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Double Action High Rate Fracture Tests

Zoltán MAJOR[1], Michael LACKNER[1] and Tamás Mankovits[2]

1) Johannes Kepler University Linz – Institute of Polymer Product Engineering, Altenberger Straße 69, 4040 Linz, Austria, E-mail: zoltan.major@jku.at;
2) Institute of Mechanical Engineering, University of Debrecen, Hungary

Introduction and scope

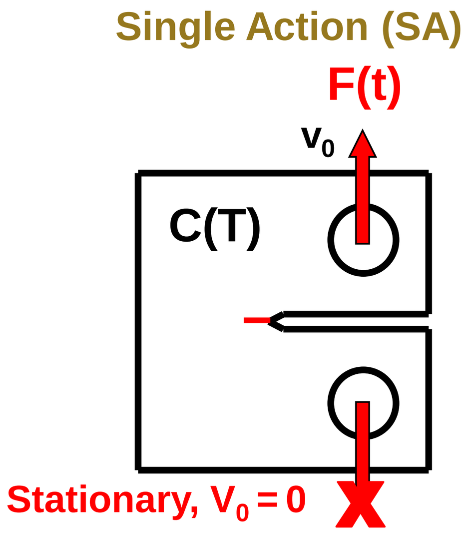
Due to the dynamic effects the applicability of conventional bending type impact tests (i.e., Charpy test) is limited and a force-based fracture mechanics analysis provides reliable results only up to about 1 m/s. Two overcome these problems two methods are proposed:

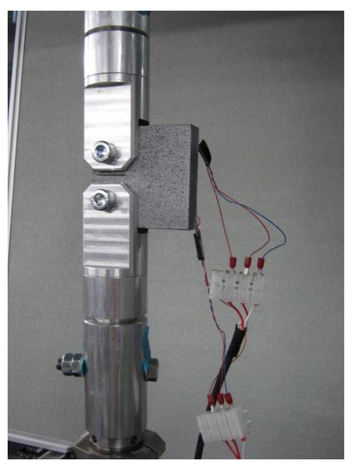
- **Tensile fracture tests.** However, due to the single action loading mode, an asymmetry of the crack tip stress field was observed [1]. This dynamic mixed mode loading condition of the crack tip makes the determination of true mode I fracture toughness using the load signal above 6-8 m/s difficult.
- **Dynamic methods** (i.e. Dynamic Key Curve [refs]) may be used to determine dynamic fracture toughness values above 1 m/s [2]. These methods are complicated both from experimental and from a data reduction point of view and require the determination a number of different loading rate dependent material parameters.

Test Set-ups and Instrumentation

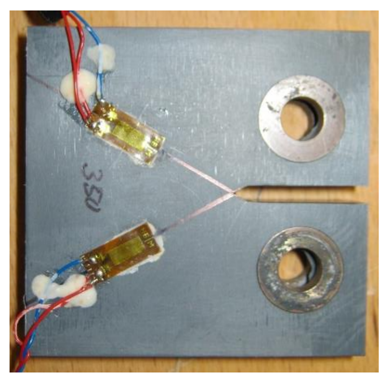
Tensile Type Fracture Specimens and Test Set-ups

Single Action (SA) Impact Tensile Test (one actuator up to 12 m/s)

