TIME TABLE

TIME	Monday	Tuesday	Wednesday	Thursday	Friday
	July 17	July 18	July 19	July 20	July 21
09.00 - 09.45	Registration	Hackl	De Lorenzis	Stainier	Stainier
09.45 - 10.30	Hackl	Hackl	De Lorenzis	Stainier	Stainier
11.00 - 11.45	Hackl	Friedrich	Knees	Govindjee	Govindjee
11.45 - 12.30	Hackl	Friedrich	Knees	Govindjee	Govindjee
14.00 - 14.45	Friedrich	De Lorenzis	De Lorenzis	Stainier	
14.45 - 15.30	Friedrich	De Lorenzis	De Lorenzis	Stainier	
16.00 - 16.45	Friedrich	Knees	Knees	Govindjee	
16.45 - 17.30	Friedrich	Knees	Knees	Govindjee	
18.00	Welcome aperitif				

ADMISSION AND ACCOMMODATION

The course is offered in a hybrid format giving the possibility to attend the course also by remote (on Microsoft Teams platform). On-site places are limited and assigned on first come first served basis.
The registration fees are:

- **On-site participation, 600.00 Euro + VAT***

This fee includes a complimentary bag, five fixed menu buffet lunches, hot beverages, downloadable lecture notes.
Deadline for on-site application is June 17, 2023.

- **Online participation, 250.00 Euro + VAT***

This fee includes downloadable lecture notes.
Deadline for online application is July 5, 2023.

Application forms should be sent on-line through the following web site: http://www.cism.it
A message of confirmation will be sent to accepted participants.

Upon request a limited number of on-site participants can be accommodated at CISM Guest House at the price of 35 Euro per person/night (mail to: foresteria@cism.it).

** where applicable (bank charges are not included)*
Italian VAT is 22%.

CANCELLATION POLICY

Applicants may cancel their registration and receive a full refund by notifying CISM Secretariat in writing (by email) no later than:
- June 17, 2023 for on-site participants (no refund after the deadline);
- July 5, 2023 for online participants (no refund after the deadline).

Cancellation requests received before these deadlines will be charged a 50.00 Euro handling fee. Incorrect payments are subject to Euro 50,00 handling fee.

GRANTS

A limited number of participants from universities and research centres who are not supported by their own institutions can request the waiver of the registration fee and/or free lodging.
Requests should be sent to CISM Secretariat by **May 17**, **2023** along with the applicant's curriculum and a letter of recommendation by the head of the department or a supervisor confirming that the institute cannot provide funding. Preference will be given to applicants from countries that sponsor CISM.

For further information please contact:
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Centre International des Sciences Mécaniques
International Centre for Mechanical Sciences

ACADEMIC YEAR 2023
The Alfred Kluwick Session

VARIATIONAL METHODS FOR COMPLEX MATERIALS AND PROCESSES

Advanced School
coordinated by

Klaus Hackl
Ruhr-Universitaet Bochum
Germany

Dorothee Knees
University of Kassel
Germany

Udine ***July 17 - 21*** **2023**

VARIATIONAL METHODS FOR COMPLEX MATERIALS AND PROCESSES

In the past decades, a better understanding of engineering materials and processes has emerged, leading to numerous technological applications as the design of tailor-made materials having specific properties or optimal solutions of engineering problems. This evolution would not have been possible without fundamental contributions from the theoretical sciences, in particular solid mechanics and mathematics, which offer both analytical and numerical tools for the solution of complex problems. Within this general framework, mathematical concepts from the broad context of variational analysis have proven to be successful.

This spectrum of methods includes, but is not limited too, the theories of homogenization and scale transition, relaxation, Gamma convergence and variational time evolution. Classical application areas involve models in the framework of nonlinear elasticity, finite plasticity, diffusion and phase transformations in general and the analysis of fracture, damage, motion of dislocations, formation of microstructure and the impact of these effects on material behavior in particular. The proposed course will approach the aforementioned topics from different perspectives and not only from one point of view. The different perspectives refer to continuum modeling techniques and the associated algorithmic treatments as well as to the different types of applications.

