

TIME TABLE

Registration at 8.30

TIME	Monday	Tuesday	Wednesday	Thursday	Friday
	May 17	May 18	May 19	May 20	May 21
09.00 - 09.45	Hopperstad	Hopperstad	Tekoğlu	Hopperstad	Tekoğlu
09.45 - 10.30	Hopperstad	Hopperstad	Tekoğlu	Hopperstad	Tekoğlu
11.00 - 11.45	Morin	Morin	Benallal	Morin	Faleskog
11.45 - 12.30	Morin	Morin	Benallal	Morin	Faleskog
14.00 - 14.45	Tekoğlu	Benallal	Faleskog	Faleskog	
14.45 - 15.30	Tekoğlu	Benallal	Faleskog	Faleskog	
16.00 - 16.45	Benallal	Rodriguez-Martinez	Rodriguez-Martinez	Rodriguez-Martinez	
16.45 - 17.30	Benallal	Rodriguez-Martinez	Rodriguez-Martinez	Rodriguez-Martinez	
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 17, 2027

- **Late On-Site Participation: € 800.00 + VAT***

Deadline: April 5, 2027

- **Live Streaming Online Participation: € 250.00 + VAT***

Deadline: April 5, 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 17, 2027, for early bird on-site participation;
- April 17, 2027, for late on-site participation;
- April 5, 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 17, 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)
Palazzo del Torso - Piazza Garibaldi 18 - 33100 Udine (Italy)
tel. +39 0432 248511 (6 lines)
e-mail: info@cism.it | www.cism.it

ACADEMIC YEAR 2027
Andreas Acrivos Session

Centre International des Sciences Mécaniques
International Centre for Mechanical Sciences



29th CISM-IUTAM International Summer School on

DUCTILE FAILURE: BRIDGING PHYSICS, MICROMECHANICS, AND PRACTICAL APPLICATIONS

Coordinated by

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Norwegian University of Science and Technology
Trondheim, Norway

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TOBB University of Economics and Technology
Söğütözü, Ankara, Turkey



Udine May 17-21 2027

DUCTILE FAILURE: BRIDGING PHYSICS, MICROMECHANICS, AND PRACTICAL APPLICATIONS

This course will address recent advances in ductile failure of structural metals, with emphasis on connecting theoretical developments, experimental observations, and engineering applications. Recent advances in experimental characterization, computational methods, and high-performance computing have transformed the field. X-ray computed tomography, for example, enables 3D observation of damage evolution, while modern finite element and constitutive modeling increasingly incorporate microstructural information into predictive frameworks.

The course will provide an overview of ductile failure, from fundamental concepts to current research topics. It is primarily intended for PhD candidates, postdoctoral researchers, and early-career scientists seeking deeper knowledge of failure mechanisms, experimental methods, and computational modeling.

The curriculum will cover six interconnected topics:

1. Phenomenological aspects and experimental observations

Experimental observations of ductile failure under quasi-static and dynamic loading will be reviewed, with emphasis on the effects of stress state, strain rate, and microstructural heterogeneity. Mechanical testing and modern characterization techniques, including X-ray tomography, will provide the physical basis for subsequent modeling approaches.

2. Constitutive and micromechanical approaches to ductile failure

Following a review of finite-strain plasticity, different approaches to ductile failure modeling will be introduced, including uncoupled fracture models, continuum damage mechanics, and porous plasticity together with micromechanical approaches such as unit-cell simulations and homogenization.

3. Localization phenomena and failure mechanisms

The course will address plastic flow localization preceding fracture, including necking, shear banding, and void coalescence. Bifurcation analysis and imperfection band approaches will be introduced and discussed.

4. Length-scale effects and regularization strategies

Because strain localization can lead to mesh-dependent numerical predictions, approaches for introducing intrinsic length scales will be presented. These include non-local damage models, and phase-field methods, with emphasis on their theoretical foundations and practical implications.

5. Computational aspects and numerical implementation

Computational modeling of ductile failure using nonlinear finite element methods will form an important part of the course. Implicit and explicit solution strategies and the implementation

of constitutive models through user-defined subroutines (e.g., UMAT/VUMAT) will be addressed through illustrative examples.

