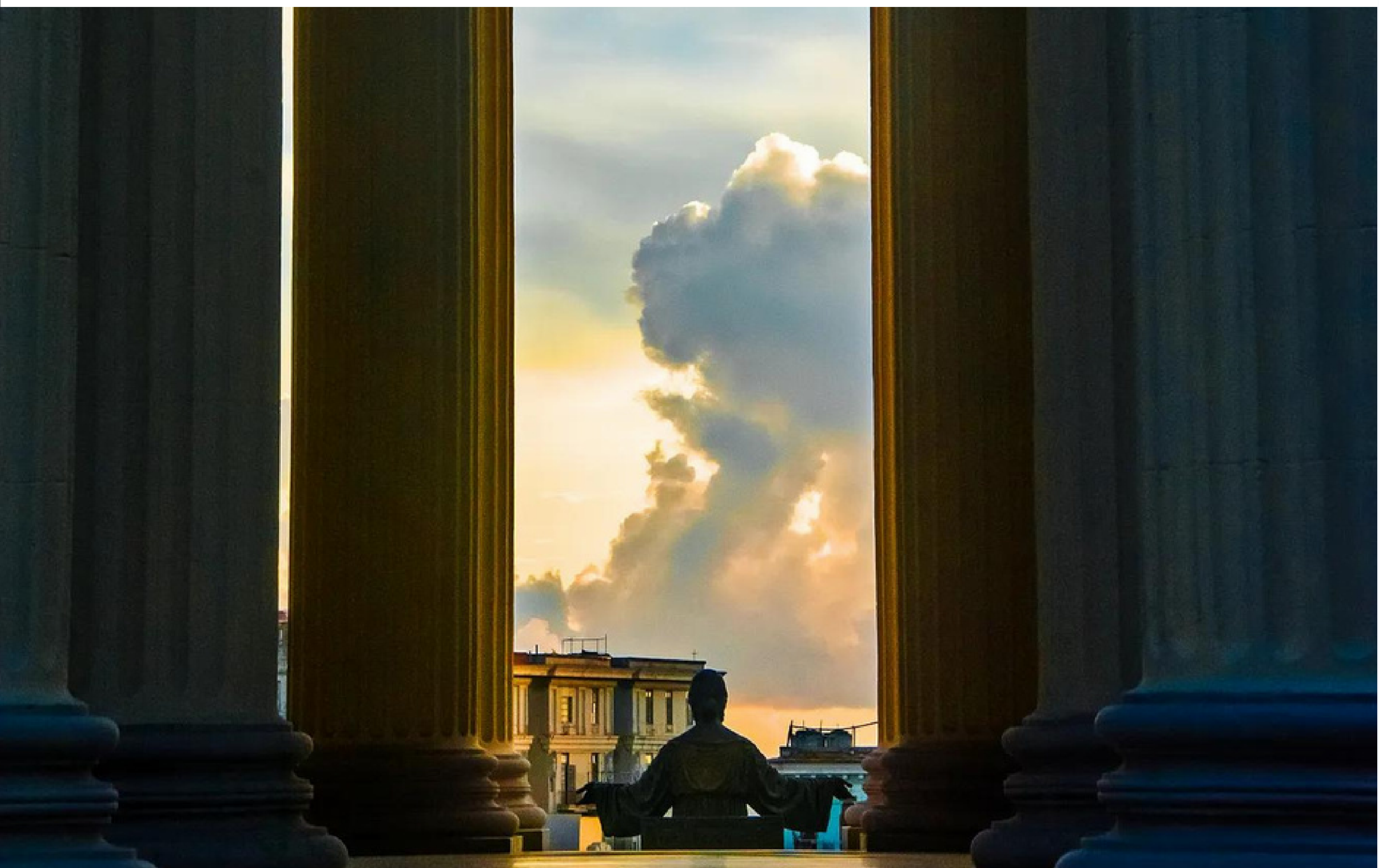
ELACTAM 2024

EUROPEAN-LATIN-AMERICAN CONFERENCE OF THEORETICAL AND APPLIED MECHANICS

FROM January 29th to FEBRUARY 2nd 2024
HAVANA UNIVERSITY, CUBA



LIBRO RESUMEN

SUMMARY BOOK

PROGRAM

III European-Latin American Conference of Theoretical and Applied Mechanics (ELACTAM-2024)

University of Havana, January 29 - February 2, 2024

http://mcct.uff.br/european-latin-american-conference-of-theoretical-and-applied-mechanics-elactam-2024/

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

Place	Time	Monday 29.01.2024	Tuesday 30.01.2024	Wednesday 31.01.2023
Protocol Room Varona Building	8:30-9:00	**Registration** Faculty of Mathematics (Building Felipe Poey, 1st floor) and Opening Ceremony (Salon 250, Varona building)	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** (Varona Building)		
	11:30-12:00	T3	T18	T36
	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**		
Room 290 Varona Building	8:30-9:00	**Registration** Faculty of Mathematics (Building Felipe Poey, 1st floor) and Opening Ceremony (Salon 250, Varona building)	T22	T40
	9:00-9:30		T23	V1
	9:30-10:00		T24	V2
	10:00-10:30	T7	T25	V3
	10:30-11:00	T8	T26	V4
	11:00-11:30	**Coffee break** (Varona Building)		
	11:30-12:00	T9	T27	
	12:00-12:30	T10	T28	
	12:30-13:00	T11	T29	
	13:00-13:30	T12	T30	
	13:30-15:30	**Lunch**		
	18:00-19:30	***Welcome Cocktail (Hotel Habana Libre)***	***Fairwell party or dinner (Tuesday, Hotel Nacional) Excursion (Wednesday, Old Habana Tour)***	

PARTICIPANTS

T1. Plate theory equations and their peridynamic formulation

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The classical plate equations and their extensions have been known for a long time [1]. Different formulation concepts lead to different sets of equations to be solved, which are suitable for solving numerous problems of engineering practice. However, this does not apply to problems in which long range internal force/moment interactions are dominant. An alternative formulation concept, which can also be applied to plate theories, is given by peridynamics (PD) [2]. PD is a non-local theory, which operates with long-range interactions. In classical continuum mechanics, the gradient of the radius-vector, its higher gradients or gradients of internal state variables are considered. The PD formulation ignored such elements, and the equations of motion are integro-differential equations instead partial differential equations. This makes PD suitable for solving problems with discontinuities (crack initiation, branching, kinking and interaction with initial heterogeneities like holes and pores, see [3]). The aim of the lecture is to derive analytical solutions to PD plate equations for both static and dynamic loading conditions. General solutions for the deflection function are derived. For SSSS (all the edges simply supported) boundary conditions in the static and in the dynamic case solutions are obtained.

