

NEWSLETTER 53

Year 2023

EUROPEAN
MECHANICS
SOCIETY

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EUROMECH Conference Reports

ETC18 – 18th European Turbulence Conference

4–6 September 2023, València, Spain

Chairpersons: Prof. Sergio Hoyas – Prof. Alberto Conejero

Co-Chairpersons: Prof. Javier Jiménez – Prof. Oscar Flores

Brief summary

The 18th European Turbulence Conference (ETC18) was held at the **Universitat Politècnica de València** from 4 to 6 September 2023. Organized with the support of Universidad Carlos III de Madrid and Universidad Politécnica de Madrid, this edition marked a significant moment in the series, as it was the last ETC before the planned consolidation into the **European Fluid Dynamics Conference** beginning in 2024.

The scientific programme included **66 parallel sessions**, grouped under **20 thematic topics**, covering a broad range of turbulence research areas. Eight plenary lectures were delivered by internationally renowned experts, addressing key advances in experimental, computational, and theoretical turbulence studies.

Participants

A total of **488 delegates** attended the conference in person, representing **more than 30 countries** across Europe and beyond. Among the most represented nations were France (67 participants), Germany (54), the United Kingdom (49), and China (45), with notable presence also from the United States, Japan, Italy, and India. The demographic reflected the strong international appeal of the ETC series and its central role in the turbulence research community.

Invited speakers

There were **8 invited plenary speakers**, whose contributions spanned a wide array of current challenges and methodologies in turbulence:

- **Marc Avila** (University of Bremen), *Drop breakup in turbulent flows*
- **Shervin Bagheri** (Royal Institute of Technology, KTH), *Functionality and stability of liquid-infused surfaces in shear flows*

- **Leonie Canet** (Université Grenoble Alpes), *Functional renormalisation group approach to turbulence*
- **Massimo Cencini** (Italian National Research Council, CNRS), *Microorganisms swimming in turbulence*
- **Soledad Le Clainche** (Universidad Politécnica de Madrid), *Modal decompositions and other machine learning tools in fluid dynamics*
- **Maria Vittoria Salvetti** (University of Pisa), *Dynamics of separating and reattaching flows*
- **Ricardo Vinuesa** (KTH Royal Institute of Technology), *Modeling and controlling turbulent flows through deep learning*
- **Paul Williams** (University of Reading), *Forecasting atmospheric turbulence from hours to decades ahead*

Scientific programme

The conference sessions were organized around the following main topics:

- Acoustic turbulence
- Artificial intelligence in turbulence
- Atmospheric flows
- Boundary layers
- Control of turbulent flows
- Geophysical turbulence
- Instability and transition
- Intermittency and scaling
- Lagrangian turbulence
- Large-Eddy Simulation (LES)
- Magnetohydrodynamics (MHD)
- Multiphase and non-Newtonian flows
- Reacting turbulent flows
- Transport and mixing
- Turbulence in superfluids
- Vortex dynamics
- Wall-bounded flows: theory and simulation

The diversity of sessions reflected the vibrant research community and the integration of emerging computational and experimental techniques.

Young Scientist Awards

As in previous editions, a Young Scientist Award competition was held. Candidates under 35 years of age were nominated to present in regular sessions, and their presentations were evaluated by members of the ETCC. The following two young researchers were selected for their outstanding contributions:

- **Chiara Calascibetta** (University of Rome, Tor Vergata), for her talk “*Optimal Strategies to Catch a Drifting Target in Turbulence*” (with co-authors L. Biferale, F. Borra, A. Celani, and M. Cencini)
- **Enzo Francisco** (Université Paris-Saclay, CNRS, SPEC, CEA), for his talk “*Quantitative Spatio-Temporal Measurements of the Dissipation Rate by Diffusing-Wave Spectroscopy*” (co-authored with S. Aumaitre)

Funding and support

The conference received support from **EUROMECH**, which offered a financial grant that, although not ultimately required, was formally acknowledged by the organizers. Additional sponsorship was provided by **Ubertone** and **Dantec Dynamics**, whose contributions helped support the successful execution of the event.

Looking ahead, the **European Fluid Dynamics Conference**, launching in **September 2024 in Aachen, Germany**, will bring together the communities of ETC and EFMC under a unified event, continuing the legacy of excellence in fluid mechanics fostered by the ETC series.

EUROMECH Colloquia Reports 2023

EUROMECH Colloquium 608

Dynamics of Gravity Currents

28 – 30 June 2023, Grenoble, France

Chairperson: Maria Eletta Negretti

Co-Chairperson: Paul Linden

Introduction

Gravity currents are widespread phenomena encountered both in natural environments and in industrial applications. They are primarily horizontal flows driven by hydrostatic pressure gradients resulting from density differences caused by variations in temperature, chemical composition, or the presence of suspended particles. Atmospheric examples include sea breezes and thunderstorm outflows, while buoyant river plumes and the outflows from the Mediterranean and Red Seas are notable oceanic instances.

In engineering and technical contexts, gravity currents are observed in scenarios such as heating and cooling of buildings, tunnel fires, water treatment facilities, oil slick dynamics, and CO₂ sequestration in depleted oil reservoirs. A particular class, particulate gravity currents—such as turbidity currents, snow avalanches, pyroclastic flows, and haboobs—are characterized by the suspension of particles due to fluid turbulence generated at the current's boundaries.

These flows, typically involving water or air as the ambient fluid, are non-conservative; they can exchange particles with the bed and fluid with the surroundings through deposition, suspension, entrainment, or detrainment.

The objective of this Colloquium was to bring together the European scientific community to exchange ideas and recent developments on gravity current dynamics. Discussions covered topics including the development of integral models incorporating vorticity arguments, high-resolution 3D numerical simulations, laboratory measurements of 3D flow fields, and new techniques for the simultaneous measurement of velocity and particle concentration. The Colloquium fostered cross-fertilization of ideas and new collaborations across disciplines.