Mathematics and especially the calculus of variations are essential in the understanding of multiscale problems, micro structured materials and localization phenomena. New solution concepts have to be introduced in order to treat the associated models. Solutions to macroscopic boundary value problems become infimizing sequences whose limits are probability measures. This is a rapidly developing area of research with essential progress made only over the last two decades, which is why this is still a relatively young field of research with many unsolved problems. Professors Manuel Friedrich and Dorothee Knees will give lectures to lay the foundation.

The mechanics side of this course aims to exploit the above mathematical concepts towards formulating and validating constitutive theories and associated numerical tools for the prediction of the behavior of complex materials and processes. Professors Laura De Lorenzis, Sanjay Govindjee, Laurent Stainier, and Klaus Hackl will contribute lectures to survey the theoretical and numerical fundamentals as well as problem classes of interest.

PRELIMINARY SUGGESTED READINGS

K. Hackl, U. Hoppe, D. Kochmann, Variational modeling of microstructures in plasticity. In: J. Schröder, K. Hackl (Eds.): Plasticity and beyond: microstructures, crystal plasticity and phase transitions, International Centre for Mechanical Sciences: Courses and lectures, 550, Springer, 65–129, 2014.

S. Müller, Variational models for microstructure and phase transitions. In: Calculus of variations and geometric evolution problems (F. Bethuel et al., eds.), Springer Lecture Notes in Math. 1713. Springer, Berlin, 85-210, 1999.

A. Mielke, T. Roubícek, Rate-independent systems. Theory and application, Chapter 1. Applied Mathematical Sciences 193. New York, NY: Springer, 2015.

L. De Lorenzis, T. Gerasimov, Numerical Implementation of Phase-Field Models of Brittle Fracture. In: Modeling in Engineering Using Innovative Numerical Methods for Solids and Fluids, CISM – International Center for Mechanical Sciences – Courses and Lectures, 599, Springer, 75-101, 2020.

Laurent Stainier, A Variational Approach to Modeling Coupled Thermo-Mechanical Nonlinear Dissipative Behaviors. In Stéphane P.A. Bordas, editor: Advances in Applied Mechanics, Vol. 46, Academic Press, . 69-126, 2013.

S. Govindjee, M. J. Zoller, und K. Hackl, A fully-relaxed variationally-consistent framework for inelastic micro-sphere models: finite viscoelasticity, Journal of the mechanics and physics of solids, 127, 1-19, 2019.

S. Govindjee, A. Mielke, G. J. Hall, The free energy of mixing for n-variant martensitic phase transformations using quasi-convex analysis,Journal of the Mechanics and Physics of Solids, 51, 1-26, 2003.

LECTURES

All lectures will be given in English. Lecture notes can be downloaded from the CISM web site. Instructions will be sent to accepted participants.

INVITED LECTURERS

Laura De Lorenzis - ETH Zurich, CH
6 lectures on: variational phase field modeling of damage and fracture: construction of the brittle fracture model and choice of its components, nucleation vs. propagation, second- and fourth-order models, irreversibility and boundedness constraints, numerical solution schemes, extensions to more complex model settings.

Manuel Friedrich - Friedrich-Alexander-Universitaet Erlangen-Nuernberg, Germany
6 lectures on: topics from the calculus of variations: lower semicontinuity and different notions of convexity, relaxation, Gamma-convergence, homogenization, multiscale modeling and discrete to continuum transition for solids as an application of Gamma-convergence.

Sanjay Govindjee - University of California, Berkeley, CA, USA
6 lectures on: extremal principles and effective models for materials and structures, applications to solid-solid phase transformations, liquid crystal elastomers, visco-elasticity, and plasticity. Lectures will build on the theoretical foundations presented by M. Friedrich and D. Knees, and the frameworks presented by K. Hackl.

Klaus Hackl - Ruhr-Universitaet Bochum, Germany
5 lectures on: fundamentals of variational methods, thermodynamic principles, relaxed envelopes from a mechanical perspective, evolution laws and applications to diffusive processes and phase transformations.

Dorothee Knees - University of Kassel, Germany
6 lectures on: weak formulations and solution concepts for rate-independent processes, discussion of approximation strategies, application to fracture and damage processes. The main focus in these lectures is on the mathematical background of these approaches.

Laurent Stainier - Ecole Centrale Nantes, France
6 lectures on: continuous and time discrete variational principles for dissipative systems, with focus on plasticity and viscoplasticity, variational formulations for coupled boundary-value problems, with focus on thermomechanics, links with thermodynamics, algorithmic aspects.