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# Book of Abstracts - Extract
# 2015

UNIVERSITÀ DEL SALENTO

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# Scientific Program - Timetable

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# GAMM 2015

Università del Salento

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## PLL: Plenary Lectures

Plenary Lectures

# On the Motion of a Rigid Body with a Liquid-filled Cavity

Giovanni P. Galdi
Department of Mechanical Engineering and Materials Science, University of Pittsburgh, USA

Let $\mathcal{S}$ be the coupled system constituted by a rigid body with an interior cavity completely filled with a viscous liquid. In this talk I shall present a number of analytical results concerning the motion of $\mathcal{S}$ around its center of mass, with or without the action of external forces. In particular, I show that the presence or absence of the liquid in the cavity can dramatically affect the ultimate dynamics of $\mathcal{S}$. I will also present suitable numerical tests that, on the one hand, corroborate the mathematical analysis and, on the other hand, pose new questions that lay the foundations for future analytic work.

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# Micromechanics based modeling of applied materials

Thomas Böhlke
Chair for Continuum Mechanics, Karlsruhe Institute of Technology (KIT)

Nowadays, micromechanical approaches and homogenization techniques are standard research methods in mechanical engineering and materials science. This is due to the increased computer capabilities and the better characterization techniques for both the material microstructures and the micro-constitutive behavior. In contrast to phenomenological approaches, homogenization techniques allow to take into account the material microstructures and the resulting fluctuations in the stress and deformation fields. From the perspective of applied mechanics, crucial issues are the ability of the scale bridging methods to reproduce experimental data and to be applied in fully coupled two-scale simulations. Additionally, the accessibility of necessary microstructure and material data and the applicability of standard software tools are of importance. In the talk, different types of materials are considered, and the aforementioned issues are addressed.

In the first part of the presentation, fiber reinforced polymers (FRP) are considered. These structures are increasingly used for different kinds of applications. A robust dimensioning of light-weight structures made of these materials is still a challenging task. FRP show heterogeneities with respect to micro-structural properties like the fiber volume fraction and the fiber length as well as the orientation distributions. As an example, the microstructure of injection-molded specimens made of polypropylene reinforced with 30wt% of short glass fibers (PPFG30) is modeled based on micro-computer tomography data. The elastic and the thermoelastic properties are predicted based on different mean field approaches. The estimates are evaluated with macroscopic testing data. Additionally, the mechanical properties of long fiber reinforced thermoplastics which depend on the heterogeneous fiber orientation distribution induced through manufacturing on a direct LFT line, are predicted for compression molded rectangular plates. Fiber orientation tensors based on measured micro-computed tomography data of selected samples as well as on filling simulations are used for the determination of mechanical properties. The results are evaluated with dynamic mechanical analysis measurements.

In the second part of the presentation micromechanics is applied to metals. As an example, automotive dual-phase steels are modeled. Within the Hashin-Shtrikman mean-field approach, the load-transfer from ferrite to martensite is captured based on simple microstructural characteristics in a physically motivated manner. The employed Estrin-Kocks-Mecking constituent models are built on a combination of the work of Ashby on geometrically-necessary dislocations, and the Mughrabi theory on long-range stresses. The proposed model is able to quantitatively predict the average macroscopic and microscopic stress-strain behavior as well as the long-range stress magnitude for the measured dual-phase steel. Finally, a gradient crystal plasticity model is presented which incorporates some of the recent developments in gradient plasticity, such as grain boundary yield conditions which are of significant importance to reproduce size effects of grain structures. Additionally, a gradient crystal plasticity framework is extended by taking into account the continuous dislocation density and curvature fields obtained by homogenization of discrete dislocation structures. Thereby, a dislocation based gradient plasticity framework is established that takes into account dislocation transport.

# Optimal placement of sensors and actuators for waves in homogeneous and heterogeneous media

Enrique Zuazua
BCAM & Ikerbasque - Bilbao - Basque Country - Spain

In this lecture we discuss some problems related to wave control, observation and numerical approximation.

We shall mainly focus on the problem of the optimal placement of sensors and actuators for wave propagation, that will be recast as spectral optimal design problems.