Scientific Program Highlights

The Colloquium welcomed contributions from engineers, geoscientists, oceanographers, and meteorologists, offering theoretical, computational, experimental, and observational perspectives on gravity currents. Emphasis was placed on fluid mechanics aspects, with contributions addressing:

- Conceptual and experimental models for density and particulate gravity currents;
- Realistic laboratory models of geophysical and industrial gravity currents;
- High-resolution numerical simulations of density currents;
- Interactions between density currents and bottom topography, including roughness, obstacles, and mobile beds;
- Interactions with stratified ambient fluids and internal wave generation;
- Modeling and parametrization of oceanic overflows;
- In situ observations of atmospheric and oceanic gravity currents;
- Dynamics of compositional and particulate gravity currents, including non-Newtonian behaviors;
- Quantification of erosion and deposition processes;
- High-resolution simulations of composite density-particle interactions;
- Gravity currents in porous media;
- Non-Boussinesq gravity currents.

Organization

Participation in the Colloquium was by invitation only. The event was organized around five main thematic sessions:

1. Oceanic flows
2. Atmospheric flows
3. Particulate gravity currents
4. Conceptual modeling of gravity currents
5. Interaction with the bottom (topography, roughness, obstacles, mobile beds)

Each day's program was structured around these five themes and the methodologies employed: (i) theoretical approaches, (ii) experimental investigations, (iii) numerical simulations, and (iv) field observations and industrial applications.

Three keynote speakers highlighted the first three main topics:

- Anna Wahlin (Oceanic flows)
- Ivana Stipersky (Atmospheric flows)
- Eckart Meiburg (Particulate gravity currents)

A poster session was inaugurated at the end of the first day and remained open throughout the event, providing additional opportunities for interaction.

Participants particularly appreciated the high quality of the contributions, the fruitful exchanges, and the integration of field data presentations, all facilitated by the informal and stimulating atmosphere of the Colloquium.

We gratefully acknowledge the financial and scientific support of EUROMECH, which made this Meeting possible.

EUROMECH Colloquium 622**Low Reynolds Number Particulate Flows: From Micro to Macro Scales**

26-30 June 2023, Nice, France

Chairpersons: *Elisabeth Lemaire – Eric Climent***Co-Chairpersons:** *Micheline Abbas– Eric Keaveny***Introduction**

Particle-laden flows are omnipresent in both natural phenomena and industrial applications, spanning across scales from microscopic biological systems to macroscopic environmental and engineering flows. Despite the large-scale impact, the behavior of these systems originates at the particle scale where Reynolds numbers are typically low to moderate. Complex phenomena such as multi-body hydrodynamic interactions, lubrication effects, Brownian motion, and interparticle forces (friction, DLVO forces) govern the dynamics.

Significant advances have been achieved in the past decades in both computational (LBM, IBM, FCM, DPD, SPH, SD) and experimental techniques (advanced rheometry, imaging, particle pressure measurements). This Colloquium gathered leading researchers to present and discuss the latest developments in experimental methods, simulations, and theoretical modeling of particulate flows at low Reynolds numbers.

Scientific Program Highlights***Low Reynolds Suspensions: From Single Particle to Collective Behavior***Keynote Speaker: **George Petekidis (University of Crete, Greece)**

The Colloquium opened with a comprehensive review of collective phenomena in particulate suspensions, with a focus on colloidal gels. The keynote lecture addressed how external fields can tune and "train" these gels, inducing memory effects and manipulating their mechanical properties. Discussions emphasized the fundamental role of hydrodynamics at low Reynolds numbers and short-range interactions, such as van der Waals forces and surface roughness. Even small variations in these properties can lead to significant changes in the macroscopic behavior, including particle migration, aggregation, and complex rheological responses such as shear-thinning and discontinuous shear-thickening.

Particle MigrationKeynote Speakers: **Ryohei Seto (Wenzhou Institute, China) and Ganesh Subramanian (JNCASR, Bangalore, India)**

This session explored the mechanisms by which particles migrate within flowing suspensions, distinguishing between two key regimes: low-concentration flows influenced by inertial effects, and high-concentration flows dominated by confinement and frictional contacts. In the low-concentration regime, the talks detailed the theoretical and numerical characterization of particle orbits, alignment phenomena, and their impact on flow rheology. In dense suspensions, the focus shifted to the development of local constitutive laws, particle plug formation in pressure-driven flows, and collective behaviors such as giant vortex structures formed by micro-swimmers in confined domains. The interplay between inertia, friction, and confinement emerged as central to understanding migration processes across flow types.

Active SuspensionsKeynote Speaker: **Corinna Maas (University of Twente, Netherlands)**

The keynote lecture introduced the intriguing world of active emulsions, where individual droplets self-propel and interact collectively. The session highlighted experimental studies on droplet auto-propulsion and boundary interactions, alongside theoretical and numerical frameworks to predict instabilities and pattern formation. Additional talks expanded on the dynamics of micro-rollers and the collective synchronization phenomena observed in active filaments, bacteria, and synthetic swimmers. Emphasis was placed on how multi-body hydrodynamic interactions lead to emergent behaviors such as vortex formation, spontaneous aggregation, and coherent structures even at very low Reynolds numbers.

Solid Contact (Roughness, Friction, Adhesion, Rebound)Keynote Speakers: **Emmanuela del Gado (Georgetown University, USA) and Francesco Bonacci (University of Perugia, Italy)**

Solid-solid contacts between particles are now recognized as fundamental in dictating the rheology of dense suspensions, particularly their non-Newtonian behaviors. The keynote lectures demonstrated how frictional interactions explain phenomena such as shear thickening and mechanical aging. Emmanuela del Gado presented how discontinuous shear thickening arises from the formation and percolation of stress-bearing contact networks. Francesco Bonacci introduced evidence that thixotropic behavior in colloidal suspensions results from aging of these interparticle contacts. The session underscored that detailed

characterizations of contact mechanics—both sliding and rolling friction—are essential for accurate predictive models of particulate flow behavior.