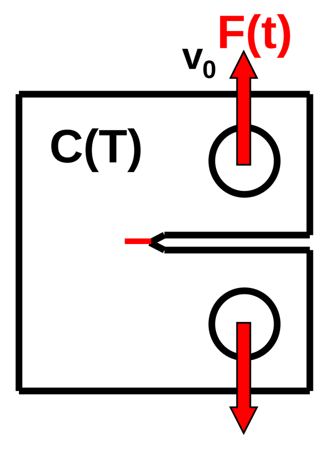


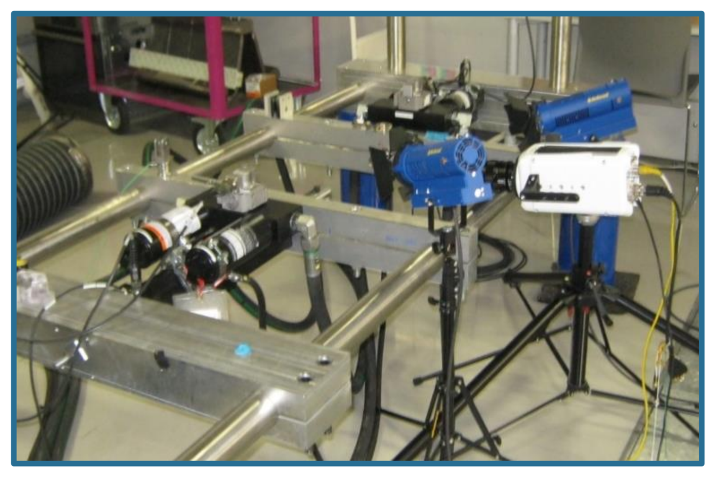


Strain gage instrumentation of the compact tension (CT) specimen



Double Action (DA) Tensile Fracture Test (two loading actuators up to 4 m/s)

