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Fraunhofer Institute for High-Speed Dynamics, Ernst-Mach-Institut, EMI

# Challenges in mode II testing under high rates of loading

**Michael May, Philipp Hahn**

**Virtual Workshop: Mode II Interlaminar Fracture Toughness and the Factors affecting it**

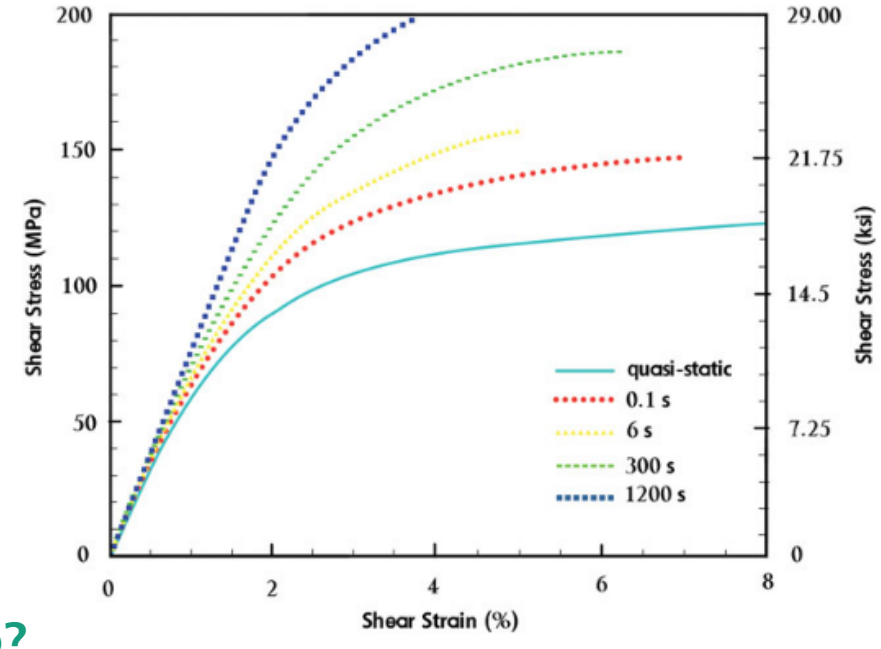
**13 May 2025**

# Motivation

## Why test mode II fracture toughness at different strain-rates?

- **Matrix dependent material properties usually improve with loading-rate.**
- **The shear behavior in particular, is strongly dependent on the strain-rate**

**→ Does the mode II fracture toughness improve with loading rate too?**




**Shear stress–strain response of 45° off-axis specimens at different strain rates [1]**

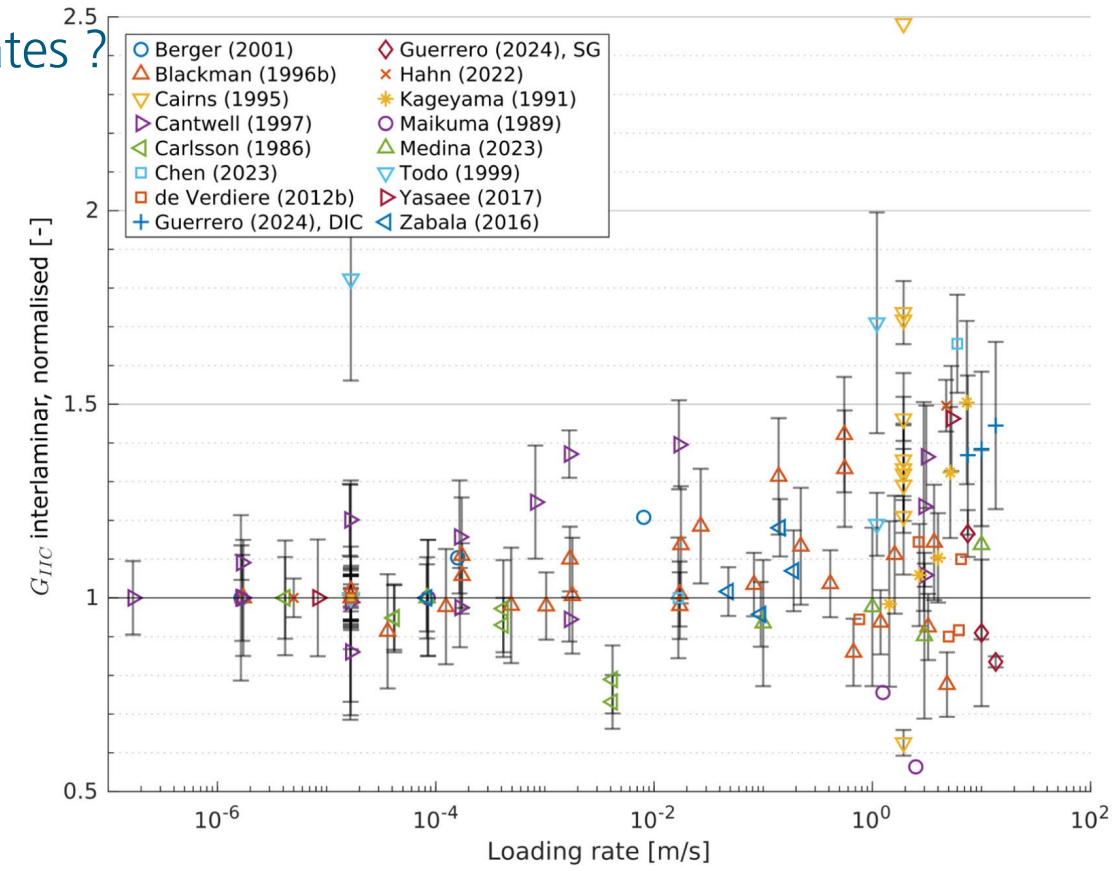
1: Fallahi, Hamed & Taheri-Behrooz, Fathollah & Asadi, Amir. (2019). Nonlinear Mechanical Response of Polymer Matrix Composites: A Review. Polymer Reviews. 60. 1-44. 10.1080/15583724.2019.1656236.