Effect of Particle Shape

Keynote Speaker: **Anke Lindner (PMMH, Paris, France)**

Particle shape drastically alters the dynamics of suspensions, as illustrated through both theoretical calculations and experimental observations. The keynote lecture reviewed the hydrodynamics of elongated and flexible particles, particularly focusing on their grand resistance tensors and deformation dynamics under shear flows. Various studies presented results on the short-term and long-term behavior of flexible fibers, elastic sheets, and other non-spherical geometries. The influence of particle flexibility on microstructural organization and suspension rheology was extensively discussed, as well as applications such as the peculiar transport properties of star-shaped particles in confined flows and the behavior of fibers in microfluidic vortices.

Soft Particles

Keynote Speaker: **Simon Mendez (IMAG, Montpellier, France)**

Soft particle suspensions, such as red blood cells or polymeric capsules, present additional complexities due to their deformability. The plenary lecture by Simon Mendez highlighted the modeling and numerical challenges associated with simulating these systems, especially the coupling between particle deformation and flow fields. The session included innovative experimental approaches on suspensions of soft capsules under constriction and resuspension flows. Discussions addressed how particle softness affects macroscopic suspension properties such as viscosity, particle migration, and stress distribution, emphasizing the relevance for biomedical applications and soft matter engineering.

Non-Viscosimetric Flows and Non-Newtonian Fluids

Keynote Speaker: **Bloen Metzger (IUSTI, Marseille, France)**

Departing from standard simple shear flows, this session tackled particulate flows in more complex configurations, including extensional and vortex flows. Bloen Metzger introduced an osmotic-like rheometer capable of revealing the dual nature of shear thickening behavior. Presentations explored the behavior of both spherical and elongated particles in Newtonian and viscoelastic fluids, addressing shear rotation effects, concentration dependence, and extensional viscosity. The need for new rheological

models capable of describing particle-laden flows in complex geometries was a recurring theme, with applications ranging from polymer processing to biological flows.

EUROMECH Colloquium 628**Complex particles in turbulent flow**

03 – 05 May 2023, Nice, France

*Chairperson: Dario Vincenzi**Co-Chairperson: Andrea Mazzino - Rama Govindarajan***Introduction**

Understanding the dynamics of particles in turbulent flows is essential for addressing challenges in mixing, combustion, and environmental pollution. Significant progress has been made thanks to the development of novel Lagrangian experimental, numerical, and theoretical techniques. These tools have enabled the detailed investigation of velocity, acceleration, and dispersion statistics for both tracer and inertial particles.

While early studies primarily focused on the behavior of point-like particles, recent research has broadened to include the dynamics of complex particles, encompassing a wide range of shapes, sizes, and material properties. These developments have opened new perspectives for understanding how particle shape, flexibility, and motility influence interactions with turbulent flows.

The EUROMECH Colloquium 628 was organized with the goal of fostering discussions and collaborations around recent advances in the field of complex particle dynamics in turbulence. It gathered researchers from physics, engineering, and related disciplines.

Scientific Program Highlights***Microscopic Complex Particles***

A central theme of the Colloquium was the dynamics of microscopic complex particles. Presentations covered topics such as the resuspension of glass particles in turbulent gas flows, the production and design of microfibrils for particle-laden turbulence experiments, and the dynamics of chiral particle suspensions. Experimental techniques for particle tracking were also introduced.

The behavior of polymers, including both rigid and elastic solutions, was extensively discussed. Numerical studies addressed turbulent drag reduction at high Reynolds numbers and mixing enhancement at lower Reynolds numbers. Additionally, talks explored the role of external fields in phytoplankton transport, linking light distribution at the surface to particle survival and growth.

Macroscopic Particle Dynamics

Another major focus was on the behavior of macroscopic particles, particularly long flexible fibres. Their transport, deformation, orientation, spinning, and tumbling were examined using both experimental and numerical approaches. The potential of fibres to act as turbulence probes was also highlighted. Other macroscopic particles discussed included rigid spheres—especially regarding their impact on turbulence—and thin disks, whose dynamics near vortices were studied.

Point-like Particle Dynamics

Several talks explored the dynamics of point-like particles. One invited lecture examined particles floating on free-surface flows, revealing how compressibility can lead to aggregate formation—relevant to marine plastic pollution. Additional contributions addressed phoretic particle dispersion under solute gradients and the impact of inertia on droplet dispersion in turbulent boundary layers. In astrophysical contexts, clustering of inertial particles in protoplanetary disks was presented, with a focus on flow rotation and particle size.

Turbulence in Clouds

Cloud microphysics emerged as a key area of interest. One invited talk focused on the dynamics of anisotropic particles in clouds, including effects on settling, orientation, collisions, and ice crystal growth. Another provided analytical insights into droplet collision dynamics, while a third shared data on droplet size distribution from a recent observational campaign near Barbados. Machine learning was also employed to classify precipitation events and identify critical parameters in real atmospheric data.

Bubbly Flows and Multiphase Turbulence

Turbulent bubbly flows were widely discussed, particularly the statistics of velocity fields, bubble shape distributions, and the effect of increasing air volume fraction on torque reduction. Simulations investigated bubble-heavy particle collisions under turbulent conditions.

Active and Swimming Particles

The Colloquium also addressed the dynamics of active or self-propelled particles. Presentations examined how swimming behavior is influenced by turbulence, using machine learning to decode navigation strategies and predator-prey interactions. An experimental study on copepods explored how turbulence drives the formation of elongated chains.