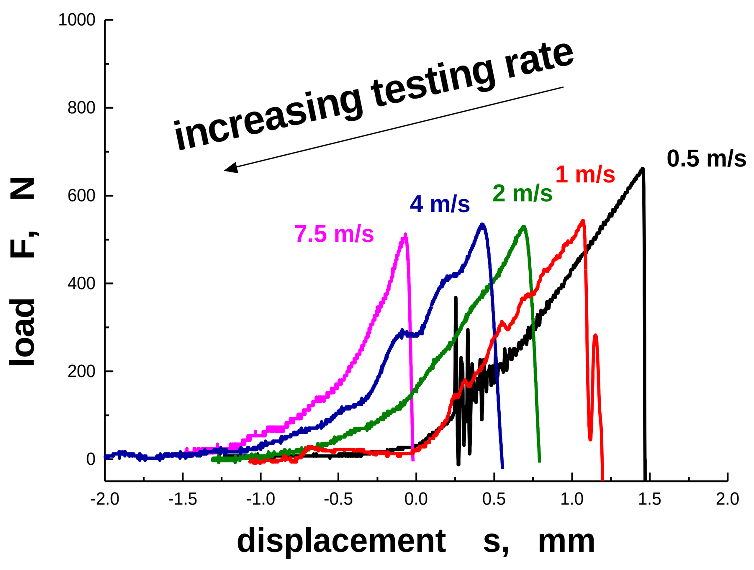




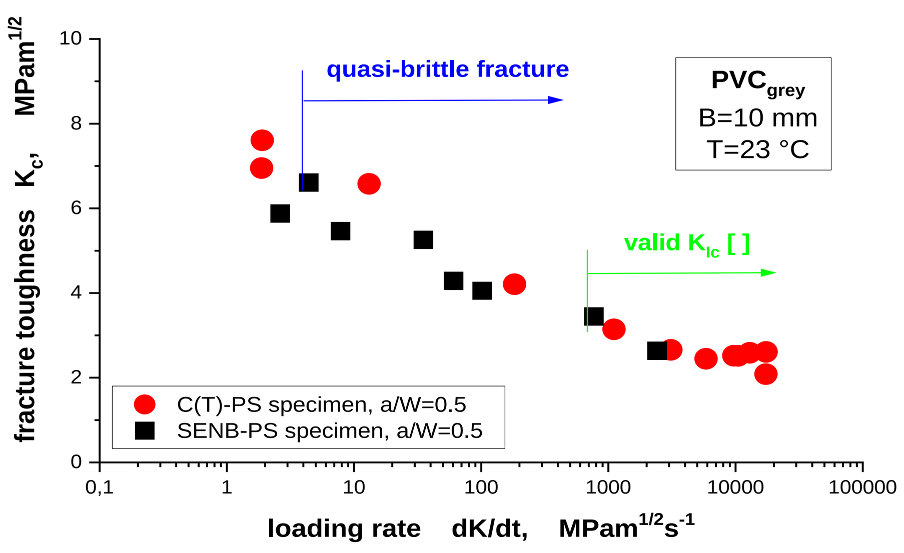
Slack adapter or rope

Results

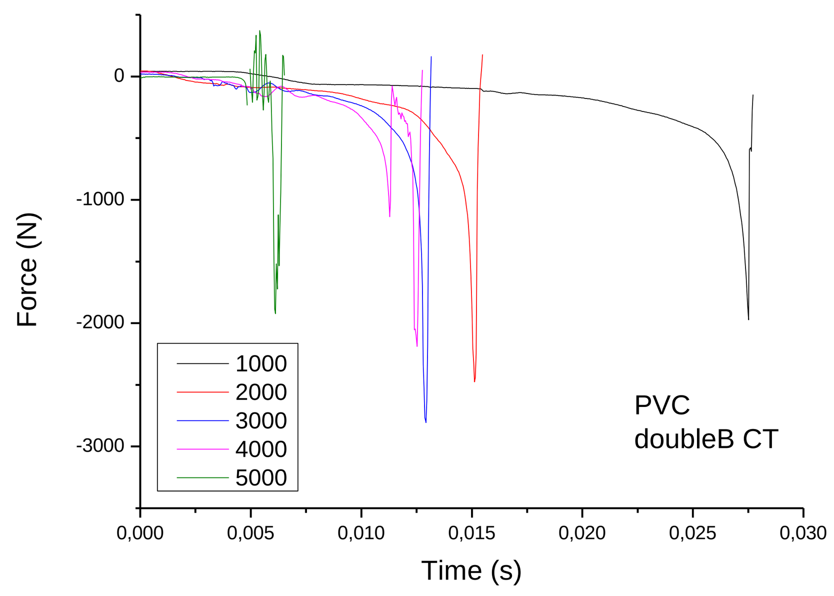
Load-Displacement Curves (SA)