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T2. Acoustic and vibration analysis of timber floor panels enhanced with porous material damping

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This work aims to investigate the impact of incorporating porous materials on noise and vibration reduction in wood floor panels and to analyze the vibroacoustic performance [1] of the assembled panel under various types of excitation and boundary conditions, particularly in the lower frequency range. First, experimental results are used to calibrate the numerical model and determine the mechanical properties of the orthotropic wood material used in the floor panels [2]. Subsequently, a finite element formulation, based on a variational approach [3], is presented to study the vibroacoustic response of an elastic structure coupled to a porous material exhibiting realistic behavior. The porous material, described using Biot Theory, is characterized by two phases: solid and fluid, represented in the formulation by the displacement field for the solid phase and the pressure for the fluid phase [4]. This formulation offers the advantage of reduced computational cost and simplifies the coupling between all domains. To calculate the acoustic radiation of the structure, the Rayleigh integral is used. Using the proposed numerical approach, an in-depth study is carried out to analyze the reduction in the vibratory-acoustic response of the floor with the porous layer incorporated, taking into account the different types of excitation and boundary conditions applied to the system.

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T3. An influence of hypotheses used for a material description on identified composite material properties

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Due to the great importance to define performance, safety and reliability requirements for advanced composite products and services significant efforts were made to study their mechanical material properties and many inverse methods based on vibration tests were developed in the last three decades. An identification of material properties in each inverse technique based on vibration tests is performed by minimization of the error functional between the experimental and numerical parameters of structural responses using direct or indirect optimization methodologies. Unfortunately, the dynamic parameters of test samples are very sensitive to experimental errors and numerical models applied in the identification procedure due to measurement inaccuracies or an approximated nature of the numerical analysis. In the present study numerical model errors associated with the hypotheses used for a material description are estimated. For this purpose, two thin panels made of four anisotropic layers with the following reinforcement schemes: [0°/90°/0°/90°] and [-45°/45°/-45°/45°] were prepared by using manual layout technology, vacuuming under the polyethylene film, and curing in an autoclave at high temperature and pressure. The selected CM-PregF-T27 200/1250 CP0041 45 prepreg carbon fiber material, reinforcement schemes and layers thicknesses were chosen with the purpose of manufacturing the power shells widely used in aircraft constructions. Lamina properties were identified from vibration tests by using asymmetric laminates and woven composite assumptions. For both samples the plans of experiments with regular distribution of the points of experiments in the domain of factors were developed for three design parameters and twenty experiments. Then the finite element vibration analysis was carried out by ANSYS in each experimental point using completely free boundary conditions for the tested samples. Non-contact excitation with loudspeaker and optical sensing with POLYTEC scanning laser vibrometer PSV-400-B were applied in the experimental set-up. More than ten first frequencies were measured for both specimens during vibration testing. To approximate accurately the numerical results, different order polynomial factions were estimated. The identified elastic material properties were successfully validated comparing the numerical and experimental resonant frequencies.

T4. A new remeshing strategy relying on level-set functions for the particle finite element method

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Since the seminal work of Idelsohn [1], the remeshing process of the Particle Finite Element Method (PFEM) has relied on a Delaunay triangulation (DT) followed by the Alpha–Shape algorithm (ASA). This DT+ASA procedure generally guarantees a good quality of the Lagrangian mesh and in the simulation of free–surface flows. However, the remeshing procedure creates and removes elements during the merging or splitting of bodies, which modifies the mass of the system. In the literature, this issue has been addressed either by mesh refinement or by adjusting the parameter ruling the ASA algorithm [2]. The ASA computes, for each element, a parameter that is representative of the size and distortion of the element and compares it to a user–defined value. If the parameter is greater than the imposed threshold, then the element is removed from the DT. Differently, in this work we propose a new DT filtering criterion that resorts to a Level–Set (LS) function instead of the ASA. The proposal maps the topology of the domain before the remeshing process using a LS function, where its sign indicates the inner or outer zone of the discretized body, while its magnitude gives an approximation of the distance

to the body boundaries. The proposed criterion accepts the elements of the DT if they are inside the body, or very close to the body boundaries. Therefore, the criterion is information-enriched since it considers not only a geometrical aspect but also a topological feature. The new meshing strategy proposed for PFEM is assessed using benchmark problems for the simulation of free–surface flows, fluid–structure interactions, and phase change, both in 2D and 3D. The results indicate that the LS allows a substantial decrease in the mass variation during the remeshing process. In addition, it preserves the smoothness of the free surface and avoids numerical artifacts that are inherent to the ASA procedure.

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T5. Efficient design of solid oxide fuel cells through machine learning

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We undertake a comprehensive study of the design parameters associated with Solid Oxide Fuel Cells (SOFCs) including six geometric parameters, twelve electrode properties parameters, and four operational parameters, all serving as inputs. For each unique set of parameters, we utilize the Finite Element (FE) method to calculate current density and power at nine polarizations/cell voltages, serving as outputs. Our primary objective is to establish a surrogate model for FE-based simulations using Artificial Neural Networks (ANNs). The (continuous) high-dimensional input space of design parameters is divided into three subspaces, namely, geometrical, electrode, and operating parameters. To discretize these subspaces, we employ Halton and Sobol techniques that are low-discrepancy sequences suitable for efficiently sampling multidimensional spaces. The corresponding outputs are determined using FE-simulations. This process generates a dense dataset which is then employed for ANN training, validation, and testing. The networks we provide not only enable the efficient evaluation of SOFC performance but also pave the way for more effective design strategies and enhanced operational outcomes. This work represents a significant step towards harnessing the power of machine learning in optimizing the design of solid oxide fuel cells.

Acknowledgement
We acknowledge the support of this research work via the framework of M.era.Net Project MEDIATE, the financial Support the Luxembourg National Research Fund (INTER/16527756) and the SMWK funding agency (Saxony).

T6. From micro computerized tomography to effective properties (CTEP) of composites with stochastic microstructure

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We present a comprehensive workflow aimed at determining the effective heat conductivity of composites with stochastic microstructure by analyzing micro–Computerized Tomography (μCT) images. The workflow encompasses image preprocessing and segmentation to identify the pores (void) and the solid matrix. This is followed by transforming the segmented image to a computational domain suitable for upscaling procedure for identification of the effective heat conductivity tensor. The asymptotic homogenization for multiscale analysis of transient heat problems is revisited to derive systems of PDEs governing the homogenized problem and two cell problems which are solved numerically using Finite Element (FE) method for identification of the effective heat conductivity. The methodology does not require enforcing Dirichlet Boundary Conditions (BCs) on the interfaces which is well-suited for analyzing stochastic microstructures with irregular interfaces. The open-source

computing platform FEniCSx is used and the periodic boundary condition (PBC) is enforced as Multi-Point Constraints (MPC) eliminating the need for one-by-one mapping of inlet and outlet computational nodes. To validate the methodology, we apply it to model a bi-laminated composite and compare the obtained results with the analytical values. Furthermore, we provide some use cases.