General Hydrodynamic Phenomena

Finally, broader hydrodynamic issues were discussed, such as Turing pattern formation in reactive flows, new forcing methods for isotropic turbulence using magnets, and the design of a jet grid for high-Reynolds-number multiphase flows in water tunnels.

Organization

The EUROMECH Colloquium 628 brought together **42 participants from 9 countries**, providing a balance of senior and early-career researchers. The scientific program included:

- **7 Invited Lectures**
- **23 Contributed Talks**
- **7 Short Presentations** (associated with poster contributions)

Presentations spanned experimental studies, numerical simulations, and theoretical modeling. The event also featured a number of interdisciplinary contributions connecting turbulence research with atmospheric science, astrophysics, and biological systems.

The book of abstracts and detailed program are available on the official website of the Colloquium.

Conclusions

The Colloquium successfully stimulated dialogue between physicists, engineers, and interdisciplinary researchers interested in particle-laden turbulence. The high scientific quality of the presentations, coupled with a collaborative and open atmosphere, promoted active discussion and potential future collaborations.

The diversity of topics—from microscopic polymer dynamics to macroscopic fibre deformation, from astrophysical applications to biological systems—highlighted the rich complexity and relevance of particle dynamics in turbulent flows.

EUROMECH Colloquium 632

Data-driven modeling of porous, composite and polycrystalline microstructures for predicting their mechanical and transport properties

20 – 22 September 2023, Ulm, Germany

Chairperson: Matthias Neumann

Co-Chairpersons: François Willot, - Paul Shearing

Introduction

The mechanical and transport properties of functional materials such as battery electrodes, alloys, biomaterials, and composites are intrinsically linked to their internal microstructure. In recent years, stochastic and numerical modeling—especially when combined—have emerged as powerful tools for virtually testing and optimizing material microstructures. These approaches enable the creation of digital twins and other statistically realistic representations that help explore and establish process–microstructure–property relationships in a virtual environment.

The EUROMECH Colloquium 632 brought together researchers working at the intersection of mathematics, physics, materials science, and engineering to discuss data-driven approaches for modeling and predicting the effective properties of porous, composite, and polycrystalline microstructures. The event provided a multidisciplinary platform for presenting advances in image analysis, machine learning, microstructure modeling, simulation, and AI-based prediction methods.

Scientific Program Highlights

Image Analysis and Pre-processing

The reconstruction of microstructures from 3D imaging data requires advanced image processing techniques. Machine learning methods, such as 3D-UNet and Barisin's RieszNet, were presented as highly effective for segmentation tasks, especially in identifying complex features like cracks in concrete and battery materials. Special emphasis was placed on segmentation that is scale-invariant and robust, even when faced with variable crack thicknesses.

To mitigate the limitations of hand-labeled data, stochastic geometry-based methods were used to generate semi-synthetic training datasets. These provide a well-defined ground truth for enhancing machine learning segmentation results.

Stochastic Microstructure Modeling and Spatial Statistics

Stochastic models offer flexibility in generating realistic micro- and nanostructures, allowing for extensive virtual testing. Talks covered diverse materials, including battery electrodes, fuel cells, foams, polycrystalline structures, and short fiber reinforced polymers. Methods such as Laguerre tessellations and balanced power diagrams were discussed for accurately fitting polycrystalline geometries to image data.

Further contributions highlighted novel descriptors for characterizing spatial correlations and connectivity in porous and crystalline materials. These included geodesic path-based metrics that quantify bottleneck effects and tortuosity-related characteristics crucial to transport properties.

Advanced foam modeling techniques were also introduced. The combination of random tessellations with Brakke's surface evolver allowed the generation of more realistic foam structures, including partially closed cells and accurate edge/facet distributions.

Machine Learning for Microstructure Analysis and Prediction

Three main uses of machine learning were featured:

1. Image segmentation – for computing morphological descriptors and effective properties from 3D datasets.
2. Generative modeling – creating virtual microstructures (digital twins) statistically consistent with experimental observations. These methods, though powerful, were noted for being prone to overfitting.
3. Property prediction – employing neural networks for nonparametric regression or convolutional neural networks (CNNs) for directly predicting material properties from 3D images.

Open-source platforms implementing these machine learning models were demonstrated, and discussions addressed the interpretability vs. accuracy trade-offs in AI-based predictions.

Tortuosity and Effective Transport Properties

The session on transport processes emphasized the crucial role of tortuosity—a measure of the complexity of paths through a porous medium. The lack of standardization in the literature was addressed by proposing a new nomenclature distinguishing between geometric, hydraulic, and effective tortuosity.

Use cases involved solid oxide fuel cells and lithium-ion batteries, focusing on both nano-scale and micro-scale features. Homogenization approaches and spatially resolved models that include the carbon binder domain (CBD) were presented as essential for improving simulation accuracy of cathode structures.

The software GeoDict was showcased as a comprehensive platform for data-driven modeling, including AI tools, PDE solvers, grid coarsening techniques, and parallel computing resources to simulate effective properties based on 3D imaging data.

Mechanical Property Modeling

Innovative data-driven approaches to fracture mechanics were introduced that remove traditional modeling assumptions while retaining fundamental fracture laws based on variational principles. These methods were validated against standard fracture models, showing strong agreement.

Image-based finite element modeling was used to study the effects of geometric defects on metallic cellular structures produced by laser powder bed fusion (LPBF). The virtually designed architectures enabled detailed simulation and performance analysis.

In the domain of short fiber reinforced polymers, the role of fiber length distributions on mechanical behavior was analyzed. Virtual composites generated via stochastic methods were used in computational homogenization workflows and compared with industrial materials to validate simulation results.

Organization

The Colloquium featured a structured scientific program that included:

- Invited lectures from leading experts in materials modeling and AI
- Contributed presentations by researchers across disciplines
- Poster sessions showcasing early-stage research and applications

Participants included specialists in materials science, applied mathematics, mechanical engineering, and computational physics. The sessions were designed to promote cross-disciplinary exchange, facilitate collaborative discussions, and support the growth of an integrated community working on data-driven microstructure modeling.