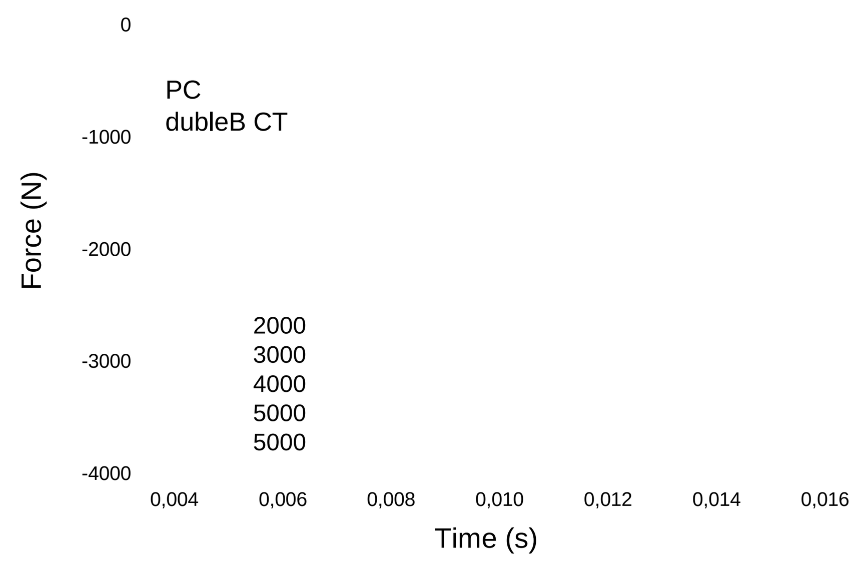


Fracture Toughness

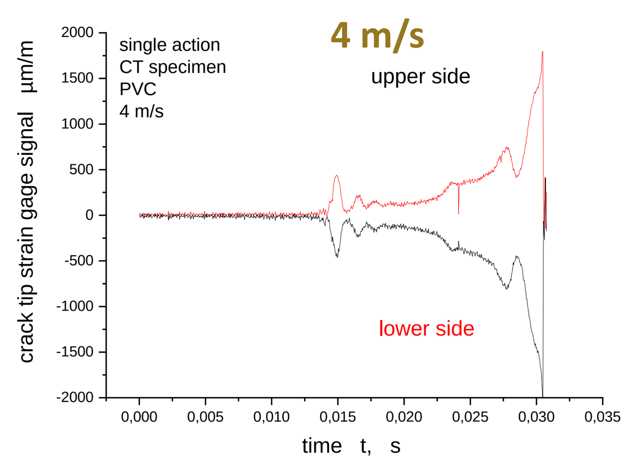


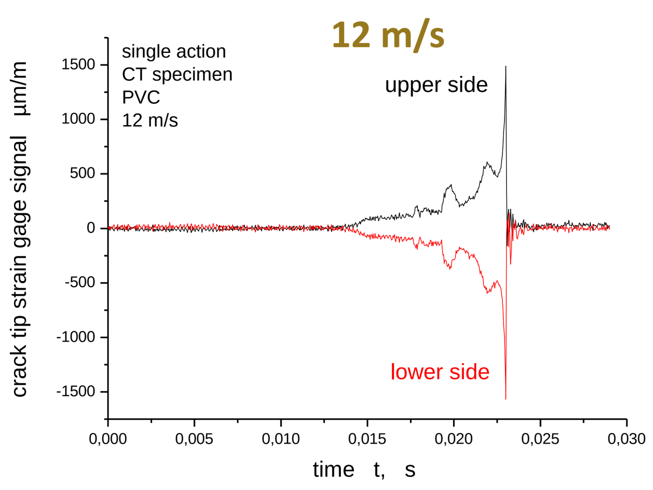
Load-Displacement Curves (DA)



