4-5 NOVEMBRE 2022

GIORNATE SIGNORINI

IN OCCASIONE DEL SETTANTESIMO COMPLEANNO
DEL PROF. MAURIZIO VIANELLO

DIPARTIMENTO DI INGEGNERIA
UNIVERSITA' DEGLI STUDI DI PERUGIA

Programma

Venerdì 4 Novembre

9:00–9:30	IS	**Paolo Podio-Guidugli** Accademia Nazionale dei Lincei	Alcune considerazioni sull'eredità scientifica di A. Signorini
9:30–10:15	KL	**Maurizio Vianello** Politecnico di Milano	Cauchy's Theorem: a different perspective
10:15–10:45	IS	**Angelo Morro** Università di Genova	Un nuovo approccio alle restrizioni termodinamiche per continui dissipativi
10:45–11:15	IS	**Tommaso Ruggeri** Università di Bologna ed Accademia Nazionale dei Lincei	Recent Results on Rational Extended Thermodynamics
11:15–11:45	**Pausa caffè**		
11:45–12:15	IS	**Pasquale Ciarletta** Politecnico di Milano	Transizioni morfologiche nella materia soffice ed attiva
12:15–12:45	IS	**Davide Bigoni** Università di Trento	Shear band instabilities and architected materials
12:45–13:15	IS	**Luigi Preziosi** Politecnico di Torino	Modelling cell reorientation under stretch
13:30–14:30	**Pranzo**		
14:45–15:15	IS	**Sandra Forte** Politecnico di Milano	Classi di simmetria in elasticità lineare
15:15–15:45	IS	**Michael Slawinski** Memorial University, St. John's Newfoundland, Canada	Power for the Hour
15:45–16:15	IS	**Davide Ambrosi** Politecnico di Torino	A rods model of the mitral valve
16:15–16:45	IS	**Paolo Biscari** Politecnico di Milano	Elasticità e plasticità in materiali iperelastici cristallini
16:45–17:00	**Pausa caffè**		
17:00–17:30	IS	**Luciano Teresi** Università Roma Tre	3D Morphing through Compatible Distortions
17:30–18:00	IS	**Luca Deseri** Università di Trento	Applications of the theory of structured deformations of continua
18:00–18:30	IS	**Stefano Turzi** Politecnico di Milano	Modelli matematici per la materia soffice attiva
20:00	**Cena sociale**		

Sabato 5 Novembre

9:00–9:30	IS	**Paola Nardinocchi** Università “La Sapienza”	Passive and active fiber reorientation in anisotropic materials
9:30–10:00	IS	**Jacopo Ciambella** Università “La Sapienza”	Fiber orientation and its evolution in finite inelasticity
10:00–10:30	IS	**Giuseppe Puglisi** Politecnico di Bari	Role of the temperature for decohesion phenomena in biological materials
10:30:–11:00	IS	**Alfredo Marzocchi** Università Cattolica del Sacro Cuore di Brescia	Some Analytic Features of second-gradient Fluid Motion
11:00–11:20	**Pausa caffè**		
11:20–11:50	IS	**Marco Sammartino** Università di Palermo	Interactive boundary layer theory
11:50–12:20	IS	**Lorenzo Fusi** Università di Firenze	Dynamics of Viscoplastic flows
12:20–12:50	IS	**Giuseppe Tomassetti** Università Roma Tre	Surface accretion of a pre-stretched half-space: Biot’s problem revisited
12:50–13:20	IS	**Andrea Nobili** Università di Modena e Reggio Emilia	Stroh/Hamiltonian formulation for complex media
13:30	**Pranzo**		

