the homogenization process to a family of these problems will be described when the coefficients of the equations are differentiable, periodic and rapidly oscillating, with the aim of obtaining expressions that describe the homogenized problem, local problems and the effective coefficients. Local problems will be solved for the isotropic case by means of undetermined coefficients, which will be found as a solution of certain linear quadratic systems which, in turn, each linear quadratic system is a successive truncation of a certain infinite linear system. In addition, analytical expressions of the effective coefficients will be given, under certain conditions of regularity, and the real and imaginary part of the effective coefficients will be compared for a successive truncation where uniform convergence is obtained whose limits are numerical results presented in [2].

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HOMOGENIZATION IN A MULTISCALE CONDUCTION PROBLEM
Abstract: Heterogeneous media are widely used in heat transfer where there are multiple spatial scales. We consider two microscopic scales, but the procedure could be generalizable to more scales. The objective of this work is to formulate the strong form of the Fourier heat conduction equation for such media and use the reiterated homogenization to compute the macroscopic properties of heterogeneous conductive media dependent on several micro-structural scales. We will assume that the constituent phases have a thermal barrier (imperfect contact) at the interface because this feature greatly affects the effective behavior of the environment [1]. Through repeated homogenization, it was possible to separate the problem into two local problems that depend only on the conditions of each scale [2]. It is possible to find these solutions by different means and combine them to obtain the macroscopic properties of the medium [3]. The methodology used is analytical and applicable to a large number of three-dimensional problems, although it can also be combined with numerical solutions to the problems obtained. We will evaluate how the properties such as volume fraction, conductivity and interfacial thermal resistance in smaller scales affect the medium in macroscale (effective behavior). For a one-dimensional case, we analyze the presence of gain between single and two micro scale and how it depends on the thermal barrier property. Finally, different applications will be shown: The first one inspired by the work of [4] on the problem of aggregation in nanofluids, in which several micro-structural scales appear naturally. In [4] an Ad-hoc homogenization model was developed to analyze the role of aggregation processes and interfacial thermal resistance in the effective thermal conductivity of nanofluids and nanocomposites, thus finding that thermal conductivity can be significantly improved with this assumption. The second application aims to illustrate how even a one-dimensional development of the problem enables the study of more complex media, specifically, fibrous materials with nano inclusions.
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EFFECTIVE ELASTIC PROPERTIES USING MAXWELL APPROACH FOR TRANSVERSELY ISOTROPIC COMPOSITES AND COMPARISONS WITH NANOTUBE REINFORCEMENTS
Abstract: In this work, effective properties of transversely isotropic composites are estimated through Maxwell Homogenization approach, in transversely isotropic composites constituted by an homogeneous matrix material with homogeneous embedded inclusions aligned in the same direction whose center is randomly distributed. The inclusions have spheroidal type and same shape and size. This Maxwell method doesn't take into account interaction between inclusions, however it gets same results that other self-consistent approaches encountered in literature. Results are shown using two different density distribution functions for describing inclusion's alignment within matrix material. The method allows to report the overall static elastic coefficients in composites with inclusions of different geometrical shapes embedded within passive or active matrix. Numerical results are compared with some other theoretical approaches and experimental data. Initially, the whole composite (it means the matrix with all the inclusions embedded) is considered as one whose volume is representative, with unknown effective elastic properties and unknown reaction to external fields, then every inclusion is considered like a representative volume inside the matrix material with known elastic properties and known reactions to external loads. Thus, the effective equation of Maxwell approach is obtained by means of equating the perturbation fields generated by the inclusions and by the whole composite. This approach has an explicit analytical solution for this problem and is a forthright and efficient way to solve this kind of problems.