# Motivation

## Why test mode II fracture toughness at different strain-rates ?

**Does the fracture toughness change, too?**

**→ It is very hard to measure**




**Normalized mode II ERR for various UD-reinforced CFRP materials from quasi-static to dynamic loading rates[2]**

2: D. Thomson, M. Ploeckl, J. Hoffmann, M. Lißner, C. Pohl, G. Quino, K. Ramakrishnan, M. Toenjes, H. Cui, N. Petrinic, A review of the effect of loading rate on the mechanical properties of unidirectional carbon fibre reinforced polymer composites, Composites Part A: Applied Science and Manufacturing, Volume 193, 2025, https://doi.org/10.1016/j.compositesa.2025.108773.

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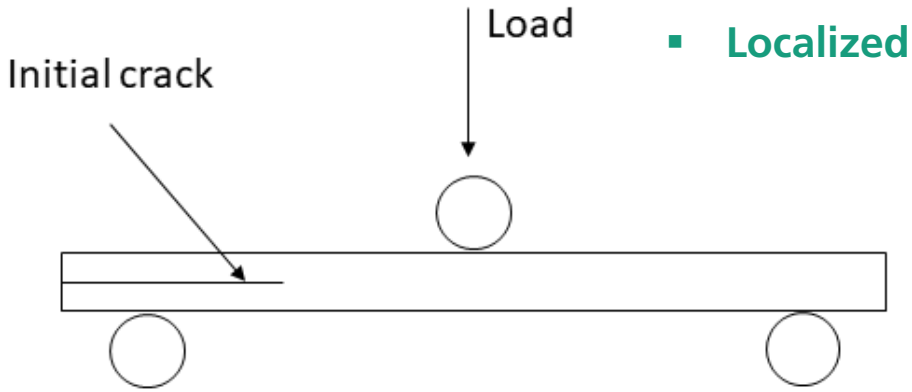
# Challenges of high-rate mode II testing

## What defines loading rate in mode II:

- Velocity of the test machine?
- Strain rate of the specimen?
- Shear rate at the crack tip?
- Crack velocity?

## Measurement challenges:

- Inertia effects
- Oscillations in the load signal
- Difficult crack tracking
- Asymmetrical specimens
- Localized stress peaks within the specimen




Michael May, Harichandana Channammagari, Philipp Hahn, High-rate mode II fracture toughness testing of polymer matrix composites – A review, Composites Part A: Applied Science and Manufacturing, Volume 137, 2020, https://doi.org/10.1016/j.compositesa.2020.106019.

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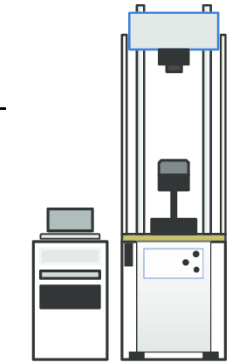
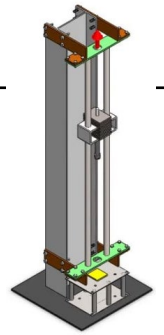
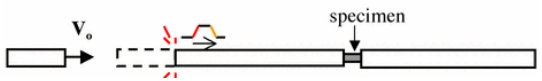
# Challenges of high-rate mode II testing

## How to achieve fast loading of specimen

| | | Large displacements | Constant test velocity | Force measurement |
|---|---|---|---|---|
|  | Servo-hydraulic testing machine | ++ | + | - - |
|  | Drop-tower | + | - | - - |
|  | Split-Hopkinson-Bar | - | + | ++ |