Partecipanti

- Davide Ambrosi (Politecnico di Torino)
- Giuseppe Bevilacqua (università di Siena)
- Davide Bigoni (Università di Trento)
- Paolo Biscari (Politecnico di Milano)
- Jacopo Ciambella (Università di Roma “La Sapienza”)
- Pasquale Ciarletta (Politecnico di Milano)
- Luca Deseri (Università di Trento)
- Domenico De Tommasi (Politecnico di Bari)
- Angiolo Farina (Università di Firenze)
- Sandra Forte (Politecnico di Milano)
- Lorenzo Fusi (Università di Firenze)
- Alfredo Marzocchi (Università Cattolica del Sacro Cuore di Brescia)
- Angelo Morro (Università di Genova)
- Gaetano Napoli (Università del Salento)
- Paola Nardinocchi (Università di Roma “La Sapienza”)
- Andrea Nobili (Università di Modena e Reggio Emilia)
- Paolo Podio Guidugli (Accademia Nazinale dei Lincei)
- Luigi Preziosi (Politecnico di Torino)
- Giuseppe Puglisi (Politecnico di Bari)
- Tommaso Ruggeri (Accademia Nazionale dei Lincei e Università di Bologna)
- Giuseppe Saccomandi (Università di Perugia)

- Marco Sammartino (Università di Palermo)
- Michael Slawinski (Memorial University, St. John’s Newfoundland, Canada)
- Luciano Teresi (Università di Roma Tre)
- Giuseppe Tomassetti (Università di Roma Tre)
- Stefano Turzi (Politecnico di Milano)
- Luigi Vergori (Università di Perugia)
- Maurizio Vianello (Politecnico di Milano)
- Giovanni Zanzotto (Università di Padova)

Seminari

Venerdì 4 Novembre

Alcune considerazioni sull'eredità scientifica di Antonio Signorini

Paolo Podio-Guidugli IS

Accademia Nazionale dei Lincei

Senza alcuna pretesa di completezza o di ordinamento gerarchico, cercherò di suggerire come certi temi di ricerca cari a Antonio Signorini siano giunti fino a noi per tramite di suoi allievi e discepoli.

Cauchy's Theorem: a different perspective

Maurizio Vianello KL

Politecnico di Milano

A "known" but not so "well known" point of view about the Cauchy stress tensor, which is somewhat alternative to the most standard approach, greatly simplifies the proof of Cauchy's Theorem on a surface. The extension to the three dimensional context, which goes back to some observations by Brillouin and Marsden (and maybe earlier) and was later further developed by Segev, is based on the stress vector viewed as a vector valued two-form, rather than as a function of the unit normal. This will be presented for discussion and scrutiny in the continuum mechanics community.

Un nuovo approccio alle restrizioni termodinamiche per continui dissipativi

Angelo Morro IS

Università di Genova

Partendo dalla formulazione e dal metodo di Coleman e Noll, si considerano metodi ed esempi di deduzione di restrizioni, su equazioni costitutive, imposte dalla seconda legge della termodinamica. Si ricordano le modifiche concettuali successive di Müller, sul flusso di entropia, e di Green e Naghdi, sulla produzione di entropia. Si riguarda la produzione di entropia come funzione costitutiva e si mostra una formula di rappresentazione per le conseguenti restrizioni. Si considerano due esempi: solidi deformabili dissipativi e solidi elasto-plastici. Nel primo esempio seguono come casi particolari i solidi iperelastici e i solidi ipoelastici. Nel secondo si perviene alla descrizione dei cicli di isteresi.

Recent Results on Rational Extended Thermodynamics

Tommaso Ruggeri IS

Università di Bologna ed Accademia Nazionale dei Lincei

In this talk, some recent results of Rational Extended Thermodynamics both in the classical and relativistic framework are presented. In particular, the problem in which the relaxation times for internal states are different and the relativistic case of polyatomic gases, including its classical limit, are discussed. Finally, some thermodynamic aspects of similarity between gas mixtures and flocking and synchronization are studied.

[1] Ruggeri T., Sugiyama M.: Classical and Relativistic Rational Extended Thermodynamics of Gases; Springer: Cham (2021).

[2] Arima T., Carrisi M.C., Pennisi S., Ruggeri, T.: Relativistic Rational Extended Thermodynamics of Polyatomic Gases with a New Hierarchy of Moments. Entropy, 24(1), 43 (2022).