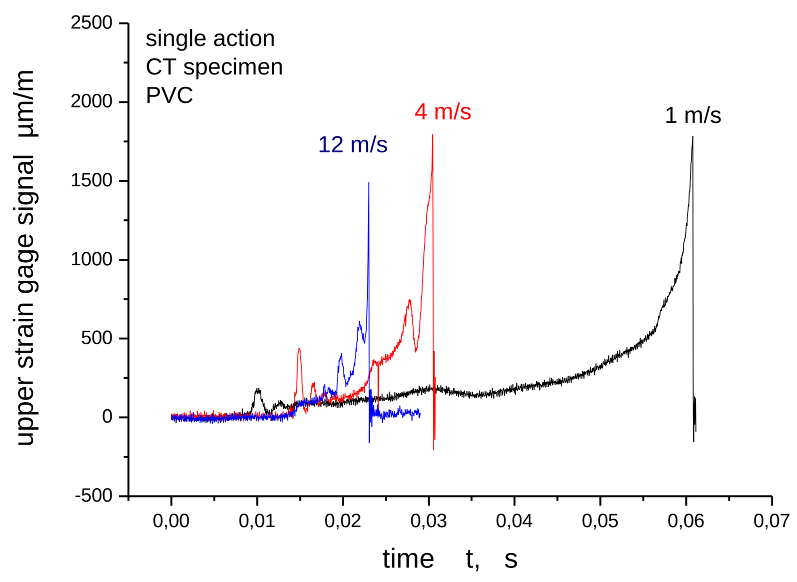


Single Action Impact; Strain Gage Instrumented CT Specimens



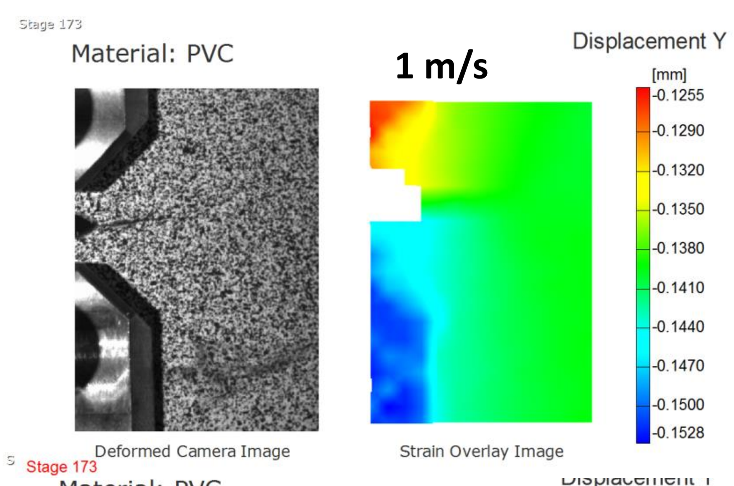


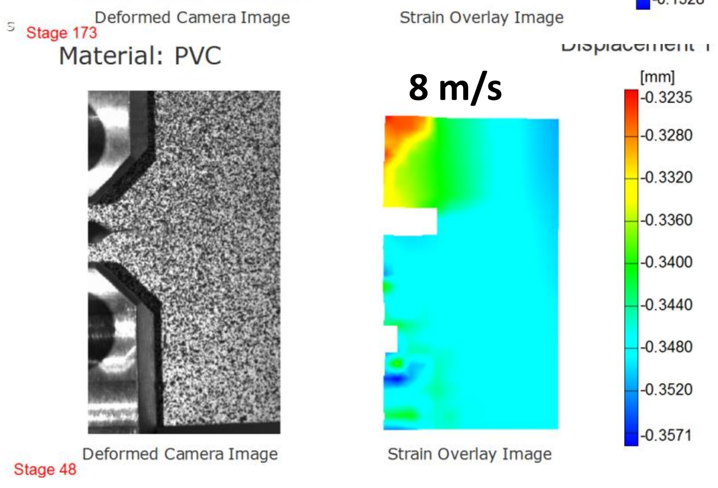
A slight decrease of the crack top strain gage signals was observed



With increasing loading rate somewhat higher difference between the upper (stationary) and lower strain gage (actuator) was observed.

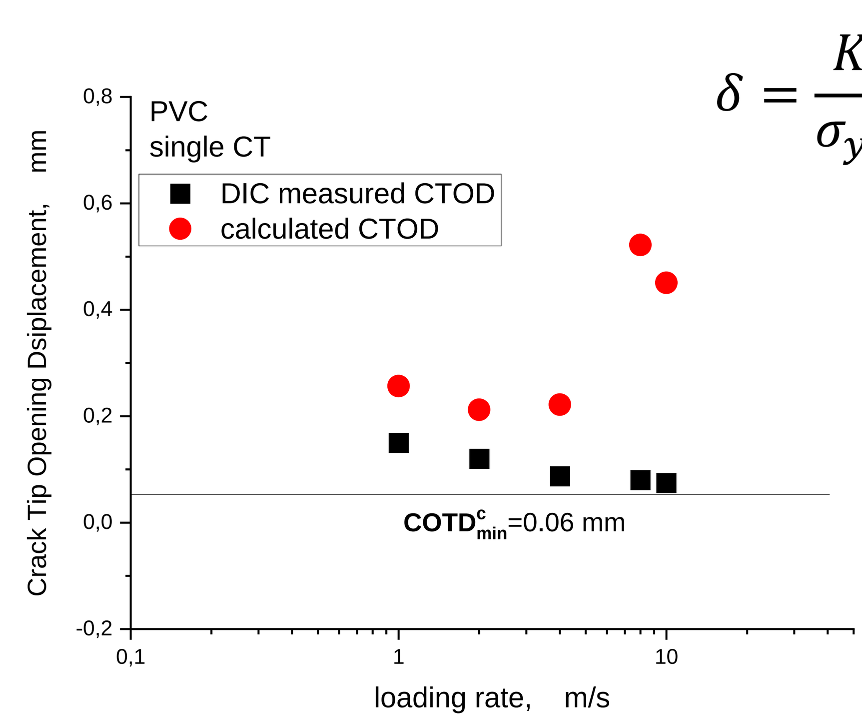
Single Action Impact; High Speed Camera and DIC – Determination of CTOD