We show that, depending on the complexity of the data to be observed/controlled, several scenarios have to be distinguished and, in particular, those in which the solution is a classical set constituted by a finite number of simply connected subdomains, Cantor type sets and those leading to relaxation phenomena.

We also explain how closely this topic is related to the fine properties of the high frequency behavior of the eigenfunctions of the laplacian, which is intimately linked to the ergodicity properties of the dynamical system generated by the corresponding billiard.

We then discuss numerical approximation issues, emphasizing the unexpected spurious effects that heterogenous grids may have on the propagation properties of numerical waves.

This talk will be inspired in recent joint work with, in particular, Y. Privat and E. TrÃ©lat (LJLL-Paris VI), S. Ervedoza (Toulouse) and A. Marica (Bucharest).

# Particle methods for complex flows of complex fluids

Nikolaus A. Adams, Xiangyu Hu, Stefan Adami
Technische Universität München
Institute of Aerodynamics and Fluid Mechanics
Boltzmannstrasse 15
85748 Garching
Germany

In this contribution we will review the state of the art of Lagrangian particle discretizations of the Navier-Stokes equations. We will focus on low-Mach-number flows and consider mainly the Smoothed-Particle-Hydrodynamics (SPH) approach. We will show that the weakly-compressible formulation of SPH under certain constraints provides a reliable approach for the approximate solution of incompressible single- and multi-phase flows, and how it can be extended for monolithic fluid-structure interaction and modeling of free-surface flows. Limitations of standard formulations of SPH will be discussed, and we will derive conditions under which high-order convergence of the formally zero-order consistent conservative SPH discretizations can be achieved. The recently derived transport-velocity formulation will be motivated and explained, and related to the conditions for effective high-order consistency. We will demonstrate that with the transport-velocity formulation SPH delivers reliable results for classical flow problems of similar quality as can be obtained by grid-based methods. Unlike grid-based methods, however, SPH can deal with physically very complex multi-phase flows as it maintains inherently discrete mass and momentum conservation. We will conclude in showing how SPH can be converted to a mesoscopic model for microfluidic simulations, a variant which is called Smoothed Dissipative Particle Dynamics (SDPD) and what kind of numerical issues are faced with this approach. Finally we will demonstrate that state-of-the-art SPH has the capability to serve as reliable tool for industrial applications.

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# Nonlinear optimal control for airborne wind energy systems

Moritz Diehl, Greg Horn, and Mario Zanon
Systems Control and Optimization Laboratory
IMTEK, University of Freiburg and
ESAT-STADIUS, University of Leuven

Airborne wind energy (AWE) [1], is an emerging technology to harvest power from the strong and consistent winds in altitudes between 200 and 600 meters. AWE systems consist of fast flying wings that are anchored to the ground by a tether, and an electrical generator converting the wing's motion into usable power. One can distinguish two ways to generate electricity, one using a ground-based generator and a periodic reel-out and reel-in of the tether, the other using small wind turbines on-board the flying wing. In both cases, the motion of the wing in the windfield is a strongly nonlinear and unstable process that requires advanced control and estimation technology. In this talk, we first outline the physical background of the technology and then discuss the differential-algebraic equation (DAE) models describing the dynamics of AWE systems. We then show how state-of-the-art direct methods for nonlinear optimal control - that are available in the open-source software packages CasADi [2] and ACADO [3] - can be used to answer relevant questions such as which periodic orbits are power optimal or which system topology is best [6], and help to generate model-based predictive controllers that use fast online optimization in order to generate an approximation to optimal feedback controls [4, 5].