[3] Ha S.-Y., Ruggeri, T.: Emergent dynamics of a thermodynamically consistent particle model, Arch. Ration Mech. Anal., 223:1397–1425, (2017).

[4] Ha S.-Y., Park H., Ruggeri T., Shim W.: Emergent behaviors of thermodynamic Kuramoto ensemble on a ring lattice. J. of Stat. Phys. 02611-2 (2020).

Power for the Hour

Michael Slawinski IS

Memorial University, St. John's Newfoundland, Canada

In certain sports, records can be viewed as a symbiosis of athletic ability and scientific thought. The bicycle hour record is a case in point. Herein, to estimate the power needed to set an hour record, we invoke classical mechanics and examine quantities that allow us to optimise the attempt. An empirical adequacy of a proposed model relies on including all pertinent aspects, while its pragmatic simplicity requires that negligible effects be ignored. Furthermore, a phenomenological model is not derived from first principles; hence, it needs an experimental validation. Since the most recent hour record has been set based on our model, we present it within that context.

Shear band instabilities and architected materials

Davide Bigoni

IS

Università di Trento

Shear bands are local instabilities, ubiquitously observed in ductile materials to strongly affect their failure. Therefore, modelling of shear band formation and growth provides a fundamental understanding of the intimate behaviour of failure and can be used in the design of materials displaying superior mechanical properties. The perturbative approach to shear bands [1-3] will be introduced and applied in particular to the case in which a dispersion of thin rigid inclusions (lamellae) is present inside a metallic matrix material [4-5]. Results on shear bands are shown to be related to instabilities of architected materials made up of linear elastic rods, prestressed with axial force. A rigorous application of homogenization theory shows that the inclusion of sliders in a grid of rods leads to loss of ellipticity in tension, so that the locus for material instability becomes bounded. This result explains: (*i.*) how to design elastic materials passible of localization of deformation and shear banding for all radial stress paths; (*ii.*) how for all these paths a material may fail by developing strain localization and without involving cracking [6, 7]. Finally, inclusion of follower microforces is shown to lead to materials elastic, but not hyperelastic [8].

Acknowledgements - Finanical support from ERC-ADG-2021-101052956-BEYOND is gratefully acknowledged.

References

[1] Bigoni D. and Capuani, D. (2002) Green's function for incremental nonlinear elasticity: shear bands and boundary integral formulation. J. Mech. Phys. Solids, 50, 471–500.

[2] Bigoni D. and Capuani, D. (2005) Time-harmonic Green's function and boundary integral formulation for incremental nonlinear elasticity: dynamics of wave patterns and shear bands. J. Mech. Phys. Solids, 53, 1163–1187.

[3] Giarola, D., Capuani, D., Bigoni, D. (2018) The dynamics of a shear band. J. Mech. Phys. Solids, 112, 472–490.

[4] Dal Corso, F. and Bigoni, D. (2009) The interactions between shear bands and rigid lamellar inclusions in a ductile metal matrix. Proc. Royal Society A, 465, 143–163.

[5] Giarola, D., Dal Corso, F., Capuani, D., Bigoni, D. (2022) Interactions between multiple rigid lamellae in a ductile metal matrix: shear band magnification and attenuation in localization patterns. J. Mech. Phys. Solids, in press.

[6] Bordiga, G., Cabras, L., Piccolroaz, A., Bigoni, D. (2021) Dynamics of prestressed elastic lattices: Homogenization, instabilities, and strain localization. J. Mech. Phys. Solids, 146, 104198.

[7] Bordiga, G., Bigoni, D., Piccolroaz, A. (2022) Tensile material instabilities in elastic beam lattices lead to a bounded stability domain. Phil. Trans. Royal Soc. A, 380, 20210388.

[8] Bordiga, G., Piccolroaz, A., Bigoni, D. (2022) A way to hypo-elastic artificial materials without a strain potential and displaying flutter instability. J. Mech. Phys. Solids, 158, 104665.