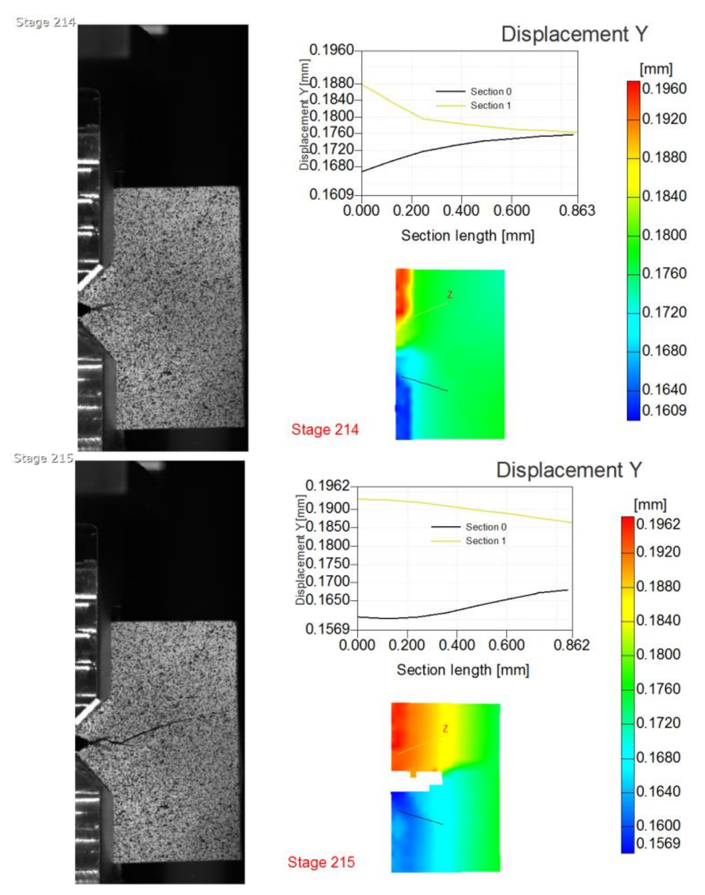
Loading rate dependent E and σ_y were used

