Mechanical characterization of materials at EMS

Overview, application driven testing, and multiphysics experiments

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Overview: main activities

1. Provide testing and research infrastructure as well as support for the research groups
   - E.g metals technology, composites and polymers, coatings, technical ceramics…
   - Collaboration with other units of TAU, research organizations and the industry

2. Methodology development in the focus areas
   - New technologies, optimization of processes → pressure to develop experimental methods
   - Currently a strong push towards multiphysics *in-situ* measurements

Overview: infrastructure and resources

Commercial testing equipment
- Servohydraulic and electromechanical testing machines
- Temperature control systems
- Impact hammers, hardness testers etc.

In-house customization
- Special jigs and fixtures on demand
- Capabilities to develop fully customized test setups

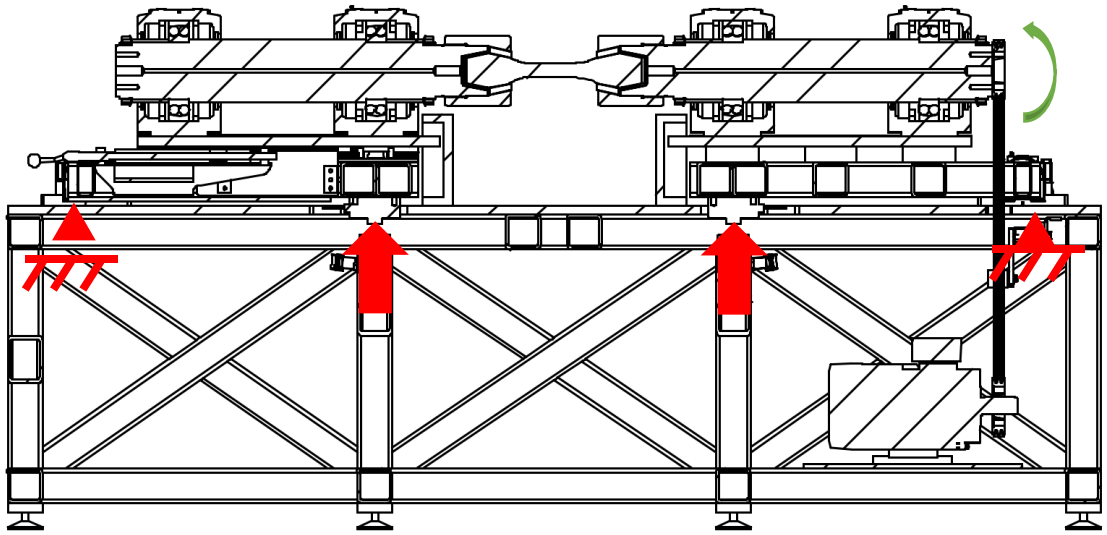
Advanced mechanics of materials - group
- High speed loading
- Micromechanical testing
- Large scale fatigue
- *In situ* measurements in synchrotron centers

Supporting resources
- High speed optical and IR cameras
- Analysis and numerical simulation software
- Expertise from various fields, such as non-destructive testing

+ Tribology and wear testing
- A large variety of commercial and in-house built testing devices

Application driven testing: large scale fatigue

- Rotating 4-point bending, cylindrical specimen, gauge area Ø32 x 100 mm → **realistic**
- Testing frequency up to 48 Hz → typical test duration ~1-5 days
- Loading amplitude up to 1000 MPa → testing of high strength structural materials
- Developed during the BF/ÄVE project with technical support from Sandvik Mining and Construction Oy