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# Shape memory alloys: from recent modeling proposals to cardiovascular device simulations

F. Auricchio

Dipartimento di Ingegneria Civile e Architettura, Università di Pavia, Italy

The present contribution wishes to address several aspects related to shape-memory alloy (SMA) materials and structures, with a final emphasis on the use of such tools for the simulations of stent cardiovascular devices. In particular, we plan to:

- review some recent 3D constitutive model developments (with models taking into account with different level of accuracy several physical phenomena, e.g., martensite reorientation, different kinetics between forward/reverse phase transformations, smooth thermo-mechanical response, low- stress phase transformations, transformation-dependent elastic properties) and their numerical treatment (for the more complex models through the use of Fischer-Burmeister complementarity conditions) to predict experimental results on spring-like actuators [1]
- explore the use of simpler constitutive models to capture the response of geometrically complex biomedical devices like self-expandable cardiovascular stents in the large deformation regime, with particular attention to a correct modeling of buckling phenomena [2]
- investigate the extension of Dang Van high cycle fatigue criterion to SMAs and its application to uniaxial experimental data taken from the literature with the final goal of approaching the development of a general multiaxial SMA failure criterion [3]

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# Low-rank techniques for high-dimensional problems in engineering and data-analysis

Daniel Kressner
EPF Lausanne, Switzerland

The last few years have seen a quite some activity in the development of low-rank matrix and tensor approximation techniques for addressing high-dimensional computational tasks arising from engineering and data analysis. These developments have resulted in new algorithms capable of solving linear algebra problems whose sheer size renders the use of traditional approaches infeasible. The aim of this talk is to give a survey of this exciting research direction and point out the many challenging questions that remain.

The basic idea of low-rank techniques is to formally consider a regular discretization, for example of a $d$-dimensional partial differential equations. As $d$ increases, the number of degrees of freedom grow exponentially, which implies an excessive cost of standard methods for computing the solution. To address this issue, the solution is approximated on a manifold of much lower dimension. Low-rank matrix and tensor decompositions constitute such manifolds that appear to be very well suited for this purpose, often resulting in highly accurate approximations at a much lower cost. This will be illustrated for a variety of high-dimensional situations, including high-dimensional partial differential equations, parameter-dependent and stochastic equations, as well as applications in data analysis.

# Interfacial energy and size effects in evolving martensitic microstructures

Stanisław Stupkiewicz
Institute of Fundamental Technological Research (IPPT), Warsaw, Poland

Shape memory alloys (SMA) exhibit unusual effects, such as pseudoelasticity and shape memory effect, which are utilized in many advanced practical applications. These effects are associated with martensitic phase transformation that can be induced by temperature changes or mechanical loading. At the microscale, the transformation proceeds by formation and evolution of complex martensitic microstructures at multiple length scales. Understanding these multiscale phenomena is crucial for development of reliable predictive models of SMA behaviour. Significant research efforts have thus been spent in the last two decades on micromechanical modelling of shape memory alloys, martensitic microstructures, and related phenomena.

Evolution of martensitic microstructures is associated with formation and propagation of interfaces at multiple scales. It is well known that size effects are governed by size-dependent interfacial energy contributions. Modelling of size effects in SMA requires thus consideration of the interfacial energy contributions at various scales of martensitic microstructures. For that purpose, an incremental energy minimization framework has been recently developed [1, 2] in which interfacial energy is assumed to contribute both to the free energy and to the dissipated energy. Related applications include modelling of grain-size effects in pseudoelastic polycrystalline SMA [2, 3] and a study of stability of equilibrium of evolving laminates [4]. In the latter work, it has been shown that a homogenized phase-transforming laminate with no length scale exhibits a localization instability. However, for a laminate of finite spacing, its evolution is stabilized by the elastic micro-strain energy at the boundary of the localization zone.

Interfacial energy of austenite–twinned martensite interfaces constitutes an essential input to the modelling of size effects such as that discussed above. An interface between austenite and twinned martensite is a typical example of a microstructured interface where the local incompatibility of transformation strains is accommodated by elastic micro-strains in a thin transition layer along the interface. The associated interfacial energy of elastic micro-strains is a bulk energy at a suitably fine scale, and it is interpreted as an interfacial energy at a higher scale. This corresponds to a kind of scale transition. Importantly, this interfacial energy cannot be measured directly so that theoretical predictions seem to be the only alternative. A suitable micromechanical sharp-interface framework has been developed in [5, 6, 7]. Currently, we are studying a related class of problems using the phase-field (diffuse-interface) approach. Preliminary results of the phase-field modelling confirm the main findings of our earlier sharp-interface modelling.

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