

TIME TABLE

Registration 8.30 - 9.00

TIME	Monday	Tuesday	Wednesday	Thursday	Friday
	May 24	May 25	May 26	May 27	May 28
09.00 - 09.45	Iurlano	Iurlano	Marigo	De Lorenzis	Hale
09.45 - 10.30	Iurlano	Iurlano	De Lorenzis	De Lorenzis	Maurini
11.00 - 11.45	Bourdin	Marigo	De Lorenzis	Hale	Closing
11.45 - 12.30	Bourdin	Marigo	De Lorenzis	Hale	
14.00 - 14.45	Marigo	Bourdin	Student presentations	Maurini	
14.45 - 15.30	Marigo	Bourdin	Student presentations	Maurini	
16.00 - 16.45	Iurlano	Hale	-	Maurini	
16.45 - 17.30	Bourdin	Hale	-	Maurini	
18.00	Welcome apéritif				

ADMISSION AND ACCOMMODATION

The course is offered in a hybrid format, allowing participants the flexibility to attend either in person or remotely via the Microsoft Teams platform. Admission to on-site attendance is granted on a first-come, first-served basis to comply with the capacity of the lecture room.

Registration fees:

- **Early Bird On-Site Participation: € 650.00 + VAT***
Deadline: March 24, 2027
- **Late On-Site Participation: € 800.00 + VAT***
Deadline: May 12, 2027
- **Live Streaming Online Participation: € 250.00 + VAT***
Deadline: May 12, 2027

On-site participation includes a complimentary bag, five fixed menu buffet lunches, hot beverages, downloadable lecture notes.
Online participation includes downloadable lecture notes.

Application forms should be submitted online through the website: <http://www.cism.it>. A confirmation message will be sent to participants whose applications are accepted.

Upon request, and subject to availability, a limited number of on-site participants can be accommodated at the CISM Guest House for € 35 per person per night. To request accommodation, please contact: 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 the CISM Secretariat in writing (via email) no later than:

- March 24, 2027, for early bird on-site participation;
- April 24, 2027, for late on-site participation;
- May 12, 2027, for online participation.

No refunds after the deadlines. Cancellation requests received before these deadlines and incorrect payments will be subject to a € 50.00 handling fee.

CISM GRANTS

A limited number of participants from universities and research centers who do not receive support from their institutions can request a waiver of the registration fee and/or free lodging.

Requests must be submitted via the CISM website by **March 24, 2027**. Applicants should select the relevant option in the online application form and provide a curriculum vitae and a letter of recommendation from their department head or supervisor confirming that their institution is unable to provide financial support. Preference will be given to applicants from countries that sponsor CISM.

For further information please contact:

CISM (Seat of the course)
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tel. +39 0432 248511 (6 lines)
e-mail: info@cism.it | www.cism.it

Centre International des Sciences Mécaniques
International Centre for Mechanical Sciences

ACADEMIC YEAR 2027
Andreas Acrivos Session



VARIATIONAL FRACTURE MECHANICS AND PHASE-FIELD MODELS

CISM Advanced School
coordinated by

De Lorenzis Laura
ETH Zürich, Switzerland

Maurini Corrado
Sorbonne Université, Paris, France

Udine May 24 - 28 2027

VARIATIONAL FRACTURE MECHANICS AND PHASE-FIELD MODELS

The course provides a complete and multidisciplinary presentation of the variational phase-field approach to fracture. Emerged over the past two decades, this paradigm has become a game changer for the theoretical and computational treatment of damage and fracture, attracting wide attention in the fracture mechanics community and in industry. It connects Griffith's theory of fracture through the mathematical notion of Gamma-convergence, gradient damage models in continuum mechanics, and the phase-field modelling of phase transformations used in materials science, while offering substantial advantages for computations. The course deliberately takes all of these viewpoints, so that participants gain a presentation of the subject that is both broad and deep.

- From the variational approach to fracture to phase-field modelling: variational formulation of brittle fracture with pre-assigned crack path and in the general case ("sharp-crack" formulation), and its regularization.
- The variational approach to damage and plasticity: local damage models, the variational approach to damage, the transition from local to non-local (gradient) damage models, and the basics of the variational approach to plasticity.
- Phase-field models of brittle fracture as gradient damage models: model ingredients and their consequences, homogeneous and localized solutions, nucleation as loss of stability of the homogeneous solution, the role of energy decompositions under multi-axial stress states, numerical aspects.