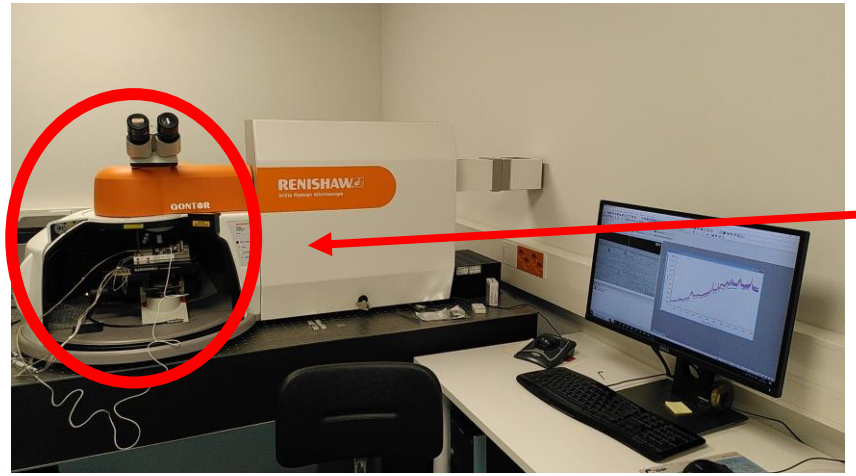


[Isakov, Rantalainen, Saarinen, Lehtovaara, *Experimental Techniques*, 2023, 47(3), pp. 553–563]

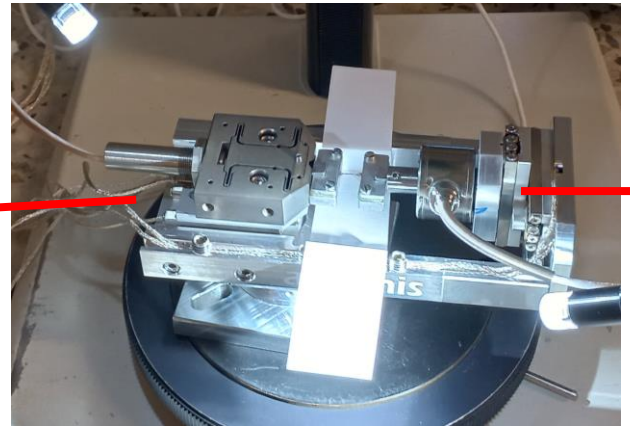
Photo by Jonne Renvall

Multiphysics experiments: epoxy in small scale

- Epoxy matrix in composites is squeezed between the fibers, could it thus have **properties not revealed by standard tests**?
  → reduction of test volume → miniature testing



Raman spectroscopy:
in situ-measurement of molecular movement



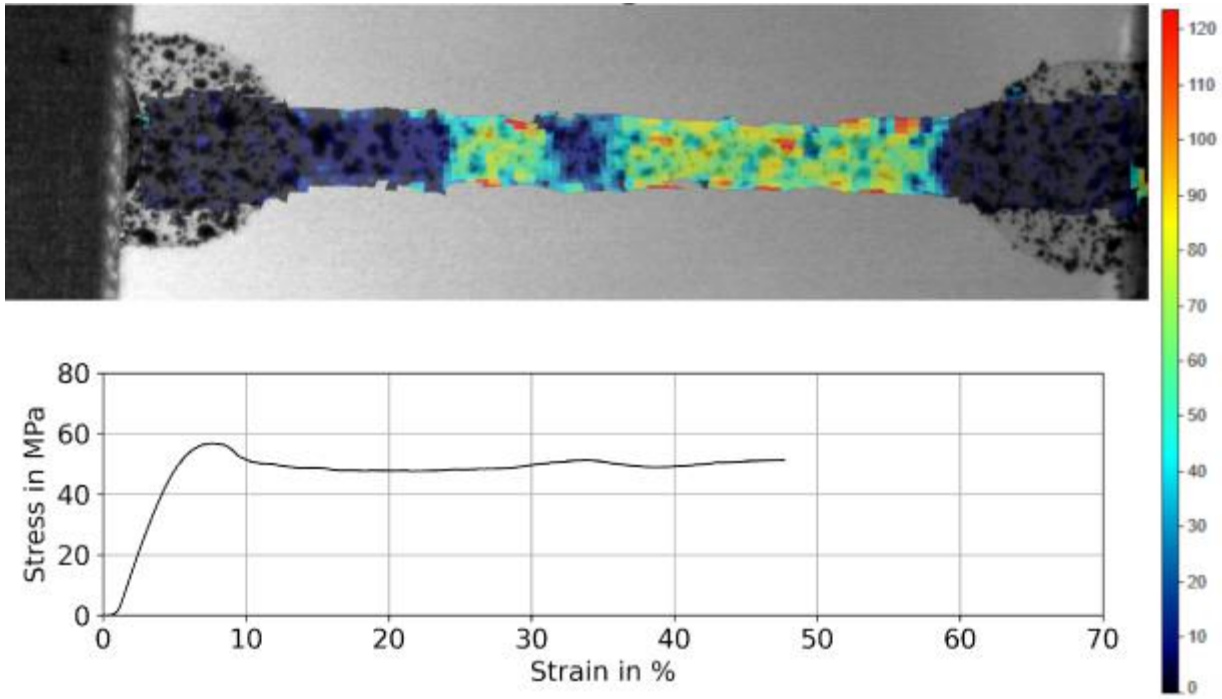
Alemnis miniature loading stage equipped with tensile grips