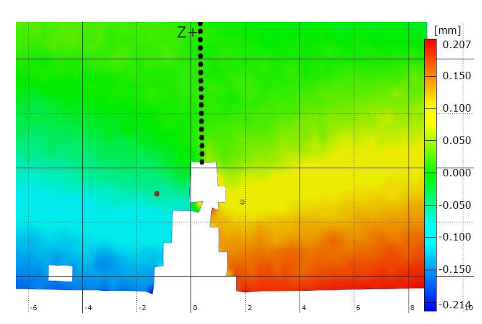
$$\delta = \frac{K_I^2}{\sigma_y E}$$

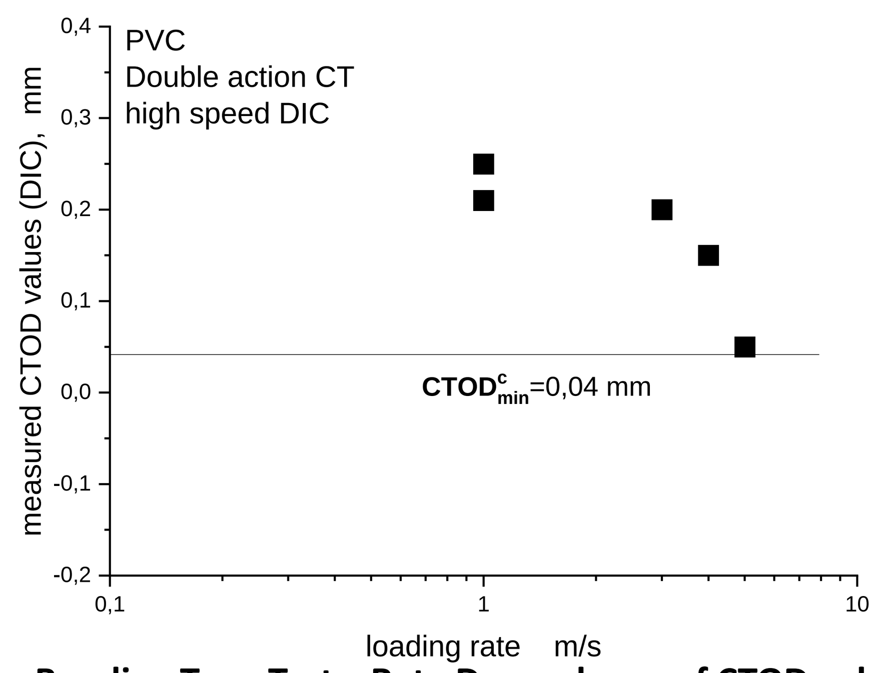


Tensile Fracture Tests: Rate Dependence of CTOD values

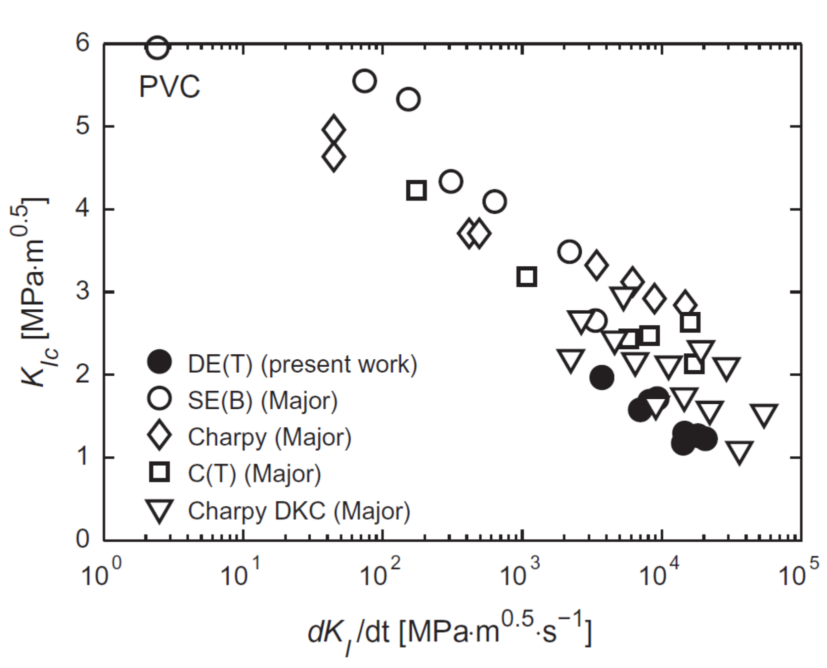
Double Action Impact; High Speed Camera and DIC – Determination of CTOD