- Phase-field models of cohesive and ductile fracture: a formulation in which damage degrades material strength rather than stiffness, allowing arbitrary convex stress-based failure criteria within a consistent variational structure; the equivalent cohesive fracture law; convex programming tools for stable and efficient solvers.
- The mathematical link between the sharp-crack model and its regularized version: Gamma-convergence explained to non-mathematicians, and the key mathematical aspects of phase-field models for fracture and for free-discontinuity problems.
- High-performance phase-field fracture computations: linear and non-linear solvers, parallel computing, incremental constrained minimization for coupled phase-field problems,

and hands-on examples in FEniCS.

A short student presentation session on Wednesday afternoon allows participants to introduce themselves and present their current research.

The course addresses a broad public: doctoral students, young researchers and practicing engineers. Since most of it is devoted to theoretical modelling and numerical computation, an inclination for mathematics is advised. No specific prerequisite in damage mechanics or phase-field modelling is required, but knowledge of the basic concepts of continuum mechanics, elasticity and fracture mechanics is recommended. Preliminary knowledge of Python is useful for active participation in the numerical tutorials; participants should bring their own laptops.

PRELIMINARY SUGGESTED READINGS

R. Alessi, F. Colasanto, and M. Focardi, Phase-Field Modeling of Cohesive Fracture. Part I: Gamma-Convergence Results, SIAM Journal on Mathematical Analysis, 58(1): 513 - 546.

Bourdin, B., Marigo, J.-J., Maurini, C., Zolesi, C. (2025). A variational approach to fracture incorporating any convex strength criterion. arXiv preprint arXiv:2506.22558.

A. Braides, Gamma-Convergence for Beginners. Meccanica, 2007.

J.S. Dokken, et al., The FEniCSx Tutorial. Web (2023): <https://jsdokken.com/dolfinx-tutorial/>

L. De Lorenzis, T. Gerasimov (2020), 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: 75-101.

J.S. Hale, et al. "FEniCSx examples at CISM 2024". Web (last updated 2026) <https://jhale.github.io/cism-2024-varfrac-code>

León Baldelli, A. A., Maurini, C. (2021). Numerical bifurcation and stability analysis of variational gradient-damage models for phase-field fracture. JMPS, 152, 104424.

Marigo, J.-J., Maurini, C., Pham, K. (2016). An overview of the modelling of fracture by gradient damage models. Meccanica, 51(12), 3107–3128.

Tanné, E., Li, T., Bourdin, B., Marigo, J.-J., Maurini, C. (2018). Crack nucleation in variational phase-field models of brittle fracture. JMPS, 110, 80–99.

F. Vicentini, J. Heinzmann, P. Carrara, L. De Lorenzis (2026), Variational phase-field modeling of cohesive fracture with flexibly tunable strength surface. Journal of the Mechanics and Physics of Solids, 207:106424.

F. Vicentini, C. Zolesi, P. Carrara, C. Maurini, L. De Lorenzis (2024). On the energy decomposition in variational phase-field models for brittle fracture under multi-axial stress states. International Journal of Fracture, 247: 291-317.

INVITED LECTURERS

Blaise Bourdin - McMaster University, Hamilton, Ontario, Canada
5 lectures on: Variational formulation of brittle fracture.

Sharp-crack energy minimisation with a pre-assigned crack path, then the general case where the path is unknown a priori, followed by an introduction to the regularized (phase-field) models.

Laura De Lorenzis - ETH Zürich, Zürich, Switzerland
5 lectures on: Variational formulation of gradient damage models. Optimal damage profile and homogeneous evolution in 1D, crack nucleation as loss of stability, the effect of energy decompositions under multi-axial stress, and numerical aspects.

Jack Hale - Université du Luxembourg, Esch-sur-Alzette, Luxembourg
5 lectures on: Numerical implementation of phase-field fracture models. Introduction to FEniCS and parallel computing with MPI, elasticity, plasticity and variational inequalities, the alternate minimization solver, and hands-on numerical examples.

Flaviana Iurlano - University of Genoa, Genoa, Italy
5 lectures on: An introduction to the mathematical aspects of phase-field models. Gamma-convergence explained for non-mathematicians, phase-field models for phase transitions, and their application to fracture and free-discontinuity problems.

Jean-Jacques Marigo - LMS, Institut Polytechnique de Paris, CNRS, Palaiseau, France
5 lectures on: Variational approach to damage and plasticity. Construction of local brittle damage models, the variational approach to damage and the transition to non-local gradient models, plus the variational approach to plasticity.

Corrado Maurini - Institut Jean Le Rond d'Alembert, Sorbonne Université, Paris, France
5 lectures on: Variational approach to coupled damage and plasticity models. Coupling damage and plasticity, cohesive fracture and its equivalent phase-field law, plus an overview of current research topics and open issues.

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.