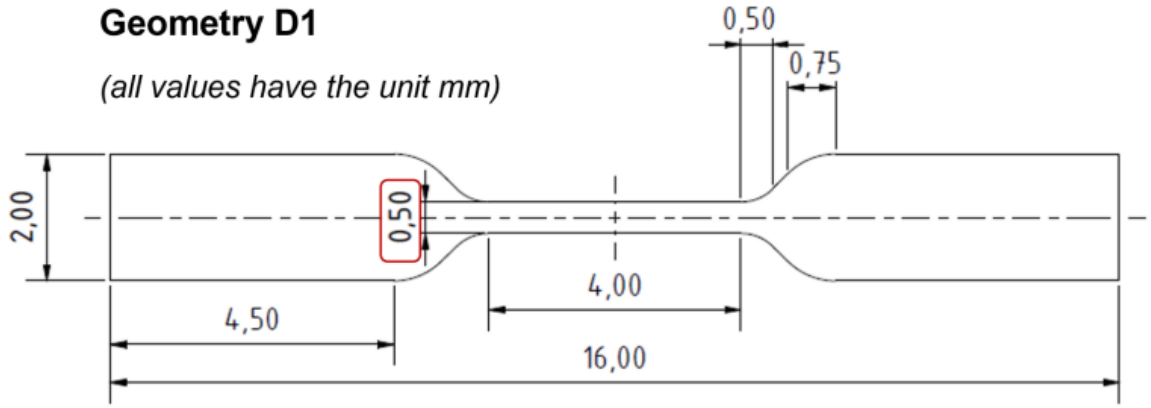
Loading under optical microscope:
specimen deformation tracking with Digital Image Correlation

[Collaboration between Hamburg University, TAU, and University of Bayreuth; manuscript submitted to *Polymer*, Mittelhaus et al. 2024]

Result: significant increase in ductility

Reason: local shear band formation and molecular reorientation (not observed in bulk specimens)





Gauge section length 4 mm, width 0.5 mm and thickness 0.03 mm, total volume ~0.06 mm^3.

(Typical bulk specimen ~250 mm^3)

[Collaboration between Hamburg University, TAU, and University of Bayreuth; manuscript submitted to *Polymer*, Mittelhaus et al. 2024
Video prepared by Janina Mittelhaus]