Conclusions

EUROMECH Colloquium 632 provided an outstanding forum to explore cutting-edge methods for understanding and predicting the mechanical and transport properties of complex materials. Contributions emphasized the integration of image-based analysis, stochastic modeling, and machine learning, offering scalable and efficient solutions for modern materials design.

The presentations underlined the need for standardization of descriptors, especially in defining tortuosity, and highlighted the value of open-source tools to promote transparency and reproducibility. By fostering dialogue across academic and industrial domains, the Colloquium advanced the collective knowledge in microstructure-informed material optimization.

EUROMECH Colloquium 634

Multi-physics of fibrous networks and fibre composite materials

19–21 June 2023, Eindhoven, the Netherlands

Chairperson: Emanuela Bosco

Co-Chairpersons: Artem Kulachenko - Catalin Picu

Introduction

This EUROMECH Colloquium focused on recent developments in computational multi-scale modeling and experimental methodologies for the analysis of fibres, fibrous networks, and fibre-composite materials. A total of **41 oral presentations** were given, addressing a wide range of physical, biological, and engineering applications. The event featured a **keynote lecture by Prof. G. Holzapfel** (Graz University of Technology), a leading figure in biomechanics and material modeling.

Fibrous network materials play a pivotal role in both natural systems (e.g., biological tissues) and engineered products (e.g., paper, non-wovens, metamaterials, and composites). Unlike traditional composites, in fibre-based materials, the fibre network itself acts as the primary load-bearing component. A central objective of the colloquium was to identify shared challenges across these diverse applications and to foster cross-disciplinary collaboration among the various scientific communities involved.

Discussion Topics

Advanced Multi-scale Methods for Fibrous Materials

Multi-scale modeling is essential for understanding the macroscopic behavior of fibrous materials, which results from complex interactions at the fibre level. Talks focused on homogenization strategies to bridge micro- and macro-scales, including:

- **Asymptotic homogenization** for analyzing hygro-chemo-mechanical degradation of paper;
- **Computational homogenization** for the fracture behavior of fibre-reinforced composites;
- **Localized orthogonal decomposition** methods for modeling paper networks;
- **Statistical models** for stretch distributions in biological tissues;

- **Numerical homogenization** approaches for damage in long-fibre-reinforced thermoplastics.

The complexity of fibrous systems stems from their non-linear, time-dependent response, sensitivity to moisture and temperature, and failure mechanisms that initiate at the fibre scale. Accurate multi-scale approaches are key to simulating such systems reliably.

Continuum Models Capturing Micro- and Meso-mechanical Phenomena

To model the stiffness and strength of fibre-based materials, it is necessary to account for microstructural features such as fibre morphology, orientation, inter-fibre bonding, and network disorder. Presentations included:

- **Elastoplastic models** for paper damage and creasing;
- **Continuum visco-plastic models** for fibre-reinforced biological tissues;
- **Phase-field models** for anisotropy in contracting cellular systems;
- **Fracture models** for orthotropic paperboard;
- **Statistical mechanics frameworks** for fibre assemblies, with parameters inferred from experiments.

These models aim to reconcile micro-scale fibre behaviors with continuum-scale predictions, enabling better design and quality control in fibre-based materials.

Parameter Identification from Experiments

Accurate experimental determination of fibrous material properties is challenging, particularly at small scales. Presentations addressed:

- **In-situ microprofilometry** for assessing micrometric fibre mechanics;
- **Brillouin light scattering** to determine elastic stiffness tensors of cellulosic fibres;
- **Mode I and Mode II tests** for characterizing fibre–fibre contact mechanics.

While biological materials like collagen present ongoing challenges for direct measurement, methods developed for cellulose fibres show promise and potential transferability to the biological domain.

Moisture Effects in Cellulose Networks

Moisture is a critical factor affecting the mechanical response of paper and cellulose-based materials. The colloquium explored this via:

- **Continuum models** of liquid transport and swelling in paper sheets;
- **Multi-scale experimental studies** examining hygro-expansion across different structural levels (fibres, fibre bonds, and sheets).

Understanding moisture-induced deformation is essential for applications involving packaging, printing, and structural performance in variable environments.

Organization

The colloquium was structured around invited and contributed oral presentations, allowing for in-depth technical discussion and interdisciplinary knowledge exchange. Participants came from the fields of materials science, biomechanics, applied mathematics, and mechanical engineering. Key thematic areas included:

- Multi-scale modeling and homogenization
- Experimental characterization of fibrous materials
- Continuum and statistical mechanics modeling
- Moisture effects and environmental interactions

Ample time was reserved for informal exchanges during breaks and social activities, which greatly facilitated idea sharing and cross-disciplinary networking.

Conclusions

The colloquium succeeded in bringing together different research communities—ranging from paper mechanics to biological tissues and composite materials—to address common challenges in the modeling and characterization of fibrous networks. The breadth of topics highlighted recent progress in continuum and network modeling, while also underscoring open research questions in fracture prediction, moisture interactions, and scale bridging.

Participants strongly valued the informal discussions and community building. A

consensus emerged to organize a follow-up event within 2–3 years, potentially expanding participation to researchers outside Europe. The colloquium met its scientific goals and fostered new collaborations.

The organizers thank **EUROMECH** for its financial and organizational support, which was essential for the success of the meeting.

Invited Speakers and Plenary Lecturers

The colloquium featured a **plenary lecture by Prof. G. Holzapfel** (Graz University of Technology), who provided a comprehensive overview of the mechanical modeling of biological tissues and fibrous materials.