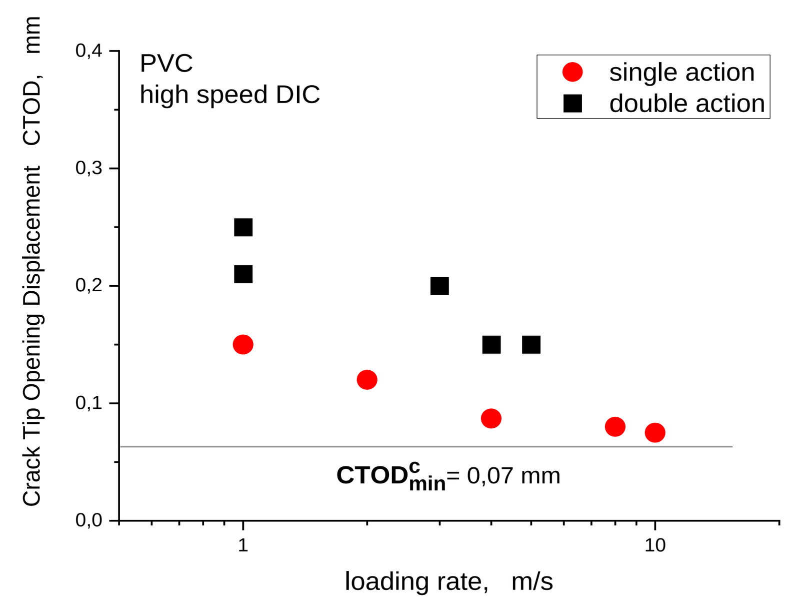




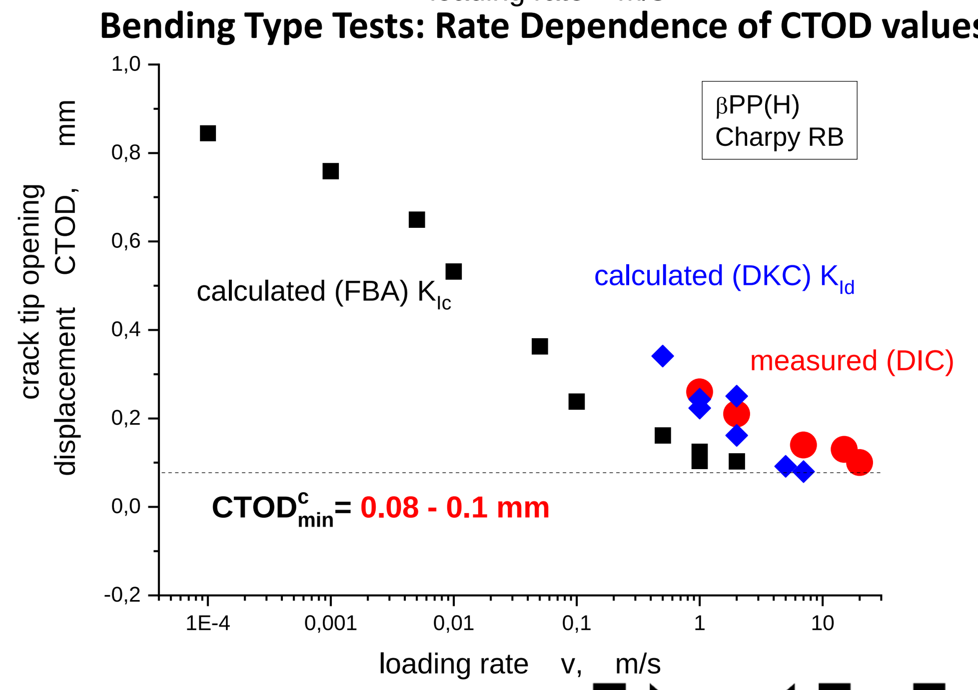


Summary and Future Work





Bending Type Tests: Rate Dependence of CTOD values



The extensive characterization work using both bending and tensile fracture tests has shown a clear rate dependence of the fracture toughness for a number of polymers investigated. These results were verified several times by comparing with the results of other laboratories [3].

The double impact test setup requires two synchronized twin actuators. Due to the large compliance of the slack adapters in the load line the mechanical synchronization is difficult. Generally, a high data scatter of the peak loads was observed, hence the determination of fracture toughness values is unreliable. The measured and calculated Crack Tip Opening (CTOD) values revealed a more consistent rate dependence. The **critical tensile CTOD values (0,04 to 0,06 mm)** were somewhat lower than **the bending CTOD values (0,08 to 0,1 mm)** over the entire loading rate range investigated. As it was shown [2] before, the determination of rate dependent fracture toughness values is more reliable using displacement based methods.

Future work

The double action impact test setup will be further developed and in addition to the bulk polymer fracture test, it will be used for medium rate (up to 8 m/s) mode I laminate testing of thermoplastic composites.
Cooperation with the Technical University of Prague (Prof Ondrej Jirousek).

Institute of Polymer Product Engineering

References

1) Ph. Beguelin, H. H. Kausch, Journal of Materials Science 29 (1994) 91-98
2) P.S. Leevers et al, Polymer Testing, Volume 33, February 2014, Pages 79–87
3) H.A. Visser, F. Caimmi aand A. Pavan, Engineering Fracture Mechanics 101 (2013) 67–79

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