Modelling Cell reorientation under stretch

Luigi Preziosi IS

Politecnico di Torino

The active response of cells to mechanical cues due to their interaction with the environment has been of increasing interest, since it is involved in many physiological phenomena, pathologies, and in tissue engineering. In particular, several experiments have shown that, if a substrate with overlying cells is cyclically stretched, they will reorient to reach a well-defined angle between their major axis and the main stretching direction. The aim of this talk will be to investigate the interplay between mechanics and cell organization. It will be shown that cells organise their internal structure to minimize an elastic energy that then drives this reorientation process. Viscoelastic effects will then be included to explain the dependence of the appearance of the phenomenon as a function of oscillation frequency. Finally, randomness is taken into account and discussed on the basis of a Fokker-Plack equation.

Classi di simmetria in elasticità lineare

Sandra Forte IS

Politecnico di Milano

In queste giornate dedicate a Maurizio Vianello, parlerò di uno dei suoi lavori più citati, “Symmetry classes for elasticity tensors”, Forte - Vianello, (1996). Attraverso tecniche della teoria delle rappresentazioni dei gruppi, sporadicamente utilizzate in precedenza nell’ambito della meccanica dei continui, è stata data una risposta definitiva all’antico problema circa quali e quante siano le possibili simmetrie elastiche. Questo lavoro ha dato un forte impulso a numerose ricerche, anche attuali, volte soprattutto al riconoscimento della classe di simmetria di un assegnato materiale.

Transizioni morfologiche nella materia soffice ed attiva

Pasquale Ciarletta IS

Politecnico di Milano

In questo intervento discuterò modelli fisico-matematici e strumenti numerici per studiare l’emergenza di pattern in sistemi multifisici, con applicazioni che vanno dalla meccano-biologia alla fabbricazione digitale. Si evidenzierà come alcune transizioni topologiche non convenzionali che si osservano nella materia soffice ed attiva siano controllate dalla mutua interazione di nonlinearità, non-convessità e non-località nei relativi modelli differenziali alle derivate parziali.

A rods model of the mitral valve

Davide Ambrosi IS

Politecnico di Torino

A mitral valve can, in a first approximation, be represented as a mechanical system composed by two rods that bend under the action of a pressure difference; they have one fixed endpoint and are partially in contact. We obtain the balance equations of the mechanical system exploiting the principle of virtual work and the contact point is identified by a jump condition. The problem can be simplified exploiting a first integral. In the case of quadratic energy, another first integral exists: its peculiarity is discussed and a further reduction of the equations is carried out. Numerical integration of the differential system shows how the shape of the beams and the position of the contact point depend on the applied pressure. For small pressure, an asymptotic expansion in a small parameter allows to find an approximate solutions of polynomial form which is in surprisingly good agreement with the solution of the original system of equations, even beyond the expected range of validity. Finally, the asymptotics predicts a value of the pressure that separates the contact from the no-contact regime of the beams that compares very well with the one numerically evaluated.
The chordae tendineae are then modelled as a force applied to the free endpoint of the flaps. Different possible boundary conditions are investigated at the mitral annulus and, by an asymptotic analysis, we demonstrate that in the pressure regime of interest generic boundary conditions generate a tensional boundary layer. Conversely, a specific choice of the boundary condition inhibits the generation of high tensional gradients in a small layer.

Elasticità e plasticità in materiali iperelastici cristallini

Paolo Biscari IS

Politecnico di Milano

La simmetria materiale $\mathrm{GL}(n, \mathbb{Z})$ che caratterizza i solidi cristallini impone la costruzione di un'energia elastica che soddisfi gli opportuni requisiti di periodicità.
In 2D le funzioni modulari consentono di ricavare esplicitamente espressioni analitiche sia per lo studio del flusso plastico di materiali dotati di un unico reticolo cristallino stabile, che delle transizioni solido-solido di materiali con più reticoli stabili, come le leghe a memoria di forma.
Si presenteranno e discuteranno i risultati di simulazioni numeriche, che mostrano gli effetti tipici osservati sperimentalmente in questi casi, come l'intermittenza, la creazione e l'annichilazione di dislocazioni.