Other invited talks addressed topics including:

- Multi-scale modeling strategies in complex networks
- Experimental techniques for micro- and meso-scale measurements
- Phase-field and continuum approaches in fibre composites

EUROMECH Colloquium 635

Finite Fracture Mechanics

12–15 September 2023, Lyon, France

Chairperson: Dominique Leguillon

Co-Chairpersons: Vladislav Mantic, Aurélien Doitrand, Nicolas Carrère

Introduction

The EUROMECH Colloquium 635 focused on theoretical, numerical, and experimental advances in **finite fracture mechanics (FFM)**. The event brought together researchers investigating analytical models, numerical simulations, and experimental validations in fracture prediction. Particular attention was given to comparisons with alternative approaches such as **phase-field models, cohesive zone models, and configurational force methods**.

Fracture phenomena were discussed across a wide range of applications including **adhesive joints, fiber–matrix interfaces, bio-inspired composites, 3D printed materials, laminates, hydraulic fracturing, fatigue crack growth, and thermal shock**. The colloquium highlighted the strengths and limitations of the **Coupled Criterion (CC)** approach and its role in crack initiation and propagation analysis.

Scientific Program Highlights

Crack Nucleation and Model Comparisons

A central discussion focused on the definition of **crack nucleation** in different fracture models. In the Coupled Criterion, crack nucleation is strictly defined as the load at which both energy and stress criteria are satisfied, resulting in a binary and sharp crack representation. This contrasts with **phase-field models**, where **diffused damage** may occur throughout the specimen when the internal length scale is comparable to specimen size. Comparative studies showed that a **stiffness-based criterion** best matches the CC's predictions.

Notably, good agreement between CC and other models was demonstrated across **mode I (opening), mode II (in-plane shear), and mode III (out-of-plane shear)** fracture modes. However, discrepancies were observed in the presence of large **process zones**, particularly affecting the estimate of the critical shear energy release rate.

Length Scales in Fracture Mechanics

Several discussions centered on characteristic **length scales** in different fracture models:

- Displacement jumps in **cohesive zone models**
- The **critical distance theory**
- Internal length (**l_{PF}**) in phase-field models
- Initiation length (**l_c**) in the Coupled Criterion

These scales were found to be proportional to **Irwin's characteristic length (l_{mat})**, though their physical measurability remains under debate. Only **arrest lengths** (post-initiation) can generally be measured experimentally. Nonetheless, **inverse identification** of fracture properties based on arrest length remains an effective strategy.

Experimental Crack Initiation and Tip Definition

The creation of **sharp cracks** in experiments (e.g., via V-notches or saw cuts) was discussed. Despite challenges due to **tip radii** or **residual stresses**, stable crack initiation can be achieved ahead of a V-notch under certain conditions, predictable using the Coupled Criterion.

Defining the **crack tip** was also explored, especially in cases where theoretical (LEFM) and experimental/molecular dynamic (MD) definitions diverge. Techniques such as **Williams' series** and **matched asymptotic expansions** were reviewed, along with **Generalized Stress Intensity Factor (GSIF)** calculations. MD simulations showed localized stresses exceeding material strength limits, resembling predictions from **spectral splits** in phase-field models.

Plasticity, Crack Propagation, and Energetic Considerations

The role of **plastic zones** in crack propagation was extensively discussed. It was noted that even small plastic zones significantly affect the **failure load**, and that **elastic calculations** may underestimate failure in such cases. Two approaches emerged:

1. Simplicity-first: continue with linear models and expand their application limits.
2. Refined modeling: incorporate **plasticity** into energy balances and failure criteria.

The influence of **crack velocity** on energy variation during initiation was also reviewed. Experiments capturing **crack speed profiles** are complex but necessary for accurate modeling, especially in configurations where **initiation and arrest lengths** coincide.

Experimental Design and Model Validation

The **Coupled Criterion** proved valuable in designing fracture experiments, particularly in **adhesively bonded specimens**, helping to distinguish between **interface** and **cohesive failure mechanisms**. The CC also enables **scenario-based fracture analysis**, providing insight even into failure configurations that do not materialize.

The **influence of notch geometry** (especially small V-notch angles) was explored. Due to small theoretical variations in failure load across these geometries, experimental **scatter** often exceeds the signal, complicating validation. Nonetheless, **size effects** in materials like **sapphire** were confirmed experimentally, aligning with CC predictions. The colloquium highlighted the need for **small-scale, in-situ** tests under both **force-** and **displacement-controlled** conditions to verify these predictions.

3D Crack Modeling and Topology Effects

In three dimensions, crack surface **definition and topology** play a critical role. Different 3D geometries lead to varying **SIF distributions** along crack fronts. The **optimal crack shape** was shown to depend on material characteristic length and loading mode, with:

- **Stress-based shapes** optimal for small characteristic lengths
- **Energy-based shapes** favored in large-scale problems
- **No universal optimum** for intermediate scales

Proposals included using **configurational forces** or **phase-field modeling** to determine realistic crack paths and curvatures.

Cracks intersecting **free surfaces**—common in experiments—were recognized as **3D singularities** requiring analysis beyond standard plane strain or plane stress assumptions.

Mode III and Facet Formation

Under **mode III loading**, cracks may form **facets** inclined to the primary crack plane.

Phase-field models can replicate this via **tension/compression energy decomposition** and **perturbations** in toughness. This penalizes straight crack growth and mimics stress-based criteria in tandem with energetic conditions. In 3D, neither stress nor energy criteria alone are sufficient, highlighting the need for more advanced modeling strategies.

Stress Criteria and Failure Prediction

The use of **pointwise vs. average stress criteria** in the CC was debated. Pointwise criteria are stricter and may prohibit crack nucleation in certain geometries (e.g., wide V-notches under pure shear), while **average stress criteria** may predict alternative initiation points. The discussion emphasized that **independent fracture property calibration** is essential before comparing models. The potential for a **strain-based criterion** was also noted.