Acknowledgement

We acknowledge the support of this research work via the framework of SUMO, funded by the Luxembourg National Research Fund (INTER/16355360)

T7. Modal Analysis of a Violin

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Violins have been a subject of significant interest in society throughout history. From a structural dynamics perspective, a violin is a particularly intriguing instrument to investigate, given its complexity characterized by anisotropic behavior, multiple interfaces, and the nonlinearity arising from the tension of its strings. The present work aims to accurately understand the structural dynamics of a specific violin. The investigation of the violin employs a novel step-by-step approach. Firstly, we gather the raw wood parameters for each component of the violin through numerical and experimental modal analysis. Secondly, we conduct experimental modal analyses on the subcomponents of the violin to determine the modal parameters. Additionally, we carry out a numerical investigation using finite element models of the subcomponents, incorporating the material parameters previously identified. After conducting a thorough comparison between the numerical results and the experimental data, we proceed to assemble the subcomponents of the violin until its final completion. Throughout this process, we investigate each production step utilizing the modal analysis methods. The strong correlation between the modal parameters obtained in the experiment and the numerical results, evaluated at various stages of production, demonstrates the feasibility of employing conventional modal analysis techniques on complex mechanical systems such as the violin. An example is presented in Figure 1. [1]

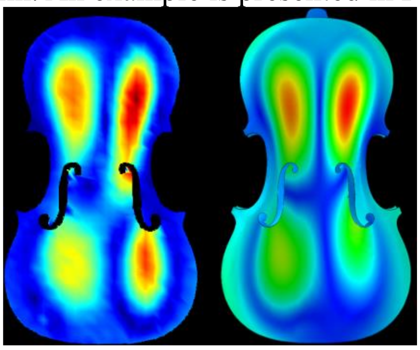

Figure 1: Experimental violin body mode 9 at 938 Hz (left), numerical violin body mode 9 at 948 Hz (right).

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T8. Higher-order effective stiffness tensors of periodic laminated structures via asymptotic homogenization

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In [1] a homogenization methodology is described for deriving effective strain-gradient constitutive laws for heterogeneous materials, and it is applied to a one-dimensional example illustrating that the effective behavior do not depend on the size of an elementary representative volume (ERV). In recent years, this methodology has been combined with numerical and asymptotic methods for studying of microstructure-dependent effective higher-order constitutive laws in composite materials with complex structures ([2, 3] and references therein). In this work, the methodology of [1] is combined with the asymptotic homogenization method to study the effective behavior of "-periodic laminated composites. Basic cells can have any finite number of non-centrosymmetric anisotropic layers. Analytical formulas were obtained for all components of the effective stiffness tensors of fourth (C^M_{ijkl}), fifth (H^M_{ijkl}) and sixth (D^M_{ijkl}) ranks. For example, the effective coefficients corresponding to the perpendicular direction to the layers are $C^M = \left\langle E^{-1}(y) \right\rangle^{-1}$, $H^M = 2\varepsilon (C^M)^2 \left\langle E^{-1}(y) \right\rangle$ and $D^M = \varepsilon^2 C^M \left\langle y^2 (C^M E^{-1}(y) - 1) \right\rangle$, where E(y) denotes the variation of Young moduli on the periodic cell (ERV) $Y = (0;\, l) \ni y$ and $\left\langle f(y) \right\rangle$ is the mean value of function f(y) over Y . In particular, for a specific value of ε , from $D^M = \varepsilon^2 C^M \left\langle y^2 (C^M E^{-1}(y) - 1) \right\rangle$, formulas (42) and (43) of [1] were recovered.

Acknowledgments Projects PAPIIT DGAPA UNAM IN101822, Mexico, and CNPq Universal Nº 402857/2021-6, Brazil, are gratefully acknowledged.

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T9. Toward stochastic imperfect interfaces

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Interphases between solids play a crucial role in the behaviour of structures, whether natural or industrial. It is very important to predict their ageing under various stresses (mechanical, thermal, environmental, etc.). The difficulty in modelling is essentially due to the very small dimensions of the interphases compared with those of the structures. A classical technique for overcoming this difficulty is to use asymptotic techniques, with the interphase modelled by an interface [1,2]. These techniques can be used to introduce a damage parameter, which can be interpreted as a microcrack density [3]. A further step in modelling is to take account of the heterogeneous distribution of microcracks. The mathematical technique we propose in this presentation consists of adding a stochastic term to the damage evolution equation. However, these problems are difficult to analyse mathematically [4] and solve numerically. The presentation will include some elements of mathematical analysis and the first numerical results obtained for academic examples.

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T10. On the existence of weakly nonlocal Rayleigh waves with impedance boundary conditions

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In this paper, the existence of Rayleigh waves propagating in weakly nonlocal incompressible isotropic elastic half-spaces subsect to the tangential impedance boundary condition (at the surface of half-spaces, the tangential stress is proportional to the horizontal displacement and the normal stress is zero) is investigated for some set of nonlocality and impedance parameters using the complex function method. It is shown that for the considered case there always exist two Rayleigh waves. The first wave is the counterpart of the Rayleigh wave in local incompressible isotropic elastic half-spaces and the second is a new Rayleigh mode appearing due to the presence of nonlocality. Formulas for their velocities have been derived. Remarkably, the second wave can travel with very high velocity.

T11. Determination of effective conductivity properties of fibrous composites

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Approximate analytical expressions of the effective coefficients for fibrous composites are obtained in [1],[2] using the Asymptotic Homogenization Method. In [3], analytical expressions are derived based on the Eshelby equivalent inclusion concept. The results obtained in these works have demonstrated a good coincidence but are difficult to reproduce by interested readers. In this works we present the formulas derived in [2] in a simpler form. The considered composite contains circular inclusions in a matrix with rhombic periodicity and a thermal barrier around the fibers. The results facilitate their use for the validation of numerical codes and experimental models.

Acknowledgments: RGD appreciates the support of PREI-DGAPA-UNAM (DGAP/DFAJ27 2OI2O23). PAPIIT DGAPA UNAM (IN101822) project is also acknowledged.

References

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T12. Numerical solution of Helmholtz equation in biological tissues using isogeometric analysis

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Inspired by medical applications related with ultrasound we study the solution of Helmholtz equation with mixed boundary conditions in biological tissues. For this problem, the wave number is a function depending on spatial variables with values of order 103. This introduces several difficulties in the computation of the approximated solution with the classical Finite Element Method.

In our work we compute the acoustic field, solution of Helmholtz equation, using the isogeometric approach based on bicubic B-splines functions. Simulations of acoustic wave propagation in a medium composed by three types of tissues are obtained with the free software GeoPDE.
KEYWORDS: Isogeometric analysis, Helmholtz equation, radiation problem.

T13. Glioma growth model with Cuban immunotherapy: Nimotuzumab. New treatment scheme vs Conventional Treatment

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The exploration of the use of mathematical models to develop cancer therapies represents a developing field that intersects the disciplines of mathematics and oncology[1]. This document presents a novel mathematical model, intended to describe the response of high-grade malignancy gliomas after surgery, to Radiotherapy [2] and Nimotuzumab, the latter is a monoclonal antibody developed by the Center for Molecular Immunology in Havana, Cuba [3]. The model described a dynamic analogous to that recorded in previous studies and to that of real patients, despite having few volumetric data from them. After calibrating specific parameters for some patients, computational tests of various therapeutic strategies were carried out on virtual patients. Two groups were taken into account, classified as patients who started the study with a higher degree of tumor mass resection and another with a lower degree. The two groups behaved in the same way with the conventional scheme and the proposed one that has fewer cycles of the biotherapeutic drug and some more spaced out. However, for other schemes more spaced out than the previous ones, there was a reduction in survival, highlighting significant differences compared to the two previous schemes.
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Journal of Clinical Oncology 22(9).