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TURING-HOPF INSTABILITIES IN KELLER-SEGEL MODEL WITH GLYCOLYTIC REACTION
Abstract: The present work classifies in the study of Keller-Segel drift-diffusion PDE system modelling the driving answer of cell populations to chemical signs, so-called chemotaxis, coupled with the glycolysis model, where glycolysis is the metabolic process through which the cell obtains energy from the glucose. We work on the two-dimensional space. The topic of the work is the qualitative study of the solutions to the Keller-Segel chemotaxis models of parabolic-elliptic and parabolic-parabolic types. In this case the parabolic-parabolic model is a coupling with the parabolic glycolysis system with two species. We investigate the presence of Turing instabilities at the Hopf bifurcations and spatiotemporal patterns formation in the glycolysis reaction-diffusion system coupled with the Keller-Segel equation. Here we obtain positive results that depend on the values of the involved parameters. We analyse the presence of generic Hopf bifurcations and with it the appearance of limit cycle solutions in the system of ordinary equations of glycolysis, in terms of the positive parameters. Also, we obtain an asymptotic expansion of the limit cycle. We analyse too the appearance of strong Turing-Hopf instabilities for the glycolysis system with diffusion in terms of the parameters, the emergence of twinkling patterns product of these diffusive instability of the limit cycle and the influence of such instabilities in the generalized parabolic-parabolic chemotaxis system in the domain. In the case of the Hopf bifurcation analysis, the Turing and Turing-Hopf instabilities, and the formation of stationary and spatio-temporal patterns in the solutions, we use tools such as the generic Hopf bifurcation theory and the first Lyapunov coefficient method, perturbation methods and the averaging method for the Hopf bifurcation and the obtaining of an asymptotic expansion of the limit cycle solution for systems of Ordinary Differential Equations (ODE), as well as R. Ricard-Mischler theorem to analyse the appearance of strong Turing-Hopf instabilities and twinkling patterns in EDP systems.

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MODELO Y RESOLUCIÓN DEL DESPLAZAMIENTO DE UNA ONDA EN UNA LÁMINA MEDIANTE FEM
Abstract: La propagación de ondas en materiales elásticos es un problema de interés constante en las últimas décadas. Con esta técnica se puede conocer el estado de un material sin tener que realizarle estudios que puedan dañar al mismo. Con FEM se puede ver el comportamiento del material al aplicarle un pulso sin tener que realizar experimentos físicos que pueden resultar más costosos. En el trabajo se realiza la modelación de la propagación de un pulso ultrasónico en una placa de aluminio mediante FEM y se determina el resultado mediante el software FreeFem++. Para ello determinamos la formulación

variacional de nuestro trabajo y comprobamos la existencia y unicidad de la solución obtenida, además estudiamos la convergencia del método.

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COEFICIENTES EFECTIVOS DE UN COMPUESTO LAMINADO PIEZOELÉCTRICO CON CONTACTO IMPERFECTO NO UNIFORME EN LA INTERFASE
Abstract: The aim of this article is to describe the application of the Asymptotic Homogenization Method to a laminated piezoelectric composite, considering uniform and non-uniform imperfect interface's adhesion. Are also obtained numerical results for the effective properties of a periodical bi-laminated material, comprised by sheets of Epoxy 2 y PZT-7A with 6mm symmetry. The Asymptotic Homogenization Method in this case is applied after the definition of the original conditions of any laminated piezoelectric composite. And after being applied the method, there is described, in a general way, the algorithm applied to obtain the formula of the effective properties (dependent the physical properties, the composite's geometry and the considered imperfection parameters). By last, in this paper are included some plots with the obtained results, where are compared with other approaches, that consider perfect contact, fact that allows to validate the results of the present research.