3D Morphing through Compatible Distortions

Luciano Teresi

IS

Università Roma Tre

We study the morphing of 3D solids within the framework of non-linear elasticity with large distortions. In this work, we explore the possibility of deforming elastic 3D bodies through distortions with the aim of proposing a blueprint for the characterization of compatible metric tensors to which there correspond a sought shape transformation, that is a 3D morphing towards a target shape having zero stress. Shape-morphing has been used as modeling tools to the study of biological growth [1], and the morphing of 2D bodies has been extensively studied in the recent decade, both from the theoretical point of view [2, 3], and from the point of view of morphing design [4].
We support that morphing through compatible distortions is a key strategy exploited by nature, enabling living organisms to perform vital tasks such as change shape, move, adapt to the environment [5]. Design of morphing is now at the core of many applications, and our work investigates about the possibility of designing stress-free morphing for 3D bodies, following [6, 7].

References

[1] A. Goriely, The Mathematics and Mechanics of Biological Growth 45, Springer, (2017).

[2] D. Grossman, E. Sharon, and E. Katzav, Shape and fluctuations of positively curved ribbons, Phys. Rev. E, 98(2) 022502, 2018.

[3] M. A. Dias, B. Audoly, "Wunderlich, Meet Kirchhoff": A General and Unified Description of Elastic Ribbons and Thin Rods, Journal of Elasticity, 119, 1-2, 49 (2015).

[4] C. Modes, and M. Warner, Shape-programmable materials, Physics today 69, 32 (2016).

[5] S. Armon, E. Efrati, R. Kupferman, and E. Sharon, Geometry and mechanics in the opening of chiral seed pods, Science 333, 1726 (2011).

[6] P. Nardinocchi, L. Teresi, and V. Varano, Strain induced shape formation in fibred cylindrical tubes, Journal of the Mechanics and Physics of Solids, 60(8), 1420–1431 (2012).

[7] I. Colorado Cervantes, V. Varano, and L .Teresi, Stress-free morphing by means of compatible distortions, PHYSICAL REVIEW E 106, (2022).

Applications of the theory of structured deformations of continua: the case of receptors clustering on lipid rafts during ligand binding across the cell membrane

Luca Deseri

IS

Università di Trento

The multiscale geometric framework provided by the theory of Structured Deformations (see e.g. [1,2,3,4,5]) is utilized to predict the submacroscopic rearrangements and the deformation occurring in the cell membrane during receptor clustering on lipid rafts induced by ligand binding across the cell membrane. Here, each material particle of the cell membrane in the virgin configuration is first mapped into an active reference configuration through a pair of smooth bijections (i, K), where i is the vector-valued identity and the tensor K accounts for all the submacroscopic changes. Secondly, each location in the latter configuration gets classically deformed through a pair $(y, \nabla y)$, where y is a smooth deformation field mapping the reference configuration onto the current one, and where ∇y is its gradient.

Clustering of receptors on lipids rafts across the cell membrane during ligand-binding is an experimentally noted phenomenon (see e.g. [6, 7] among many others). Various explanations of such phenomenon and its influence on the cell's response have been proposed in the literature, although the role of the coupling between mechanical processes and multi-physics involving the active receptors and the surrounding lipid membrane during ligand binding has not yet been understood. The focus of this work is on G-Protein-Coupled Receptors (GPCRs), well known ubiquitous transmembrane proteins. GPCRs are known to regulate cell processes through signaling pathways. Those turn out to involve a synergistic balance between the cyclic Adenosine Monophosphate (cAMP) produced in the intracellular environment and its efflux, mediated by Multidrug Resistance Proteins (MRPs) (see e.g. [8] among many others). It is worth noting that GPCRs may be relevant for clinical targeting in several diseases, including cancer. Henceforth, predicting receptors activity associated with the remodeling, here characterized by det K, of the cell membrane may helpfully support quantitative diagnostics, by potentially conceiving new cAMP-based markers for discriminating cells from their membrane activity.