T14. Growth model of a breast tumor in the continuum mechanics range

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Cancer is a disease that is taken very seriously because it can be life-threatening and affects millions of people around the world. Breast cancer is especially important because it is one of the most common types of cancer in women, and it can affect men as well. If detected at an early stage, it can be highly curable. Mathematics can significantly contribute to modeling tumor growth, particularly in breast cancer. Mathematical models can help researchers understand how tumors develop and spread, as well as how they can be treated. These models can also aid in predicting how a tumor will develop in the future and how it will respond to different treatments. For the completion of this work, previous studies and existing models addressing tumor growth were reviewed, to identify aspects or areas that have not yet been fully addressed or understood. Most existing models have focused on the chemical and biological aspects of tumor development, which are of vital importance. However, they have not significantly considered the mechanical aspects that may have an influence on tumor evolution. Based on the previous works of [1], [2], the present work proposes a model of tumor growth within the realm of continuum mechanics, while considering the tumor as a thermoelastic medium, emphasizing that temperature variation in the affected tissue may also influence tumor growth. Furthermore, some studies reveal thermography as an effective

detection technique, more suitable and cost-effective than others, highlighting its validity and potential for early detection of breast cancer. Additionally, this work proposes a more comprehensive and accurate equation for nutrient concentration compared to the work of Ravelo et al. [2]. This is achieved by including the effect of angiogenesis and modeling the rate of nutrient consumption as a function of concentration in the surrounding environment, which is more realistic than considering a constant rate.

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T15. Smart water injection modeling including surface complexes

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In addition to Carbonated Water Flooding (CWI), this study aims to extend its scope by incorporating the modeling of Smart Water techniques. Smart Water involves modifying the properties of injected water, such as salinity and chemical composition, to enhance oil recovery from reservoirs. By adjusting these factors, Smart Water can influence the interactions between water, oil, and rock, optimizing the displacement of residual oil. Accurate modeling of CWI and Smart Water techniques is crucial for understanding their combined effects on oil recovery. Compositional modeling, coupled with surface complexation modeling (SCM), is employed to investigate the impacts of low salinity carbonated water injection on reservoirs containing oil equilibrated with high salinity carbonated water. Furthermore, we examine the positive effects of treated water, explicitly focusing on modifying minerals in the water. Beyond assessing the influence of low salinity, the study will also evaluate the effects of other minerals, providing a comprehensive analysis of how various water treatments can enhance oil recovery. This comprehensive approach allows for a unified examination of the dissolution effects, viscosity reduction, and wettability alterations associated with these improved oil recovery methods. Additionally, numerical and semi-analytical solutions will be presented for all the studied cases, enhancing the depth and applicability of the findings.

T16. Application of the asymptotic homogenization method to a material composed of two porous media

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Darcy0s Law, discovered by French engineer Henry Darcy, describes the flow of fluids through porous media. As can be seen in [1] and [2], this law is obtained by homogenizing the Stokes equations, equations that describe the movement of a viscous fluid. The intention of this work is, first of all, to derive Darcy´s law from the Stokes equations, following [1], and secondly, to use the Asymptotic Homogenization Method (AHM), following texts [3-6], in order to estimate the global effective properties of a laminated composite formed by two different porous media that respond to Darcy´s law.

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T17. Dispersion problems for a one-dimensional periodic medium using the three-scale homogenization method

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Composite materials are essential for many industrial and engineering applications. To study their properties, we can use homogenization techniques that average the effects of different scales and structures. In this work, we develop the Asymptotic Homogenization Method for one-dimensional hyperbolic problems with periodic and fast-varying coefficients that depend on three microscales. We focus on the linear elastodynamic problem and present an algorithm that gives the local problems and the effective coefficients for the homogenized problem. The present model generalizes the results of [1] and includes a numerical algorithm based on [2] to verify the dynamic model with two microscales. We also check the static limit case and reproduce the results of [3]. Finally, we apply the algorithm to a dynamic case with three microscales and show its performance.
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T18. Simulation of tumor growth in various regions of the human body in 3 dimensions

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Cancer is a disease characterized by the uncontrolled growth of abnormal cells in the body. It is a complex and multifaceted disease that has challenged researchers and doctors for decades. The ability to visualize and understand the growth of tumors can provide valuable insight into how cancer develops and spreads, which can lead to significant improvements in cancer diagnosis, treatment, and prevention. The tool being developed is an important step in this regard. It allows for detailed visualization of tumor growth in different parts of the human body, which can provide valuable insight into how cancer develops and spreads. Furthermore, its ability to simulate tumor growth in different regions means it can be used to

study a wide range of cancer types. A cellular automaton and a small-world network are used to create connections between cells, allowing for a more accurate representation of the structure of organs and tumors. Additionally, it allows for loading configurations and parameters from external files, which provides great flexibility and allows the simulation to be adapted to the specific needs of each case. For 3D rendering, the Marching Cubes technique is used, which allows for a detailed and accurate three-dimensional representation of tumors. The goal is to implement a device through a cellular automaton that simulates the emergence, development, and metastasis of a tumor originating from the epithelial tissue of organs, as well as the interaction of the immune system with it and the influence of many internal and external factors on its evolution. The aim is to obtain results like those obtained in literature, so that our automaton could be useful in tracking the development of a tumor in real life.

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T19. Micromechanical analysis of the effective stiffness of poroelastic composites and a first approximation to modelling microstructural changes induced by myocardial infarction

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We investigate the role that the microstructure of a poroelastic material has on the resulting elastic parameters. We are considering the effect that multiple elastic and fluid phases at the same scale (LMRP model [1]) have on the estimation of the materials elastic parameters when compared with a standard poroelastic approach. We present a summary of both the LMRP model [1] and the comparable standard poroelastic approach, both derived via the asymptotic homogenization technique. We provide the 3D periodic cell problems with associated boundary loads that are required to be solved to obtain the effective elasticity tensor for both model setups. The results of our numerical simulations show that when investigating a poroelastic composite material with porosity exceeding 5%, then the LMRP model provides a more accurate representation of the structural details in the Young's moduli E1, E3, and the shear C44. Whenever the porosity exceeds 20%, the model [1] should also be used to investigate the shear C66 [2]. We find that for materials with less than 5% porosity that the voids are so small that a standard poroelastic approach or the LMRP model produce the same results. Finally, we investigate how

physiologically observed microstructural changes induced by myocardial infarction impact the elastic parameters of the heart. The results of our simulations agree with the physiological observations that can be made post-infarction [3].

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T20. Machine Learning applied to skin cancer detection. An EfficientNet approach

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Machine Learning is a discipline in the field of Artificial Intelligence that, through algorithms, gives computers the ability to identify patterns in massive data and make predictions [1]. Convolutional Neural Networks (CNNs), a specialization of this discipline, known for their efficiency in image processing, are ideal for detecting common features in dermatological images. By implementing advanced models, such as EfficientNet, and adjusting the learning rate, these systems can be trained to classify different types of skin diseases, especially skin cancer, with high accuracy. This work presents a series of implementations, including CNN, the EfficientNetB5 model, and the use of Learning Rate Adjustment to the HAM10000 dataset of skin cancer images, to achieve effective detection. These results can lay the foundation for future research and improvements in the field of early skin cancer detection using machine learning techniques and convolutional neural networks.