Numerical Integration and GSIF

While GSIFs are traditionally obtained via **contour integrals**, their extension to **surface integrals** in 3D is under consideration. This could simplify computation and improve robustness. For comparisons across geometries, the use of **force or displacement metrics** rather than GSIFs was recommended due to experimental accessibility and independence from angle units.

Organization

The colloquium featured a series of in-depth technical presentations, open discussions, and collaborative sessions. Topics covered:

- Theoretical frameworks and analytical modeling
- Numerical simulation techniques
- Experimental validation strategies
- Multiscale and multiphysics approaches to fracture mechanics

Support from **INSA Lyon, MATEIS Laboratory, Région Auvergne-Rhône-Alpes, MECAMAT Association, Carnot Institute**, and **EUROMECH** was instrumental in the organization and success of the event.

Conclusions

EUROMECH Colloquium 635 served as a comprehensive forum for exploring the **state of the art in finite fracture mechanics**. The event bridged theory, simulation, and experiment, addressing current challenges in modeling, scale transition, and validation. The Coupled Criterion was shown to be a versatile tool, valuable both for theoretical analysis and experimental planning.

Participants expressed a strong interest in continuing the dialogue and exploring further the integration of **plasticity, 3D crack modeling, and velocity effects** into predictive fracture frameworks. A potential follow-up colloquium was suggested to revisit open questions and share advancements.

EUROMECH Colloquium 636 Modulation of physico-chemical processes by elastic strain engineering

22–24 May 2023, Besançon, France

Chairperson: Fabien Amiot

Co-Chairperson: Javier Llorca

Introduction

Elastic strain engineering offers a powerful strategy for tailoring the physical and chemical properties of materials by modifying their electronic structure through mechanical deformation. While traditionally requiring hydrostatic conditions for significant effects in bulk materials, advances in material science now allow for large elastic deformations—up to the theoretical limit of ~10%—in **nanomaterials, thin films, and architected solids**, regardless of material class (metals, ceramics, organics).

Applications of this technique span **semiconductor performance enhancement, magnetic property tuning, and catalytic activity optimization**. The field is highly interdisciplinary, residing at the interface of **mechanics, physics, chemistry, materials science, and surface science**. The EUROMECH Colloquium 636 was conceived as a platform to bring together researchers from diverse disciplines to assess the current landscape of elastic strain engineering and explore its potential.

The colloquium gathered **21 participants**, with **18 presentations** covering theoretical modeling, experimental techniques, and application-driven case studies. Ample time was dedicated to discussion, fostering engaging exchanges during sessions, coffee breaks, and social activities.

Scientific Program Highlights

Modeling of Coupled Phenomena

Two main families of coupled processes were discussed:

1. **Ferroelectric Thin Films and Heterostructures**
 - Coherent and incoherent strain phase diagrams were introduced as analogues to temperature–composition diagrams.

- **Phase field models** were used in combination with thermodynamic stability analysis to predict material behavior under strain.
2. **Chemomechanical Coupling at Interfaces**
 - Concepts such as **metal/water hybrid materials** mimicking piezoelectric behavior were discussed.
 - **Interstitial solid solutions** like hydrogen in palladium were used to validate theories of **open-system elasticity**.
 - **Micro-cantilever systems** and **elasto-capillarity models** were introduced as experimental setups to explore chemo-mechanical interactions with local measurement capabilities.

Experimental Techniques for Large Elastic Strain

Several innovative experimental approaches were presented to induce and measure large strains in nanoscale systems:

- **Strained substrates** used to deform thin films.
- **Femtosecond laser pulses** to modify underlying substrates and release strain.
- **Strain engineering in 2D materials** (e.g., graphene, MoS₂), exploiting their high theoretical strain limits.
- **Spin crossover in van der Waals heterostructures** to enable controllable strain.
- **Raman spectroscopy and moiré pattern analysis** for strain mapping in 2D crystals.

Challenges in achieving uniform and measurable strains at the nanoscale were highlighted, particularly in 2D systems.

Tailoring Material Properties via Elastic Strain Engineering

Strain engineering was shown to influence a variety of material properties:

- **Catalytic and corrosion behavior**
- **Optical and magnetic properties**
- **Electronic and optoelectronic performance**
- **Phononic and excitonic transport**

Emerging applications include:

- **Quantum information systems**, where strain modulates the emission of single-photon sources.
- **Strain-driven exciton transport**, with control over valley lifetime and coherence.
- **Machine learning-assisted material design**, including a case study using **density functional theory (DFT)** and **decision tree regression** to identify a **cost-effective alternative to platinum** for hydrogen electrolysis.

Organization

The colloquium took place over three days and included:

- **18 technical presentations**
- **2 social lunches and 1 group dinner**
- **Daily coffee breaks** to support informal discussions

21 participants attended the event:

Funding sources included:

- **Région Bourgogne-Franche-Comté**
- **City of Besançon**
- **Mecamat Association**

The event was structured to encourage **interdisciplinary exchange** and deep discussion, both during formal sessions and in relaxed social settings.

Conclusions

EUROMECH Colloquium 636 successfully brought together researchers from a range of disciplines to explore the potentials and challenges of **elastic strain engineering**. The discussions revealed:

- The maturity of **theoretical modeling** frameworks for strain-induced phenomena.
- The need for improved **experimental techniques**, especially for 2D materials.

- The emergence of **new application areas**, including quantum technologies and green catalysis.

The colloquium reinforced the importance of combining **modeling, experimentation, and materials design**, and opened the path toward **strain-tuned functional materials** tailored for specific applications.