Multiphysics experiments: *in situ* synchrotron radiation

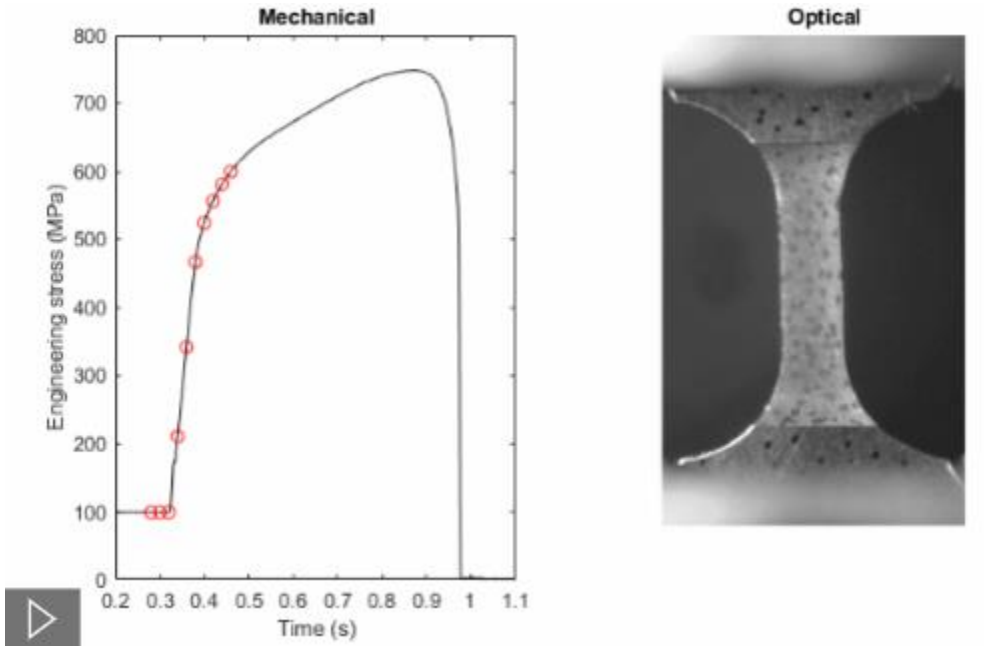
- Motivation: tracking of microstructural phenomena during loading enables in-depth analysis of material behavior
  → high intensity, high quality X-ray radiation

- Visits to DanMAX / MAX IV (Sweden)
  for X-ray diffraction: phase transformations, texture evolution, internal lattice strains

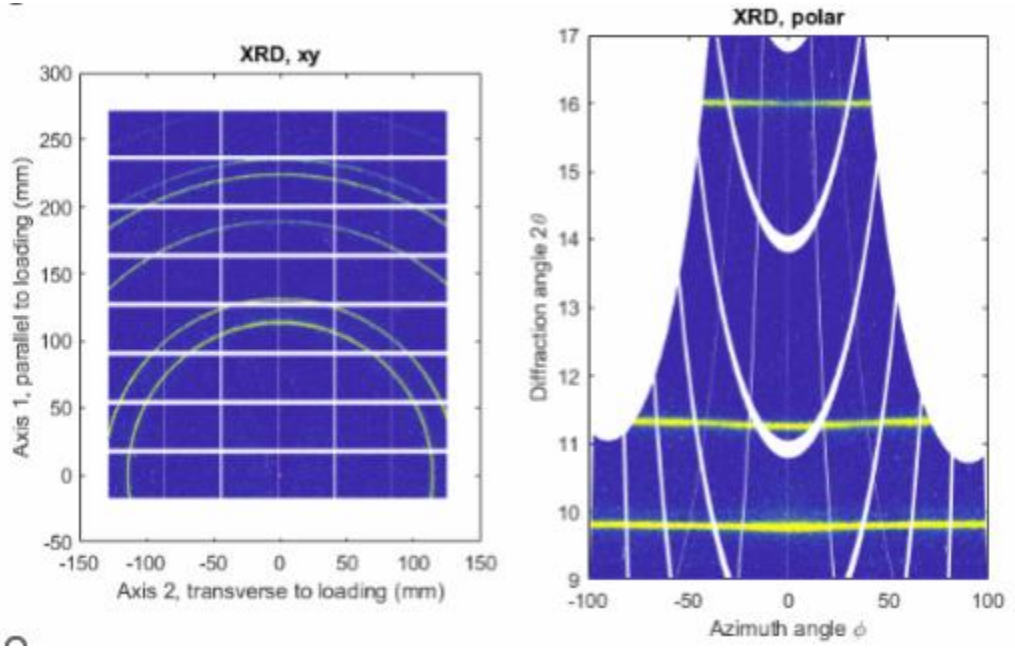
- Visits to ID19 / ESRF (France)
  for high speed X-ray tomography:
  damage mechanisms during high speed loading in composites and rock