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T21. Generalized interfaces enabling macroscopic modeling of structural and soft adhesives and their failure

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The application of soft and brittle adhesives in industrial production has been steadily increasing for decades. Such adhesive layers, commonly of small thickness have previously been modeled as zero-thickness elements for efficiency using interface elements or cohesive zone models (CZM). CZM allow for normal and tangential displacement jumps between the substrates and for damage behavior of the adhesive layer subjected to tension and/or shear loading. However, CZM do not account for jumps in the tractions across the interface. Consequently, CZM cannot capture the physical response of an adhesive being stretched in in-plane direction, i.e. its resistance versus stretch, as well as in-plane damage at sufficiently large in-plane strains. For this reason, CZM are not adequate to accurately model the response of structural and soft adhesives undergoing tension, shear and in-plane loading. In addition, experiments and micro- to macro-simulations in literature observed that the damage behavior of the investigated adhesives is not only mode dependent but also coupled. An interaction between the normal and tangential damage was observed, as well as a significant degradation of cohesive strength and fracture toughness for increasing in-plane strain. In order to take these effects into account, we present thermodynamically consistent, generalized interface models [1, 2] for small and finite strains, which extend the conventional approach by a membrane component and also allow a full coupling of all possible damage modes. Furthermore, additional shear-like stresses, often neglected in literature, arise for anisotropic decohesion in a finite strain setting. The generalized interface models are implemented in Abaqus user subroutines. Numerical examples of brittle and soft adhesives demonstrate the performance and versatility of our models.

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T22. Simulation of the development and evolution of a Glioblastoma Multiforme using a cellular automaton

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This work focuses on simulating the growth of a high-grade glioblastoma multiforme using a mathematical cellular automaton model. Glioblastoma multiforme is an astrocytoma characterized by the presence of necrosis and microvascular hyperplasia [1]. The aim of this simulation is to demonstrate how the properties of the host's microenvironment can significantly influence the tumor's morphology and growth dynamics. Various tumorhost interactions at the microscopic scale are considered, including mechanical short-range interactions between various tumor cell phenotypes, including proliferative cells, hypoxic cells, necrotic cells, and migrating cells, as well as the degradation of the extracellular matrix by invasive cells and cellular movements driven by oxygen/nutrient gradients. These cellular movements are simulated using reaction-diffusion equations [2], [3]. Furthermore, the tumor's angiogenesis process is modeled, considering how the angiogenic growth factor, secreted by hypoxic cells due to oxygen deficiency, affects pre-existing vessels, leading to new vascularization that increases the tumor's aggressiveness [4-6]. This study provides a detailed and mathematical representation of the growth of a glioblastoma multiforme, highlighting the importance of tumor-host interactions and the influence of the host's microenvironment properties on the tumor's morphology and growth dynamics.

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T23. Peridynamic formulations for the simulation of wave propagation and spalling

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Peridynamics describes the material in a non-local form and is well suited for dynamic fracture simulation. However, one significant effect regarding spallation is the correct handling of elastic waves, like the pressure and tension waves inside a body, due to dynamic boundary conditions from an impact or impulse. Different peridynamic material formulations have been developed in this regard. This contribution investigates and compares the elastic wave propagation behavior of bond-based peridynamics, continuum-kinematics based peridynamics, and the state-based peridynamic correspondence formulation, cf. [1, 2, 3]. Using the example of a longitudinal pressure wave inside an elastic bar, we show that the peridynamic formulations are able to reproduce the classical solutions to a different extent. The bond-based and continuum-kinematics-based formulations can handle wave propagation correctly but suffer largely from the surface effect. The non-ordinary state-based correspondence formulation does not suffer from the surface effect but leaves the theoretical frame of the nonlocal continuum model, [4]. By means of some numerical examples, we show that peridynamics offers a very efficient calculation method for dynamic crack propagation and spallation.

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T24. Curvature precessions in vanishing-stiffness shells

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We show how the presence of soft bending modes in almost inextensible shells leads to peculiar dynamical properties. We consider thin multistable shells that are obtained by applying a large isotropic plastic curvature to an initially flat disk [1]. Their equilibrium shape is almost cylindrical, and because of the thinness, the shell is almost inextensible. We demonstrate that the interplay of the pre-stress, geometrical nonlinearities, small material anisotropies and inertial effects results into a complex dynamics alternating chaotic and regular responses. In the regular regime, the shell converts a translational excitation in a continuous precession mode characterized by a constant-speed rotation of the curvature axis, see inset E_5 in Fig. 1, where $\frac{d\varphi}{dt} = \frac{\pi}{2} f$ (1) being $d\varphi/dt$ the precession speed and f the frequency of the sinusoidal forcing, [2].

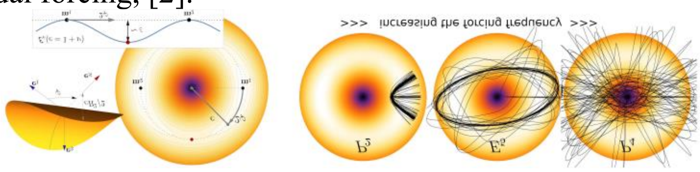

Figure 1: Right: The Lagrangian parameters c and φ describing the shell curvature and curvature direction and the contourplot of the elastic energy. Left: Trajectories as the frequency is varied: from small oscillations, to precession of the curvature axis (E5) and, finally, to chaos.

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T25. Can a Beltrami flow lead to a singular solution?

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Does Navier-Stokes equations have singular solutions? In this letter we have looked for a way to the loss of uniqueness for the Navier-Stokes equations. By projecting them at a point of $\mathbf{R}^3$, for a special type of flow $(\alpha^2(u^s \times \nabla \times u^s) = 0)$: Beltrami flow. Let x ∈ $\mathbf{R}^3$ any point in space, as well as $u^s(x)$: $\mathbf{R}^3 \rightarrow \mathbf{R}^3$ and $p^s(x)$: $\mathbf{R}^3 \rightarrow \mathbf{R}$ the solenoidal vector field of stationary velocities $(\nabla \cdot u^s = 0)$, and the stationary scalar field of pressure in the three-dimensional Euclidean space, as an example of such a field see [2]. Projected Navier-Stokes equations corresponds to the following infinite family of ordinary differential Bernoulli equations:

$$\dot{\alpha} - \left|u^s\right|^{-2}\left(\alpha\mu L_{u^s} - \beta P_{u^s,p^s} - \alpha^2 G_{u^s}\right) = 0, \tag{1}$$

and, for a fixed point in space, be x(@), (1) is transformed into an ordinary differential Bernoulli equation. Let's suppose that the time component of the pressure pulsates following the law:

$$\beta = \left(-\frac{d}{dt}\left(\alpha - \frac{1}{2}t\alpha\mu L_{u^s(x(@))}\left|u^s\left(x(@)\right)\right|^{-2}\right) + f(\dot{\alpha}) + 2G_{u^s}\int \alpha d\alpha\right)\left(P_{u^s(x(@),p(@))}\right)^{-1}\left|u^s\left(x(@)\right)\right|^2. \tag{2}$$

If we place (2) in (1), we obtain the following equation:

$$t\dot{\alpha} - \alpha + f\left(\frac{2\dot{\alpha}}{\mu L_{u^s(x(@))}\left|u^s\left(x(@)\right)\right|^{-2}}\right), \tag{3}$$

which is the well-known Clairaut's equation [1]. Our problem, (3), has a family of general solutions of the form: $u\left(t,\, x(@)\right) = \left(Ct + 2\left|u^s\left(x(@)\right)\right|^2\left(\mu L_{u^s(x(@))}\right)^{-1} f(C)\right)u^s\left(x(@)\right)$ where C is a constant, and for the pressure, $p\left(t,\, x(@)\right) = \beta\left(t,\, \alpha,\, \dot{\alpha}\right)p^s\left(x(@)\right)$. Clairaut equation (3) also has a singular solution, known as the envelope for the previous bundle of time lines, and at the points where the normal solutions of (3) intercept with the envelope, the uniqueness is lost. To discover the envelope solution, we would have to know *f*.