EUROMECH Colloquium. 638**Cellular Mechanobiology and Morphogenesis**

Dates and location: 21–24 August 2023, Sirmione, Lake of Garda, Italy

Chairpersons: Alberto Salvadori

Co-Chairpersons: Eóin McEvoy - Alessio Gizzi - Mattia Bacca

Introduction

The EUROMECH Colloquium 638, held from August 21st to 24th, 2023, in the scenic setting of Sirmione on the Lake of Garda, focused on the theme of “**Cellular Mechanobiology and Morphogenesis**”. This meeting was conceived and executed as a platform to bring together leading international researchers working at the convergence of **mechanics, biology, chemistry, biophysics, and biomedical engineering**. Organized with the institutional support of the **University of Brescia** and under the auspices of the **European Mechanics Society**, the event gathered **34 distinguished speakers** from internationally renowned institutions and **10 early-career researchers** selected for poster presentations.

Mechanobiology represents an intrinsically interdisciplinary field that investigates how physical forces and mechanical properties of cells and tissues regulate biological function and drive morphogenetic processes. This field has rapidly expanded over the last decade, proving instrumental in understanding phenomena such as **cancer metastasis, embryonic development, angiogenesis, wound healing, and mechanotransduction**.

The primary objective of the Colloquium was to provide a rigorous and collaborative environment for researchers to exchange recent findings, explore new hypotheses, and initiate multidisciplinary collaborations. By integrating theoretical modeling, computational simulations, advanced imaging, and experimental biomechanics, the colloquium aimed to advance our understanding of how **biomechanical processes regulate cellular behavior across multiple spatial and temporal scales**.

Scientific Program Highlights*Mechanobiology and Biological Function*

The scientific program included comprehensive discussions on the role of mechanical forces in modulating key biological phenomena. Among the principal topics addressed were:

- **Cytoskeletal contractility and reorganization**, including the actomyosin network and focal adhesion dynamics.
- **Cellular motility in 2D and 3D microenvironments**, examining how cells navigate complex extracellular matrices (ECM).
- **Mechanotransduction pathways** linking cytoskeletal tension to nuclear architecture and chromatin remodeling.
- **Mechanical homeostasis**, describing how cells maintain force equilibrium during proliferation, differentiation, and migration.
- **Cell–cell and cell–ECM interactions**, with particular emphasis on how matrix stiffness and topology influence tissue organization.

These mechanisms were explored both in physiological contexts (e.g., embryogenesis, tissue remodeling) and pathological scenarios (e.g., cancer progression, vascular diseases).

Multiscale Modeling and Advanced Instrumentation

An essential theme of the Colloquium was the integration of **computational models and experimental methods** for the quantitative characterization of cellular and tissue mechanics:

- **Continuum and discrete models** were used to simulate active gel behavior, actin dynamics, and myosin-induced contractility.
- **Organoids and organs-on-chips** provided platforms to replicate in vitro the complex behavior of real tissues under mechanical cues.
- **Super-resolution microscopy**, including techniques with sub-10 nm resolution, was presented as a critical tool to study **intermolecular forces and nanoscale structures** within living cells.
- **Raman spectroscopy** and **moiré pattern analysis** were discussed as effective techniques for measuring strain in **2D materials** such as graphene and MoS₂ used in biohybrid devices.
- **Machine learning-based approaches**, coupled with **first-principles simulations**, were proposed for designing material-strain combinations optimized for specific functions (e.g., catalytic activity, quantum information processing).

Applications in Biomedicine and Biotechnology

A significant portion of the colloquium was dedicated to translational applications, showcasing

how mechanobiology informs and enables:

- **Design of anti-metastatic therapies**, through modulation of cell motility and ECM remodeling.
- **Cell reprogramming and immunotherapy**, by exploiting the role of mechanical environments in gene expression and cell fate determination.
- **Device-driven tissue engineering**, including the study of strain-induced cellular reorganization post-implantation (e.g., in heart valves).
- **Quantum biomechanical devices**, such as **single-photon sources** regulated by strain fields for potential applications in **quantum medicine**.

The involvement of **industrial partners**, including **Copan, MDE, BiomimiX, and Theras**, demonstrated the increasing interest of the private sector in leveraging mechanobiological principles for **innovative therapeutic and diagnostic technologies**.

Organization

The Colloquium was held in the welcoming setting of the Congress Center in Sirmione, Lake Garda. Over three days, participants engaged in a rich program of invited talks and poster presentations, fostering in-depth discussions on cellular mechanobiology and morphogenesis. The event opened with institutional greetings from the Rector of the University of Brescia and the Mayor of Sirmione, reflecting strong academic and civic support.

Beyond the formal sessions, the program encouraged informal exchanges through well-curated social activities. These included a welcome wine and cheese reception and a memorable Colloquium dinner at the “Podere Selva Capuzza” winery in Desenzano, accompanied by live music and shared transport.

Throughout the meeting, logistical services such as remote access, on-site support, safety protocols, and poster setup were efficiently managed. Coffee breaks further supported networking in a relaxed setting.

The success of the event was made possible through the financial and institutional support of **EUROMECH**, the **University of Brescia**, the **City of Besançon**, the **Bourgogne-Franche-Comté Region**, and the **Mecamat Association**. Additional value was brought

by the presence of industrial partners such as **Copan, MDE, BiomimiX, and Theras**, who showed strong interest in the scientific themes addressed.

Conclusions

The EUROMECH Colloquium 638 served as a pivotal meeting for the international mechanobiology community, emphasizing the **central role of mechanics in biological systems**. It successfully fostered cross-disciplinary communication between **mechanicians, biologists, physicists, and engineers**, reflecting the complexity and interconnectedness of the challenges addressed.

Key outcomes included:

- Establishment of new research collaborations
- Identification of open questions regarding cytoskeletal force transmission, ECM mechanosensing, and morphogenetic signaling
- Promotion of integrative methods combining **computational modeling, experimental biomechanics, and high-resolution imaging**
- Encouragement of **industry-academia partnerships** for the development of novel biomedical technologies

The strong positive reception by all participants has laid the groundwork for organizing **future editions** of the Colloquium, potentially with broader participation and thematic expansion.