Tampere University

Mechanical and optical data:



Diffraction data:



<u>Simultaneous</u> measurement of:

- Mechanical (stress-strain) response
- Phase volume fraction evolution
- Lattice strain evolution
- Texture (grain orientation) evolution
- Temperature evolution (with high-speed IR)

→ analysis of mechanical property-microstructure relationships

→ calibration and improvement of simulation models

[Collaboration between TAU and DanMAX / MAX IV]

Recent international recognition

Society for Experimental Mechanics (USA) has given the
D. R. Harting Award (for the best paper of the year in Experimental Techniques)
for the work carried out at EMS twice during the recent years:

2022 - Guilherme Corrêa Soares, Naiara Ilia Vázquez-Fernández, Mikko Hokka, "Thermomechanical Behavior of Steels in Tension Studied with Synchronized Full-Field Deformation and Temperature Measurements" *Experimental Techniques (2021)* 45-5, 627–643

2024 - Matti Isakov, Oliver Rantalainen, Tuomo Saarinen*, Arto Lehtovaara "Large-Scale Fatigue Testing Based on the Rotating Beam Method" *Experimental Techniques (2023).* 47-3, 553-563

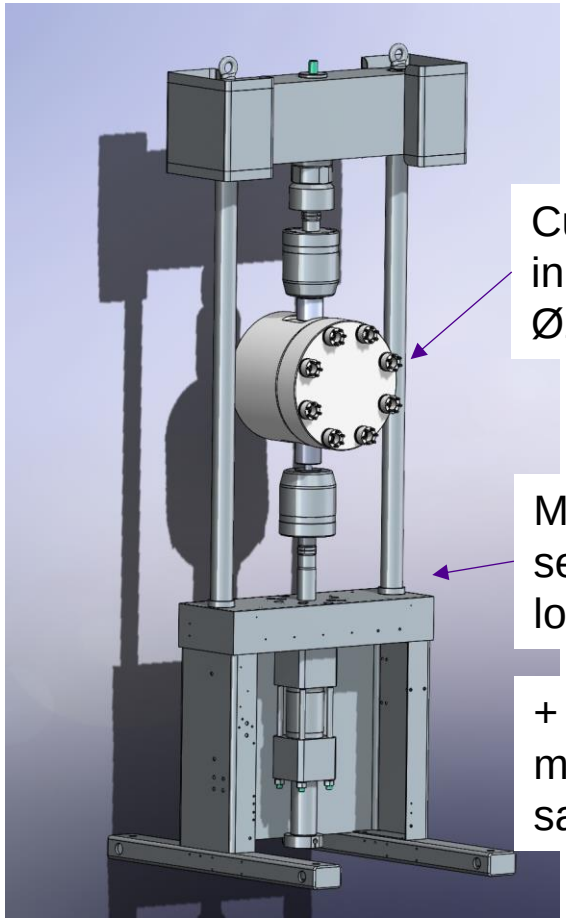
*) Tuomo Saarinen is with the Sandvik Mining and Construction Oy, Tampere, Finland

Coming soon: In situ H_2-atmosphere testing

- Hydrogen has large detrimental effects on the mechanical properties of many materials

  → *Mechanical testing in high pressure hydrogen gas environment*

- Max. pressure 400 bar,
  max. temperature 220°C,
  loading range -10 … 50 kN
- Tensile testing, fracture toughness, fatigue testing, fretting
- Confirmed external funding: RCF (FIRI)
- Scheduled commissioning: end of 2025



[Image courtesy of Antti Väinölä, Cormet Oy]

Thank you!

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