A multiphysics approach is developed in this collaborative work with the University of Napoli-Federico II and others, and preliminary results are published in [9]. This work features the chemo-mechanical principles leading active GPCRs to likely cluster on lipid rafts across the cell membrane. The proposed model is based on the interplay among entropic, conformational and membrane strain energy, diffusion and kinetics of binding and unbinding. The latter is regulated by the chemical potential associated to conformations and transport of transmembrane domains inhabited by active GPCRs and MRPs, which exchange lateral pressure while interacting with the surrounding lipids. In [9] it is shown how the mechanobiology involved in the remodeling of the cell membrane allows for motivating from a strong mechanical perspective the correspondence found between lipid rafts formation and the activity of ligand-binding receptors, in agreement with the experimentally observed cAMP levels.

References

[1] Deseri L, Owen DR, 2003. Toward a field theory for elastic bodies undergoing disarrangements. J. Elasticity **70** (I) 197-236.

[2] Deseri L, Owen DR, 2015. Stable disarrangement phases arising from expansion/contraction or from simple shearing of a model granular medium. Int. J. Eng. Sci. **96** (96) 111-130.

[3] Palumbo S, Deseri L, Owen DR, Fraldi M, 2018. Disarrangements and instabilities in augmented one-dimensional hyperelasticity. Proc. R. Soc. A **474** (2218) 149–182.

[4] Deseri L, Owen DR, 2019. Elasticity with hierarchical disarrangements: a field theory that admits slips and separations at multiple submacroscopic levels. J. Elast. **135** (1-2) 149-182.

[5] Palumbo S, Carotenuto AR, Cutolo A, Owen DR, Deseri L, Fraldi M, 2021. Bulky auxeticity, tensile buckling and deck-of-cards kinematics emerging from structured continua, Proc. R. Soc. A **477**:20200729.

[6] L. Bridge, M. D. Levin, and C. J. Morton-Firth, 1998. Receptor clustering as a cellular mechanism to control sensitivity, Nature **393** 85–88.

[7] E. Watkins, C. Miller, J. Majewski, and T. Kuhl, 2011. Membrane texture induced by specific protein binding and receptor clustering: active roles for lipids in cellular function. Proceedings of the National Academy of Sciences **108** (17) 6975-6980.

[8] Biondi C, Ferretti ME, Lunghi L, Medici S, Cervellati F, Pavan B, Vesce F, Morano D, Adinolfi E, Bertoni F, Abelli L, 2010. cAMP efflux from human trophoblast cell lines: a role for multidrug resistance protein (MRP) 1 transporter. Molecolar Human Reprod. **16** (7), 481-491.

[9] Carotenuto AR, Lunghi L, Piccolo V, Babaei M, Dayal K, Pugno NM, Zingales M, Deseri L, Fraldi M, 2020. Mechanobiology predicts raft formations triggered by ligand-receptor activity across the cell membrane, J. Mech. Physics of Solids, **141** 103974.