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MACROSCOPIC THERMAL PROFILE OF HETEROGENEOUS CANCEROUS BREASTS WITH VASCULAR NETWORKS
Abstract: The present work focuses on the modeling of the macroscopic thermal properties of cancerous breasts. A three-dimensional model is proposed based on a system of bioheat transfer equations for the healthy and cancerous breast regions, which are characterized by different microstructure and thermophysical properties. The geometrical model of the cancerous breast is identified by the presence of muscle, glandular and fat tissues, and the heterogeneous tumor tissue which is assumed to be a two-phase periodic composite with different kinds of primitive three-dimensional geometric inclusions and three orthogonal branches. A cubic lattice distribution is chosen, wherein the constituents exhibit isotropic thermal conductivity behavior. The tissue effective thermal conductivities are computed and then used in the homogenized model, which is solved numerically. Moreover, the influence of tortuosity and volume fraction of the networks present in the tumor is analyzed. Results are compared with appropriate experimental data reported in the literature.

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HOMOGENEIZACIÓN DE UN TIBURÓN ESFÉRICO Y RUGOSO: EL EFECTO DE LA SELECCIÓN NATURAL SOBRE LA OPTIMIZACIÓN DE CARACTERÍSTICAS HIDRODINÁMICAS DEL NADO DE ANIMALES
Abstract: En el presente trabajo se aproxima una solución a las ecuaciones de Navier-Stokes para el flujo alrededor de una esfera con una rugosidad superficial utilizando el método de homogenización en ecuaciones diferenciales. Dicha geometría busca modelar la textura corporal de la piel que algunos animales acuáticos presentan. Las ecuaciones de Navier- Stokes son formuladas en su versión vorticidad-función de corriente y la rugosidad de la superficie es tomada en cuenta en las condiciones de frontera impuestas a la función de corriente. La solución a estas ecuaciones también es aproximada de manera numérica mediante el método de Galerkin. Ambos resultados son comparados cuantitativamente mediante los coeficientes de arrastre obtenidos por los dos métodos. La motivación para este trabajo surge de la propuesta de D'Arcy Thompson en la que muestra que diferentes morfologías, entre ellas del

perfil de algunos peces, pueden obtenerse unas de otras mediante mapeos relativamente sencillos. Una pregunta natural es si dichos perfiles están sujetos a la selección natural y son por ello producto de un proceso de (pseudo)optimización. Un criterio cuantitativo razonable está dado por los coeficientes de arrastre de los diferentes tipos de flujo, caracterizado por el número de Reynolds y rugosidad correspondientes.

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CURVATURE TUNING IN FOLDED SHEETS THROUGH HYPERSTATIC CONFINEMENT

Abstract: Folding a sheet of paper generate extremely localised plastic strains. The relaxation of the residual stresses results in a ridge that joins two flat faces at an angle known as the dihedral angle. When constrained isostatically, the sheet will be at its undeformed roof-like state. Instead, if confined hyperstatically, the flat faces will undergo bending. We demonstrate that the generated curvatures can change their sign with appropriate rotations applied at the ends. We use Euler's theory of the Elastica and a shooting method to match the applied rotations at the boundaries. We also consider a constitutive model for the discontinuous rotation that takes into account the dihedral angle and the torsional stiffness of the fold. We show that the curvatures before and after the fold change according to a law confirmed also by the Euler-Bernoulli beam theory for small displacements and rotations. Also, for opposite applied rotations, the fold disappears in the limit of zero torsional stiffness; for applied rotations of the same sign, there exists a non-zero critical torsional stiffness that neutralizes the fold. Below such critical value, the fold can mutate, for example, from a mountain fold to a valley one.

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STOCHASTIC CELLULAR AUTOMATON IN COMPLEX NETWORKS FOR THE STUDY OF CANCER INVASION, MIGRATION AND METASTASIS