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T26. FEM-PVM: a method for guided wave measurements in curved plates

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Lamb waves have the property to propagate long distances along thin structures, because they use the structure itself as a waveguide. Hence, they are suitable in non-destructive tests (NDT) to inspect hidden or difficult to access areas, such as partially buried structures covered with protective or insulating material or structures hidden behind other elements. Lamb waves are dispersive, i.e., their propagation velocities and mode shapes depend on the frequency, on the geometric parameters of the plate (thickness, curvature) and on the material properties. This phenomenon is known as geometric dispersion and it is represented by the geometric dispersion curves. The dispersion curve is indispensable in the calibration of ultrasonic equipments used to study the position and size of defects, with a procedure based on a pitch-catch configuration. For a given frequency, the presence of flaws, such as corrosion, delaminations, or breaks in the material homogeneity produce a value of the measured phase velocity that does not agree with the value predicted by the dispersion curve. In this sense, dispersion curves are very important for NDT applications dealing with thin curved plates, such as tank containers and curved metallic structures. In this work we show the potential of the combination of the phase velocity method (PVM) with the finite element method (FEM) for computing the phase velocity dispersion curve of an ultrasonic pulse traveling in a transversally annular thin plate. FEM-PVM is based on the numerical solution of the wave

propagation equations for several selected frequencies. The open source software FreeFem++ is used with quadratic triangular elements to compute the displacements. The phase velocity for a given frequency is obtained from the computed displacements at few points on the top of the plate. A deeper understanding on the behavior of the phase velocity dispersion curve with respect to the plate curvature is obtained as result of an extensive experimentation with thin annular plates of isotropic and composite materials, such as aluminium, steel and carbon fiber reinforced polymers.
KEYWORDS: finite element method, phase velocity method, dispersion curve, curved plate, guided waves, FreeFem++.

T27. Temperature and strain rate dependent modeling of adhesive joints

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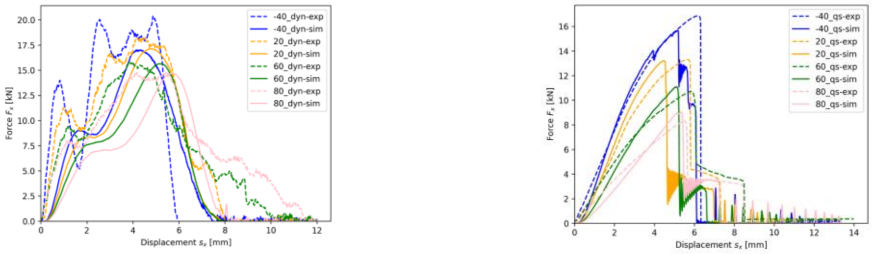
The mechanical properties of polymers depend significantly on temperature and strain rate. For a safe design of adhesive joints, it is therefore critical to identify and describe those dependencies. In a first step we already successfully extended the TAPO (Toughened Adhesive Polymer) material model to temperature dependency for quasi-static load case [1]. In a consecutive step we extended the model to temperature dependent rate dependency in the same fashion. The resulting model was then used to simulate a complex T-test specimen under transverse loading for a final validation. Four temperatures Tϵ {-40; 20; 60; 80} [ºC] and two impact velocities v ϵ {0.00016, 2.0} [m/s] were considered.



(a) quasi-static v=0.00016[m/s] (b) dynamic v=2.0[m/s]

Figure 1: Validation using the T-test specimen under transverse loading.

The results shown in Figure 1 proof that this approach is able to describe the effects of temperature on the material behavior rather well for a complex load case and different strain rates.

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T28. Pollution overturning instability in an incompressible fluid with a Maxwell-Cattaneo-Mariano model for the pollutant field

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We develop a model for a pollutant dissolved in or dispersed in an incompressible Navier-Stokes fluid when the diffusion theory for the pollutant obeys a second order in time system of equations rather than the first order in time system obtained from Fourier's law. A detailed expression for the critical pollutant Rayleigh number is found indicating precise conditions under which a convective overturning motion will arise. The investigation is performed by a linear instability analysis, but additionally we provide a completely nonlinear energy stability analysis.

Our goal is to describe this new model where the solute may be heavier in the upper part of the horizontal layer. Since gravity acts downward this situation is potentially hazardous as the pollutant may induce a downward motion leading to a convective overturning in the layer. We shall employ our model to determine precisely conditions under which convective overturning instability is possible. This is achieved by developing a linear instability analysis, although we additionally produce a fully non linear stability analysis to complement the linear theory. In addition to considering a classical Cattaneo like equation for the solute flux we also analyze the problem when a diffusion term is added to Cattaneo's equation. This leads to a novel result where, when oscillatory convection is found diffusion stabilizes, but when stationary convection dominates diffusion acts to destabilize the layer. This is an entirely counter intuitive and unexpected, exciting effect.

T29. Discontinuity waves in temperature and diffusion models

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In this article we employ the mathematical theory of waves of discontinuity in the concentration (temperature), or in the derivative of these quantities, namely, shock waves or acceleration waves. While the theory of discontinuity waves is well known it remains an exciting way to develop an exact analysis for a fully nonlinear theory and is still being used with great effect in many areas of continuum mechanics and even in mathematical theories pertaining to anthropological or social systems. We commence our analysis with a generalization of the work of Jordan [1] which developed shock evolution for a hyperbolic temperature model with a forcing term of logistic growth type. This has recently been further extended by Jordan and Lambers [2, 3]. Rather than employing simply a logistic term we employ a more general relation due to Richards [4]. The relation of Richards [4] allows for growth not dissimilar to logistic growth but encompasses a greater variety of possible real life scenarios. We calculate the shock speeds and the amplitude behaviour. The latter is very interesting and depends critically on a parameter present in Richards [4] model. For some values of this parameter the shock amplitude may blow-up in a finite time, whereas for other values the amplitude remains bounded, regardless of the initial conditions.