Modelli matematici per la materia soffice attiva

Stefano Turzi IS

Politecnico di Milano

In questo seminario mostriamo come la teoria degli elastomeri nematici possa essere un proficuo paradigma di modellazione per altri materiali con proprietà macroscopiche solo lontanamente collegate all'elasticità. Tramite il disaccoppiamento dei gradi di libertà macroscopici e microscopici, attraverso una decomposizione del gradiente di deformazione, si riescono a descrivere proprietà di riorganizzazione materiale ed effetti viscoelastici. Quando i tempi di rilassamento sono molto più rapidi dei tempi di deformazione, ritroviamo la teoria dei cristalli liquidi nematici (Ericksen-Leslie). Questo ci permette di spiegare alcune proprietà della propagazione acustica nei cristalli liquidi nematici, in cui emergono caratteristiche sia cristalline che fluide. A livello intermedio, recuperiamo la dinamica dei polimeri e il comportamento viscoelastico. Infine, questa teoria fornisce anche un quadro di modellazione per i gel nematici attivi. A differenza delle teorie standard, l'attività non è introdotta come termine aggiuntivo del tensore degli sforzi, ma viene introdotta come una forza esterna di rimodellamento che compete con la dinamica passiva di rilassamento e trascina il sistema fuori dall'equilibrio. Gli effetti viscoelastici e la dinamica dei difetti tipici dei materiali biologicamente attivi, sono naturalmente descritti dalla teoria. Inoltre mostriamo, attraverso un'analisi di biforcazione equivariante, che il flusso spontaneo di particelle attive in un canale ha caratteristiche universali che dipendono esclusivamente dalle simmetrie del problema.

Sabato 5 Novembre

Passive and active fiber reorientation in anisotropic materials

Paola Nardinocchi IS

Università "La Sapienza"

Fiber orientation in active and fiber reinforced material may evolve with time, under the influence of appropriate external stimuli. In this talk, I will present a continuum model to describe the reorientation of an anisotropic material structure, characterized by one or two fiber families able to modify their orientations following different evolution dynamics.
Kinematics of the body is described by both a position vector and one or two remodelling tensors that represents the reorientation process of the anisotropic material structure. By using suitable thermodynamical restrictions on the constitutive equations, the appropriate evolution equations of the remodelling tensors governed by Eshelby torques are obtained. A study of the stationary solutions is presented and discussed, in absence of any external source terms.

Fiber orientation and its evolution in finite inelasticity

Jacopo Ciambella IS

Università "La Sapienza"

In this talk a model for the mechanical response of anisotropic soft materials undergoing large inelastic deformations is presented. The material is consid- ered made by a isotropic matrix with embedded fibres, each component having its own relaxation dynamics. The constitutive equations are provided in terms of the free energy density and the dissipation density, which are both required to be thermodynamically consistent and structural frame-indifferent, i.e., in- dependent of a rotation overimposed on the intermediate natural state of both matrix and fibers. This is in contrast to many of the currently used anisotropic inelastic models, which do not deal with the lack of uniqueness of the inter- mediate state. This issue is thoroughly discussed and in terms of two possible choices satisfying structural-frame indifference and leading to different flow rules of the inelastic processes.

References

[1] Ciambella, J., Nardinocchi, P. (2022). Non-affine fiber reorientation in finite inelasticity. http://arxiv.org/abs/2207.10904

[2] Ciambella, J., Nardinocchi, P. (2021). A structurally frame-indifferent model for anisotropic visco-hyperelastic materials. Journal of the Mechanics and Physics of Solids, 147(September), 104247. https://doi.org/10.1016/j.jmps.2020.104247

Role of the temperature for decohesion phenomena in biological materials

Giuseppe Puglisi IS

Politecnico di Bari

The thermomechanical response of biological materials, often unattained by artificial applications, is typically the results of complex, multiscale structures. Particularly interesting, both from a biological and biomedical point of view, and in the perspective of the design of new bioinspired materials, is the observation that the notable macroscopic properties are often the results of a wise, diffuse interaction of very weak bonsd assembled in clever hierarchical structures. The correct analysis and prediction of such materials is than intrinsically multiscale. Based on classical instrument of Statistical Mechanics we derive analytical models for the thermomechaqnical behavior of these materials at the micro and meso scales, where entropic energetic contributions compete with enthalpies ones. We then apply classical methods of rubber elasticity for deducing the macroscopic constitutive laws with damage, permanent deformations, hysteresis, rate and temperature dependence,directly deduced from the micro and meso scale properties and distributions. In the talk, explicit examples of highly performant biological materials will be delivered.