Abstract: The understanding of the tumor life cycle is of crucial importance for both cancer research and public health. Most of the efforts in the field of mathematical and computational modeling are focused on studying the development of the tumor during the early stages, where mortality is very low. As the behavior of the tumor in the advanced stages of its development are those that present an imminent danger to the life of the patient, it is necessary to focus our work on producing mathematical representations and computational tools that allow the study of such behaviors. The present stochastic cellular automata model constitutes a first approach to the reproduction of the avascular and vascular growth of the tumor, where the specific behaviors of each stage are shown based on the accumulation process of the cancer mutations. Adopting as an object of study the type of cancer known as carcinoma and taking into account a variety of interactions and transitions between the different types of normal and cancer cells, it reproduces: the tumor growth towards the different layers of tissue, the invasion of the stroma of the organ, the displacement of the migratory cells through the tissue, the penetration and transport through the circulatory system, the extravasation, the formation of new micrometastasis and the dormancy period. As a representation of the locations where the development takes place, a small world network generated with the Watts-Strogatz model is used, which is interpreted as the connections map of the cells of the tissue. Finally, the model allows to obtain visualizations of the whole process and to verify how the variation of its different parameters affects the cancer life cycle, thus emulating the effects of possible treatments.

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HOMOGENIZATION OF THE EQUATIONS OF THE COSSERAT THEORY OF ELASTICITY OF INHOMOGENEOUS BODIES

Abstract: The work deals with the homogenization of a boundary value problem for an inhomogeneous body with Cosserat properties. The general idea of the homogenization methods is to obtain a equivalent body with homogeneous characteristics. The homogenization method has been widely used to solve problems for composites of regular structure by expanding the solution of the original problem in a power series in a small geometric parameter equal to the ratio of the characteristic dimension of the periodicity cell to the characteristic dimension of the entire body. That is called the Asymptotic Homogenization Method and is the one we will use in the paper to derive the effective characteristics in the micropolar theory of elasticity.

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MODEL OF BAHILL APPLIED TO THE STUDY OF THE SACCADES IN PATIENTS WITH HEREDITARY ATAXIA SCA2
Abstract: The eye movements play a fundamental roll in human vision. Its anomalies might be symptoms of neurological disorders. This research is focused on mathematical modelling of horizontal fast eye movements by means of ordinary differential equations. It is evaluated the applicability of linear homeomorphic Bahill's model in order to investigate such movements in sick patients of Spinocerebellar Ataxia type 2. In this context it is performed a sensitivity analysis by the help of the direct method. At same time, the model is implemented using the Simulink application incorporated to mathematical assistant MATLAB. It is proposed two non linear models as particular cases of Hsu's model.

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NON-UNIFORM IMPERFECT CONTACT AND EFFECTIVE MODULI OF ELASTIC FIBROUS COMPOSITES
Abstract: In this work it is proposed an obtaining method for the effective elastic moduli of biphasic fibrous composites, considering non uniform imperfect contact (spring model) in the interphase. It will be applied the Asymptotic Homogenization Method (AHM), in order to do that transversal sections shaped as a reinforced parallelogram by cylindrical fibers were analyzed. This research is complemented by the already solved antiplane problem about the same kind of contact, and it is also a generalization of the perfect contact and uniform imperfect contact.

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A BIOMECHANICAL MODEL OF THE HUMAN CORNEA
Abstract: Numerical modeling of human cornea has paramount importance to test in silica surgical procedures and to understand the effect on human eyes of injuries and other external aggressions. To prepare a numerical model that could reproduce correctly the corneal behavior, it is necessary firstly to select a type of elastic material and its mechanical model of response. Then a numerical procedure must be implemented; normally FEM is used for calculations. It is then necessary to select geometry, create a mesh and calculate the elastic constants of the model. In the present contribution, it was created a model based in Mooney Rivlin hyperelasticity, with a mesh consisting in three layers and eleven elements per meridian from the apex to limbus. Two geometries were tested: cornea fixed by limbus and a second one formed by cornea, corneal limbus and part of sclera. It was prepared and tested the numerical procedure for establishing the stress free configuration. Finally, it is shown an experimental installation that is being employed in obtaining numerical parameters of the model using inflation tests.