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T30. Multivariate intrinsic local polynomial regression on isometric Riemannian manifolds. Applications to symmetric positive data

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Intrinsic Local Polynomial Regression (ILPR) is a non-parametric regression technique used for data that have responses on Riemannian manifolds. To find the ILPR estimator, a complex optimization problem needs to be solved, which relies on the geometrical structure defined on the Riemannian Manifold. Directly exploring both general theoretical and practical properties of the results is infeasible. In this paper, we study the implications of considering the action of isometric embeddings on ILPR. By doing so, we establish a closed expression of the ILPR estimator for the Riemannian Manifold equipped with Euclidean Pullback Metrics (EPM). Building on the theoretical properties of these estimators and invoking the Nash Embedding Theorem, we develop a proof of the general consistency of ILPR in the

local linear case for a sample with responses on smooth Riemannian Manifold. To illustrate a possible application, we conducted simulations on the Symmetric Positive Definite (SPD) manifold. Our results demonstrate that the ILPR with the Log-Cholesky metric outperforms established methods in the literature in accuracy and efficiency when scaling the dimension of the SPD manifold and the number of covariates.

T31. **Heat transfer at nanoscale and boundary conditions**

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A model of nonlocal heat transfer at nanoscale in rigid bodies is considered. Depending on the relevance of the particular interaction’s mechanism between the heat carriers and the lateral walls, three different strategies for the setting-up of the boundary conditions are analyzed, and the consequent forms of the basic fields have been obtained, as well. From the physical point of view, the possible influence of those interactions on the field variables is pointed out. From the mathematical point of view, instead, the well-posedness of the problem is shown [1].

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T32. Constant force spring system with a spiral and accuracy assessment

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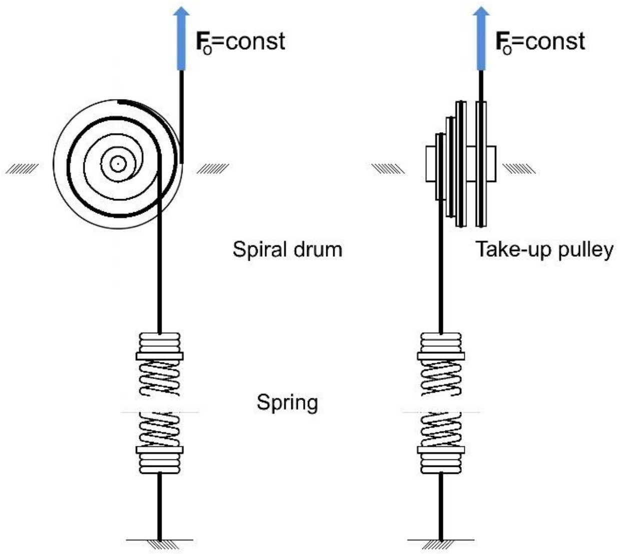
Transforming the linearly changing force exerted by a helical spring into a constant force has been an issue investigated for about a century. Only rather rudimentary solutions have been found, and mostly valid over small distances. In 2020, a brilliant approach to such problem was found [1] in a device based on the so-called Hetnarski’s spiral, whose equation is:

$$\theta(r) = -\sqrt{S^2 + r^4}/(2r^2) - 0.5\arcsin(r^2/S) + K,$$

where the angle θ and the radius r define the shape of the spiral, S is a parameter dependent on its geometry, on the elastic constant of the spring, and on the (constant) force to be maintained, while K is a constant. The device consists of a linear helical spring, a spiral drum, a take-up pulley, and two cords, as schematized in the figure.



Recently [2], the accuracy of such system has been carefully evaluated through analytical and numerical methods, contributing to the definition of technical guidelines for its optimal (concrete) implementation.

The system may, e.g., eliminate weights and weight towers in exercise machines, and be used to open windows that move upwards.

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T33. Modeling the porous properties of brain tissue

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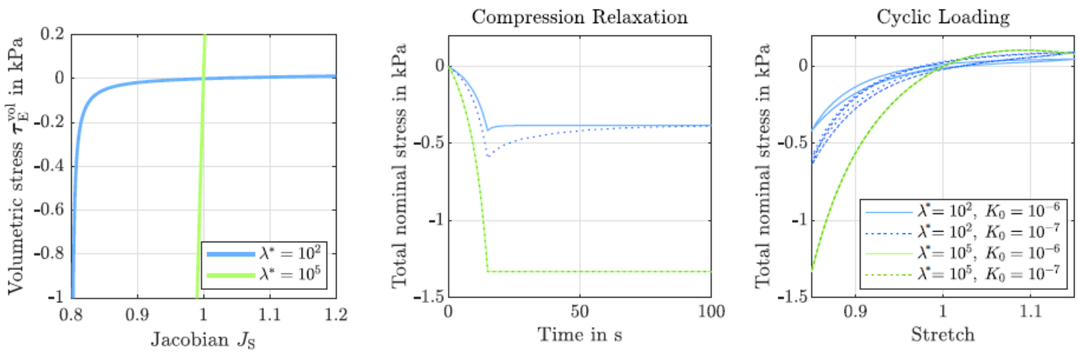
The porous properties of brain tissue remain poorly understood and their investigation requires profound experimental setups and modeling approaches. We identified a strong coupling between the volumetric response of the solid and the porous effects in our nonlinear poroviscoelastic model [1], thus, making material parameter identification even more challenging. The solid volumetric Kirchhoff stress $\tau_E^{vol} = \lambda^* \left[1 - n_{OS}^S\right]^2 \left[J_S / [1 - n_{OS}^S] - J_S / [J_S - n_{OS}^S] \right] \mathbf{1}$ depends on the initial solid volume fraction n_{OS}^S, the Jacobian J_S of the biphasic material and the first Lamé parameter λ^*. As indicated in the left figure, low values of λ^* lead to a gradual increase of the volumetric stress response towards the compaction point, i.e., when all fluid has left the tissue. In contrast, high values of λ^* lead to an immediate, strong volumetric response – even for small volumetric changes, i.e., $J_S \approx 1$. Therefore, the overall biphasic tissue response is highly sensitive to the choice of λ^*. In fact, high values of λ^* obliterate the porous effects such that our biphasic model acts like an incompressible solid model. The figure shows the poroelastic material response during compression relaxation and cyclic loading simulations for different choices of λ^* and the intrinsic permeability K_0, clearly highlighting that both λ^* and the permeability need to be chosen very carefully when modeling brain tissue behavior, and new experimental insights are needed.



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T34. Tuning the mechanical properties of alginate dialdehyde-gelatin bioinks for bioprinting approaches by varying the oxidation degree

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Extrusion-based 3D bioprinting is one of the most promising and widely used technologies in tissue engineering (TE). However, the development of 3D printable, biocompatible bioinks with tailored mechanical and biological properties remains a major challenge in this field. Alginate dialdehyde-gelatin (ADA-GEL) hydrogels face these difficulties and enable to tune the mechanical properties depending on the oxidation degree (OD) of ADA. First, we characterize the influence of the OD on the mechanical properties of molded and 3D printed ADA-GEL samples under multiple loading modes, compression, tension, and torsional shear in the large-strain regime. Second, we establish an inverse parameter identification scheme [1] using hyperelastic Ogden models and calibrate them by fitting our experimental data sets in compression and tension, simultaneously. Our experimental results confirm that a decrease in the OD of ADAGEL hydrogels from 25% to 6% leads to an increase in stiffness, a more distinct nonlinearity and a more pronounced hysteresis, while the relaxation behavior remains unaffected. The fabrication process - molding or 3D printing - does not affect the overall mechanical properties of ADA-GEL hydrogels. Our fits show that only the two-term Ogden model can resemble the compression-tension asymmetry, as well as the distinct nonlinear, S-shaped response in compression and tension of molded and 3D printed ADA-GEL samples with 6%OD. These findings highlight the importance of the OD as a crucial parameter to tune the mechanical behavior for advanced TE applications and of precise computational models for a predictive understanding of hydrogels to further optimize them and 3D printing parameters in the future.