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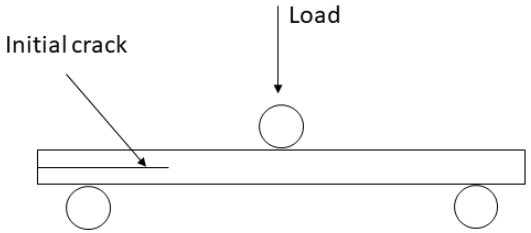
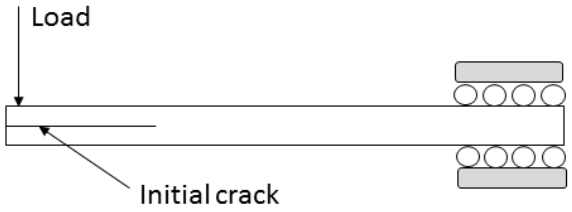
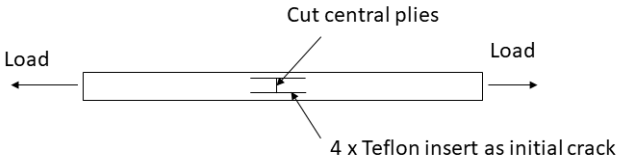
# State of the Art test methods

## Which test is most suitable for high-rate testing?

| | Test | Positive + | Negative - |
|---|---|---|---|
|  | **End notched flexure (ENF)** | - widely used in static<br>- standardized data reduction | - Unstable crack growth<br>- 3- or 4-point bending fixture needed |
|  | **End loaded split (ELS)** | - stable crack growth<br>- standardized data reduction<br>- no crack length needed | - complex fixture needed<br>- unsymmetric |
|  | **Transverse crack tension (TCT)** | - simple tensile test<br>- closed form solution, only using max. force | - through-the- thickness stresses affect fracture toughness<br>- not calibrated yet<br>- no standard |

**Michael May, Harichandana Channammagari, Philipp Hahn, High-rate mode II fracture toughness testing of polymer matrix composites – A review, Composites Part A: Applied Science and Manufacturing, Volume 137, 2020, https://doi.org/10.1016/j.compositesa.2020.106019.**

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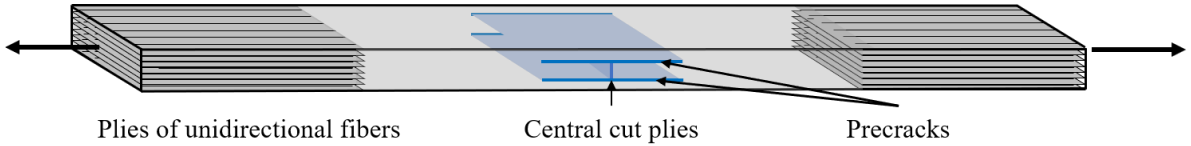
# Our Experience with the TCT test

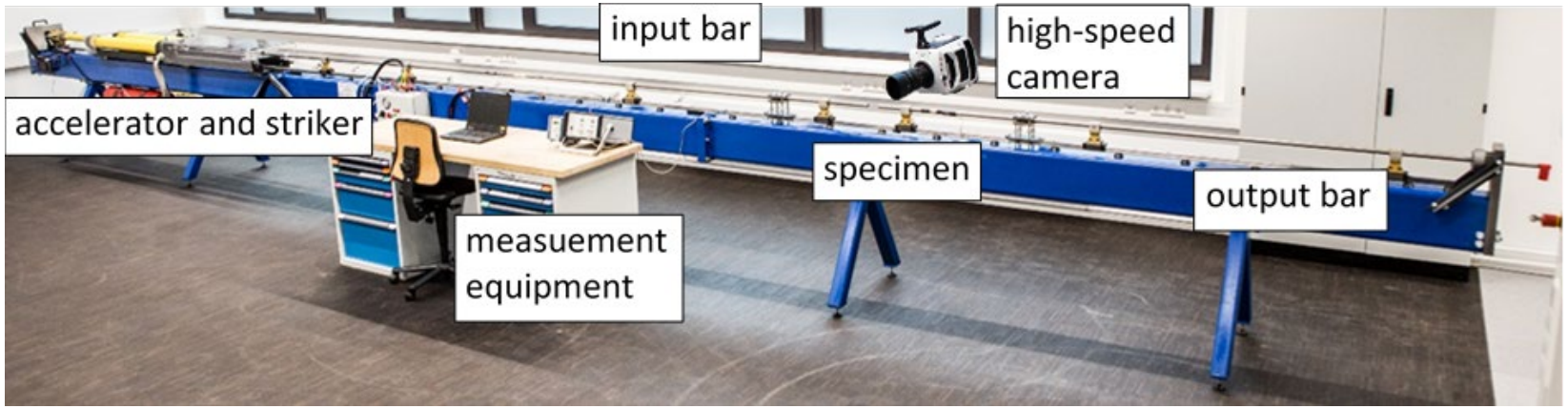



- Quasi-static TCT sample show 27% higher fracture toughness than ENF → Further analyses needed
- Big standard TCT and scaled-down TCT specimen for high-rate tests show similar results
- Scaled-down TCT specimen tested in high rate show about 60% more fracture toughness → loading rate effect


Challenges:

- Through-the-thickness stresses change fracture toughness
- The four cracks do not start simultaneously

→ Further analyses needed!




**Philipp Hahn, Harichandana Channammagari, Mathieu Imbert, Michael May, High-rate mode II fracture toughness testing of polymer matrix composites using the Transverse Crack Tension (TCT) test, Composites Part B: Engineering, Volume 233, 2022, https://doi.org/10.1016/j.compositesb.2022.109636.**

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# Thank you!