Some Analytic Features of second-gradient Fluid Motion

Alfredo Marzocchi IS

Università Cattolica del Sacro Cuore di Brescia

Second gradient fluids (which are different from second grade fluids) are fluids in which the total power expenditure depends on the second derivatives of the velocity field. They are used in a variety of models, from numerical analysis to complex fluid mechanics. Indeed, they are not just a model. Well, yes, they are, but in some sense they represent the simplest generalisation of a simple fluid, and also in the linear case they can be useful to describe some peculiar solutions like flows in thin structures. We will discuss pros and cons of this model and see some analytical results.

Interactive boundary layer theory

Marco Sammartino IS

Università di Palermo

The main aim of this talk is to give a mathematical justification of the interactive boundary layer theory. In the first part of the talk, we shall discuss the behavior of the Navier-Stokes solutions for a high Reynolds number flow interacting with a boundary. To describe these flows, one usually introduces the boundary layer and the Prandtl equations that do not allow the interaction between the BL and the outer flow. This imposes severe limitations on the theory that ultimately lead to the lack of a sound description of the transition phenomena occurring close to the boundary. In the second part, we shall describe a different asymptotic approach that seems able to overcome the above-described difficulties. The well-posedness of the resulting equations in the analytic setting is the main result of the talk.

Dynamics of Viscoplastic flows

Lorenzo Fusi IS

Università di Firenze

Viscoplastic models are based on constitutive laws for which there exists a threshold for the stress below which the symmetric part of the velocity gradient is null. In other words, below the threshold, the continuum behaves as a rigid body. It is known that some properties of viscoplastic fluids are not recovered if, instead of considering the exact viscoplastic law, one considers regularized models that mimics the viscplastic behavior and that tend to the exact viscoplastic relation when the regularizing parameter tends to infinity. Here, we propose a comparison between the classical Bingham model and a regularized model which mimics the viscoplastic response (Papanastasiou model). Using these two models we study the steady, fully developed flow in a symmetric channel characterized by a small aspect ratio. We obtain an analytical solution for both velocity profiles. We compare the yield surfaces of the Bingham model with the level set of the second stress invariant corresponding to the Bingham yield stress. The two surfaces coincide when the channel walls are flat, but they are markedly different when the channel walls are curved.

Surface accretion of a pre-stretched half-space: Biot's problem revisited

Giuseppe Tomassetti IS

Università Roma Tre

Motivated by experiments on dendritic actin networks exhibiting surface growth, we address the problem of the stability of this growth process. We choose as a simple, reference geometry a biaxially stressed half-space growing at its boundary. The actin network is modeled as a neo-Hookean material. A kinetic relation between growth velocity and a stress-dependent driving force for growth is utilized. The stability problem is formulated and results are discussed for different loading and boundary conditions, with and without surface tension. Connections are drawn with Biot's 1963 surface instability threshold.

Stroh/Hamiltonian formulation for complex media

Andrea Nobili

IS

Università di Modena e Reggio Emilia

It is perhaps not widely known that the celebrated Stroh formalism owns its outstanding structure to the fact that it represents the canonical form of the governing equations, once any space variable is treated in the fashion a time variable would when moving from the Lagrangian to the Hamiltonian formalism. Generally, in this process, the selected space variable represents the direction of propagation of waves and accordingly the new formalism is especially suited to investigate this kind of problems. More importantly, the Hamiltonian structure brings over a number of closure relations which would be very difficult to determine from the standard formulation. In this communication, we show how the equations governing complex media can be brought in Hamiltonian form. Instead of putting in guesswork, we adopt the systematic derivation of the Hamiltonian formalism and this will help us identify the correct conjugate momenta which lend the problem its canonical form. For couple stress media, which are constrained second gradient elastic materials, the resulting canonical formalism appears in the form of a Differential Algebraic system of Equations (DAE). This is then recast in a 7-dimensional coupled linear system of differential equations. The antiplane problem is especially interesting, for it shows remarkable similarity with the theory of anisotropic plates. Yet, unlike for plates, a classical Stroh formulation cannot be obtained, owing to the difference in the constitutive assumptions. This notwithstanding, the canonical formalism brings a fresh insight into the problem's structure and emphasizes important symmetry properties.