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NUMERICAL AND EXPERIMENTAL ANALYSIS OF BIOGAS COMBUSTION IN A HOMOGENEOUS CHARGE COMPRESSION IGNITION ENGINE
Abstract: The use of biogas fueled HCCI engines to produce power could be a reliable method to reduce oil derived fuels dependence and pollution from organic material decomposition in both developing and developed countries. However, there are still few reported experiments on this kind of system, and there is even less information about the main characteristics of biogas HCCI combustion. This research is focused on studying the combustion of biogas in HCCI engines for power generation using experimental and numerical analysis. The experimental part of this study was conducted on a 4-cylinder, 1.9 L

Volkswagen TDI Diesel engine modified to run on HCCI mode with biogas. At low equivalence ratios, slight changes in inlet charge temperature and boost pressures enhanced combustion parameters and reduced CO and HC emissions. At high equivalence ratios, the effects of inlet charge conditions on HCCI combustion and CO and HC emissions were attenuated; however, ringing intensities and NO_x emissions increased rapidly with slight increases in inlet charge temperature and boost pressures. Additionally, three strategies were used to expand the operating range. Oxygen enrichment of the inducted charge and gasoline pilot port injection were used at low equivalence ratios, and delayed combustion was used at high equivalence ratios. Oxygen enrichment increased cycle-to-cycle variability and total hydrocarbon emissions. Gasoline pilot port injection lowered cycle-to-cycle variability, CO and THC emissions, and increased $IMEP_g$. The highest $IMEP_g$ was around 8.5 bar at 0.33 equivalence ratio and NO_x emissions were usually below the US-2010 limit. The ringing intensity was lowered using delayed combustion, but it remained at values above the accepted limit for safe operation. A new 12-zone reduced model is developed and validated against experimental results to study biogas HCCI combustion. The proposed method is based on the sequential coupling of CFD analysis prior to auto-ignition, followed by multi-zone chemical kinetics analysis of the combustion process during the closed valve period. Using the proposed method two strategies were explored for reducing the intake temperature requirements for a biogas fueled HCCI engine: high intake pressures and high compression ratios. It was found that using high compression ratios, up to 22 with an intake pressure of 2 bar, the intake temperature could be reduced to 403 K (130 °C). Additionally, the effects of biogas composition on HCCI combustion variables were studied using the proposed method. The numerical results suggest that biogas composition does not have a significant effect on power output and indicated efficiency. Lower cycle-to-cycle variations can be achieved at low equivalence ratios if CH_4 mole fraction is increased, and lower ringing intensity can be attained at high equivalence ratios if CH_4 mole fraction is reduced.

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FINITE ELEMENT MODEL OF THE HUMAN EYE
Abstract: The deformation of the eyeball is a topic of interest for the study of ocular traumas caused by blunt objects. Hence in this work, two computational models of the ocular globe of the human eye were implemented in a finite element modeling system in order to analyze such traumas. The first geometric model of the eyes included the cornea, sclera, limbus, the optical nerve head and the adipose tissue. Lineal elastic and hyperelastic material models were selected to represent the behavior of the tissues. Using this globe model, the influence of the variation of intraocular pressure was considered in the zone of the optical nerve; when the values of the maximum shear stress obtained were comparable with those reported in the modern literature. This model was also employed to study traumas caused by the impact of blunt objects, evaluating stresses and strains in the lamina cribrosa and the retina. The rectus extraocular muscles were incorporated into in a second model, which included the cornea, limbus and sclera. The action of a blunt object at different impact velocities was simulated to study the influence of muscles on the deformation of ocular structures. The dependence of the numerical results of the simulation was analyzed with the spatial discretization of the model. An optimal meshing of the system was obtained for which the numerical simulation results are independent of the number of volumes in the computational domain. After this mesh sensitivity study, the apical displacements of the cornea were compared in the model with and without taking into account the presence of the rectus muscles. From this comparison, the minor apical displacement was obtained in the model with muscles; this result may be due to a greater distribution of the loads in the system. However, the behavior of the apical displacement when varying the impact velocity of the projectile is very similar in both cases, which shows a stability in the response of the system.