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T35. Nonlinear Fokker-Planck equations: anomalous diffusion and general thermodynamics

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Increasing interest has been shown in the subject of non-additive entropic forms during recent years, which has essentially been due to their potential applications in the area of complex systems. Based on the fact that a given entropic form should depend only on a set of probabilities, its time evolution is directly related to the evolution of these probabilities. In this talk, we discuss some basic aspects related to non-additive entropies considering their time evolution in the cases of continuous and discrete probabilities, for which nonlinear forms of Fokker-Planck and master equations are considered, respectively. For continuous probabilities, we discuss an H-theorem, which is proven by connecting functionals that appear in a nonlinear Fokker-Planck equation with a general entropic form. This theorem ensures that the stationary-state solution of the Fokker-Planck equation coincides with the equilibrium solution that emerges from the extremization of the entropic form. At equilibrium, we show that a Carnot cycle holds for a general entropic form under standard thermodynamic requirements. In the case of discrete probabilities, we also prove an H-theorem considering the time evolution of probabilities described by a master equation. The stationary-state solution that comes from the master equation is shown to coincide with the equilibrium solution that emerges from the extremization of the entropic form. The physical consequences related to the fact that the equilibrium-state distributions, which are obtained from the corresponding evolution equations (for both continuous and discrete probabilities), coincide with those obtained from the extremization of the entropic form and the restrictions for the validity of a Carnot cycle are discussed [1].

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T36. Fractional van der Pol oscillator for aeroelastic flutter

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Flutter is an important instability in aeroelasticity. In this work we derive a model for this phenomenon which can lead to an equation similar to a van der Pol oscillator [1], [2] in which the friction term is given by a fractional derivative. Motivated by these considerations we study a fractional van der Pol oscillator and show that it exhibits a Hopf bifurcation. The model is based on a one-dimensional reduction where the instabilities associated to flutter are preserved. However, due to the fractional derivative, the bifurcation analysis differs from the standard case. We present both analytical as well as numerical results and discuss the implications to aerodynamics. Additionally, we qualitatively contrast our results with experimental data [3].
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[3] Bifurcation Behavior of Airfoil Undergoing Stall Flutter Oscillations in Low-Speed Wind Tunnel 47.

T37. Invariant constitutive model for partial differential equations using fractional Caputo derivative to describe viscoelastic materials.

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A fundamental obstacle to the use of fractional constitutive models to describe the motion of linearly viscoelastic materials arises from the apparent need to redefine material derivatives in terms of parameter α. To circumvent this issue, we suggest a surrogate path that relies on the classical material derivative and the Caputo fractional derivative. This guarantees material objectivity for the proposed model as per Rivlin's results ([1][2][3][4]). Next, we illustrate an application in the form of a constitutive model where α acts as the degree of viscoelasticity of the material.
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VIDEOS

V1. Three-phase flow under gravity dominance in porous media for fluids with distinct densities

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Riemann solutions for horizontal three-phase flow (neglecting gravity) in porous media are well understood since almost 30 years, for instance see [1, 2, 3, 4, 5, 6, 7, 8, 11] among other relevant works. Near a decade ago, gravity effects were included into the models and some special cases of Riemann problems were solved for vertical three phase-flow when two of the three fluids had equal densities, see [9, 10]. In the present work we extend the study to solve a wider class of Riemann problems for the general case in which all the phases have distinct densities and the flow is essentially dominated by the gravity action. We present the structures of Riemann solutions in terms of fluid density differences. It turns out that these structures are organized around the special cases studied in [10], where two of the fluids had equal densities. The wave-curve method [8] was used to characterize the waves-structure of the Riemann Solutions. Numerical simulations through a Godunov-type finite volume scheme were performed to validate the analytical results.

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V2. Heat transfer analysis of Casson-based hybrid nanofluid flow on a stretching surface with porous heat source/sink

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Casson nanofluids are used in a variety of commercial and industrial applications, such as glues asphalts, paints, dissolved polymers, and biological solutions. Furthermore, utilizing Casson nanofluid promotes heat transfer performance. With this motivation, this study aims to analyze the influence of suction and injection in the dynamics of a Casson hybrid nanofluid in a stretching sheet numerically. The similarity converted nonlinear governing equations was determined and computed numerically. The impact of various physical parameters affecting the flow is investigated. Additionally, utilizing neural network plots and tables, the impact of different factors on the rate of heat and mass transfer as well as skin friction and

Nusselt number has been examined. For simulating the motion of Casson hybrid nanofluid (Eg-based hybrid nanofluid) via the stretching surface, the current inspection shows that ANN is the most accurate, effective, and efficient tool.

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V3. An effect of thermal radiation on Heimenz stagnation point ternarynanofluid flow with heat and mass transfer

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This analysis explores the MHD and Heimenze stagnation point influence on ternary nanofluid flow across a permeable stretching/shrinking sheet. The governing system of partial differential equations is switched into the ordinary differential equation by employing the transformation of similarity variables. A reduced differential equation is solved analytically and expressed in the form of hypergeometric and error function, the influence of MHD changes the behavior of entire flow dynamics in the stretching/shrinking case, and the significant parameters such as magnetic field, Schmidt number, radiation parameters, mass suction/injection parameters are discussed via graphically, ternary nanofluids significantly increase the thermal conductivity used in coolants for radiators due to their improved thermal performance, and adding magnetic field induce current in a moving conductive fluid which in turn generates forces on the fluid, similarly present work has many useful applications in engineering and biomedical fields.

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V4. On modeling micro-scale strain gradient elastic adhesively bonded joints

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Abstract
As a bonded structure scales down to the microscale, the role of the adhesive joint becomes more relevant concerning the overall performance of the microdevice. At the small scale, the microstructural and size-dependent properties of thin adhesive start to play a key role in the mechanical response of the layered assembly [1]. The present work focuses on the derivation of a soft imperfect interface law in a composite, constituted by two solids, separated by a thin adhesive layer in the framework of strain gradient elasticity. The model is obtained by means of the asymptotic methods. The contact laws, expressed in terms of the

jumps and means values of the displacements, normal derivatives of the displacements, represent a formal generalization of the soft elastic interface conditions [2]. The present study reveals the stiffening behaviors of layered structures and size-dependent phenomena, typical of micro-scale structures [3].

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MINICOURSES (9:00am-12:00, Thursday and Friday)

Minicourse1: Title: Basics of continuum mechanics with applications to the theory of elasticity

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Minicourse2: Title: An introduction to asymptotic homogenisation and its application to real-world biological problems

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