6. Multiscale modeling and crack propagation

Finally, the course will address crack initiation and propagation as multiscale phenomena linking microscopic damage mechanisms to structural failure. Micromechanics-informed and gradient-enhanced approaches will be presented, and applied towards engineering-scale fracture predictions.

Overall, the course integrates experimental observations, theoretical modeling, and computational implementation to provide participants with a coherent framework for understanding and predicting ductile failure in structural metals.

PRELIMINARY SUGGESTED READINGS

L. E. B. Dæhli, C. Tekoğlu, D. Morin, T. Børvik, O. S. Hopperstad, 2022. Ductile failure predictions using micromechanically-based computational models. *J. Mech. Phys. Solids*, 164, 104873.

C. Tekoğlu, J.-B. Leblond, T. Pardoen, 2012. A criterion for the onset of void coalescence under combined tension and shear. *J. Mech. Phys. Solids*, 60(7), 1363–1381.

A. R. Ferreira, S. P. B. Proença, A. Benallal, 2024. Yield criteria for voided materials with anisotropic matrix behavior. *Eur. J. Mech. A/Solids*, 104, 105079.

J. C. Nieto-Fuentes, J. Espinoza, F. Sket, J. A. Rodríguez-Martínez, 2023. High-velocity impact fragmentation of additively-manufactured metallic tubes. *J. Mech. Phys. Solids*, 174, 105248.

T. Virazels, J. García-Molleja, B. Lukič, D. Foster, A. Rack, S. Puerta, D. Pedroche, J. A. Rodríguez-Martínez, F. Sket, 2026. Real-time in-situ X-ray imaging of pore compaction and spall fracture in plate impact tests on additively manufactured metals. *J. Mech. Phys. Solids*, 211, 106551.

D. Morin, O. S. Hopperstad, A. Benallal, 2018. On the description of ductile fracture in metals by the strain localization theory. *Int. J. Fract.*, 209, 27–51.

S. Wang, J. Faleskog, 2024. A non-local GTN model with two length scales – Application to ductile failure in a wide range of stress triaxiality. *Eur. J. Mech. A/ Solids*, 104, 105056.

INVITED LECTURERS

Ahmed Benallal - Université Paris Saclay, Centrale Supélec, ENS Paris Saclay, CNRS, Gif-sur-Yvette, France

6 lectures on: Homogenization of ductile porous materials. Hill-Mandel lemma- Kinematic theorem of Limit Analysis. A first example: The Gurson model. Introduction of complex matrix behavior. Introduction to anisotropy. Couplings between hydrostatic effects and shear. Approximate models for ductile fracture.

Jonas Faleskog - KTH Royal Institute of Technology, Stockholm, Sweden

6 lectures on: Physical and multiscale aspects of ductile fracture. Gradient and non-local theories applied to ductile fracture. Calibration and application of computational models with multiple length scales. Simulation of crack initiation and propagation in ductile metals.

Odd Sture Hopperstad - Norwegian University of Science and Technology, Trondheim, Norway

6 lectures on: Physical mechanisms of ductile fracture in metals from experimental observations. Finite strain plasticity. Uncoupled, coupled, and non-local damage models for ductile fracture. Localization phenomena with emphasis on bifurcation, and imperfection analyses.

David Morin - Norwegian University of Science and Technology, Trondheim, Norway

6 lectures on: Computational aspects of plasticity and ductile fracture. User-developments in Fortran with a focus on implementation of constitutive models, uncoupled/coupled damage and porous plasticity models. Numerical aspects of non-local regularization of damage models.

José A. Rodríguez Martínez - Carlos III University of Madrid, Spain

6 lectures on: Extreme-loading experiments: spall, fragmentation, impact localization and ultrafast X-ray imaging. Stability and self-similar analyses of failure; regularization by rate effects, inertia and microstructure; microstructure-informed FE simulations.

Cihan Tekoğlu - TOBB University of Economics and Technology, Söğütözü, Ankara, Turkey

6 lectures on: Micro-Mechanics of Ductile Fracture. Unit Cell Calculations in Ductile Fracture Analysis. Kinematic Constraints and Boundary Conditions. Microscopic Localization. Mechanisms of Void Coalescence. Illustrations and Applications of Unit Cell Calculations.

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.