EUROPEAN MECHANICS SOCIETY

Colloquium n. 647 – Stability and bifurcation problems in nonlinear solid mechanics

Dates and location

23 April — 25 April 2025, Glasgow, UK

Chairperson

Dr Prashant Saxena

Co-chairperson

Prof Silvia Budday

What other funding was obtained?

James Watt School of Engineering, University of Glasgow provided funding for all local arrangements including venue hire and subsistence for 2.5 days.

What were the participants offered?

Free registration.
Subsistence (lunch, coffee, snacks) during the three days and a drinks reception to enable interaction and networking.

Scientific report

Stability and bifurcation in nonlinear solid mechanics have long been central themes in understanding the limits of material and structural performance. Traditionally, instabilities such as wrinkling, creasing, buckling, and fracture were viewed as precursors of failure. However, recent developments in materials science, biomechanics, and soft robotics have revealed that these phenomena may also be exploited as functional mechanisms for novel design. This Colloquium brought together leading experts in theory, computations, and experimentation to consolidate the state of the art, stimulate new ideas, and chart future directions in this rapidly evolving field.

The Colloquium took place from 23–25 April 2025 at the University of Glasgow, UK. It was organised in a single-stream format to maximise interaction and foster discussions across communities. In total, there were 22 presentations and ample time and opportunities for informal discussions. The event attracted a diverse mix of researchers across Europe, North America, and Asia, with strong participation from both early-career and established scientists.

Scientific themes and highlights:

Biomechanics and morphogenesis

Biological growth and morphogenesis is a key area in which large deformation and instabilities are prominent. Silvia Budday (Erlangen-Nuremberg) demonstrated how mechanical instabilities translate cellular-scale processes into organ-level patterns in the human brain. Her computational framework linking progenitor cell division and migration to cortical folding highlighted both normal development and malformations relevant to neurological disorders.

Davide Ambrosi (Milan) presented rod models for cardiovascular mechanics, showing how even reduced mathematical descriptions capture the essence of mitral valve dynamics, arterial morphogenesis, and dissection. These models opened new questions on stability, contact, and shape optimisation in living systems. Philip Bayly (Washington University) analysed

ciliary axonemes using a multifilament model, proposing flutter-like mechanisms for oscillations. His talk emphasised how mechanical instabilities may explain biological propulsion without requiring detailed biochemical regulation.

Jiong Wang (Guangzhou) addressed shape control in soft material plates and shells driven by differential growth. Combining theory, numerics, and experiments, his group established schemes for programming complex geometries, with applications to biomedical devices. Similarly, Mingchao Liu (Birmingham) drew inspiration from morphogenetic folding in plants, translating biological mechanisms into tuneable meta-ribbons with adaptive responses. Together, these talks demonstrated how growth and instability intertwine to produce complexity in both nature and engineering.

Wrinkling, creasing, and surface instabilities

Traditionally, surface instabilities have remained a strong theme in this field enabling researchers to test out new models and solve interesting problems. Prashant Saxena (Glasgow) presented an incremental stability analysis of layered magnetoelastic half-spaces, illustrating how magnetic fields can actively modulate surface patterns. Valentina Balbi (NUI Galway) reported on wrinkling of auxetic bilayers under uniaxial tension, a counterintuitive setting where tensile loading produces compressive stresses. Her work combined analytical predictions with finite element simulations to reveal conditions under which wrinkle wavelength and orientation can be tailored for applications in grafts and organ patches.

Yibin Fu (Keele) presented a reduced nonlinear model for hyperelastic layers, derived to cubic order, that simplifies complex stability problems into tractable finite-dimensional systems. His approach recovers known results while opening the way for new analyses of travelling waves and localisation. Paul Steinmann (Erlangen/ Glasgow) discussed a peridynamics based method to add a nonlocal perspective and capture wrinkling instabilities in a bilayer system. Draga Pihler-Puzovic (Manchester) presented swelling-induced wrinkling as a method for creating patterned microchannels, relevant for lab-on-chip technologies. Sushma Santapuri (IIT Delhi) contributed a mathematical model of wrinkling in electro/magneto-active thin sheets, highlighting how external fields can shift the onset of instability and potentially be used as a control mechanism.

These contributions reinforced the view that surface instabilities, far from being mere curiosities, can be precisely controlled and exploited in engineering and biomedical applications.

Multiphysics coupling in soft active materials

A significant portion of the programme was devoted to instabilities in electroactive and magnetoactive elastomers, reflecting growing interest in soft robotics and functional materials.

Abhishek Ghosh (Glasgow/ IIT Kanpur) presented a coupled finite element framework for dielectric elastomers, demonstrating instability-driven actuation in tubes and bilayers. Talks by Massimiliano Gei (Trieste) and Stephan Rudykh (NUI Galway) explored hierarchical laminates and magnetoactive composites, respectively, showing how tailored microstructures and external fields can be harnessed to tune instabilities. Kostas Danas (CNRS Paris) introduced a magneto-viscoelastic constitutive model validated against experiments, highlighting the dissipative nature of magnetorheological elastomers under dynamic fields. Daniel Garcia-Gonzalez (Madrid) explored programmable instabilities in magneto-viscoelastic structures, showing how magnetic actuation can reconfigure stiffness, force, and energy absorption.

These studies emphasised that instabilities, once viewed as detrimental, may be reimagined as design opportunities—an emerging philosophy sometimes described as “buckliphilia.”

Numerics and reduced order models

Andrew McBride (Glasgow) presented a subdivision-surface isogeometric approach to inflated hyperelastic shells, capturing bifurcations under inflation with high accuracy and applying the method to engineering systems. Lukasz Kaczmarczyk (Glasgow) introduced a mixed finite element formulation for nearly incompressible solids, implemented in the open-source MoFEM library. His method was robust on tetrahedral meshes and scalable via hybridised solvers, bridging fundamental mathematics and industrial applications.

Marcelo Dias (Edinburgh) examined damage in Maxwell lattices, showing how topology and self-stress localise failure paths, and how combining distinct lattices manipulates toughness. This line of research highlights how failure can be programmed by geometry. Atul Bhaskar (Southampton) analysed instabilities in narrow plate strips, providing asymptotic and variational insights into the transition from beam-like to plate-like behaviour.

Gilad Yakir (EPFL Switzerland), with collaborators, investigated brittle fracture in rotating beams. Experiments revealed how centrifugal and Euler forces couple to drive mixed-mode crack propagation, while preliminary studies on rotating hydrogels suggested parallels with traumatic brain injury mechanics. Daniil Yurchenko (Southampton) presented bifurcations in vibroimpact systems, with applications to energy harvesting.

Atmosphere

The Colloquium fostered lively discussion and cross-disciplinary fertilisation. By design, all talks were delivered in plenary format, enabling participants to gain a broad view of current activity. Extended coffee and networking breaks encouraged informal interaction, while a drinks reception and conference dinner provided ample opportunity for discussion in a relaxed setting.

Several participants remarked on the value of exposing early-career researchers to both established and emerging leaders in the field. The hybrid format, with both in-person and two online presentations, broadened participation and ensured contributions from two colleagues who were unable to travel due to last-minute constraints.

Conclusions

The Colloquium achieved its aims of consolidating the state of the art, highlighting new directions, and strengthening connections across communities working on stability and bifurcation in nonlinear solid mechanics.

Feedback from participants was overwhelmingly positive, praising both the scientific content and the organisation. We thank Euromech for its support, and the University of Glasgow for hosting this stimulating event.