Karlsruhe Institute of Technology

Institute of Mechanics

A continuum-micromechanical model for crazing in glassy polymers under cyclic loading

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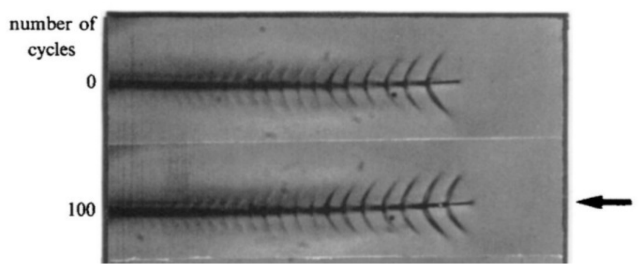
Introduction

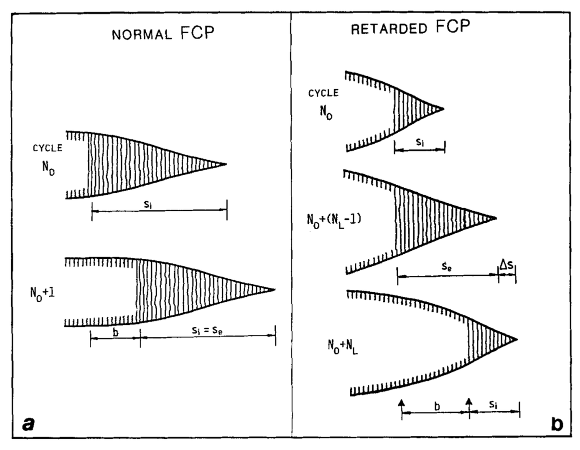
Motivation: Interesting features in fracture processes observed experimentally while theoretical studies are rare, e.g.

- interaction between crazing and shear yielding may lead to ε-shaped crack pattern
- RFCP: craze thickening as competition between creep and drawing

Aim: Development of physically-motivated crazing model for cyclic loading



ε-shaped fatigue crack in PC (Takemori [4])

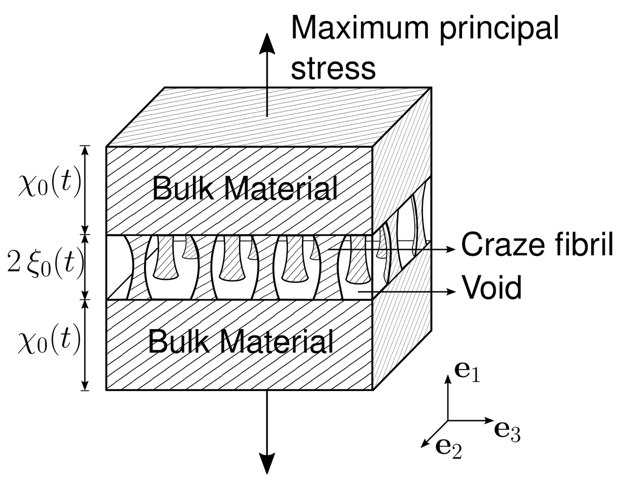


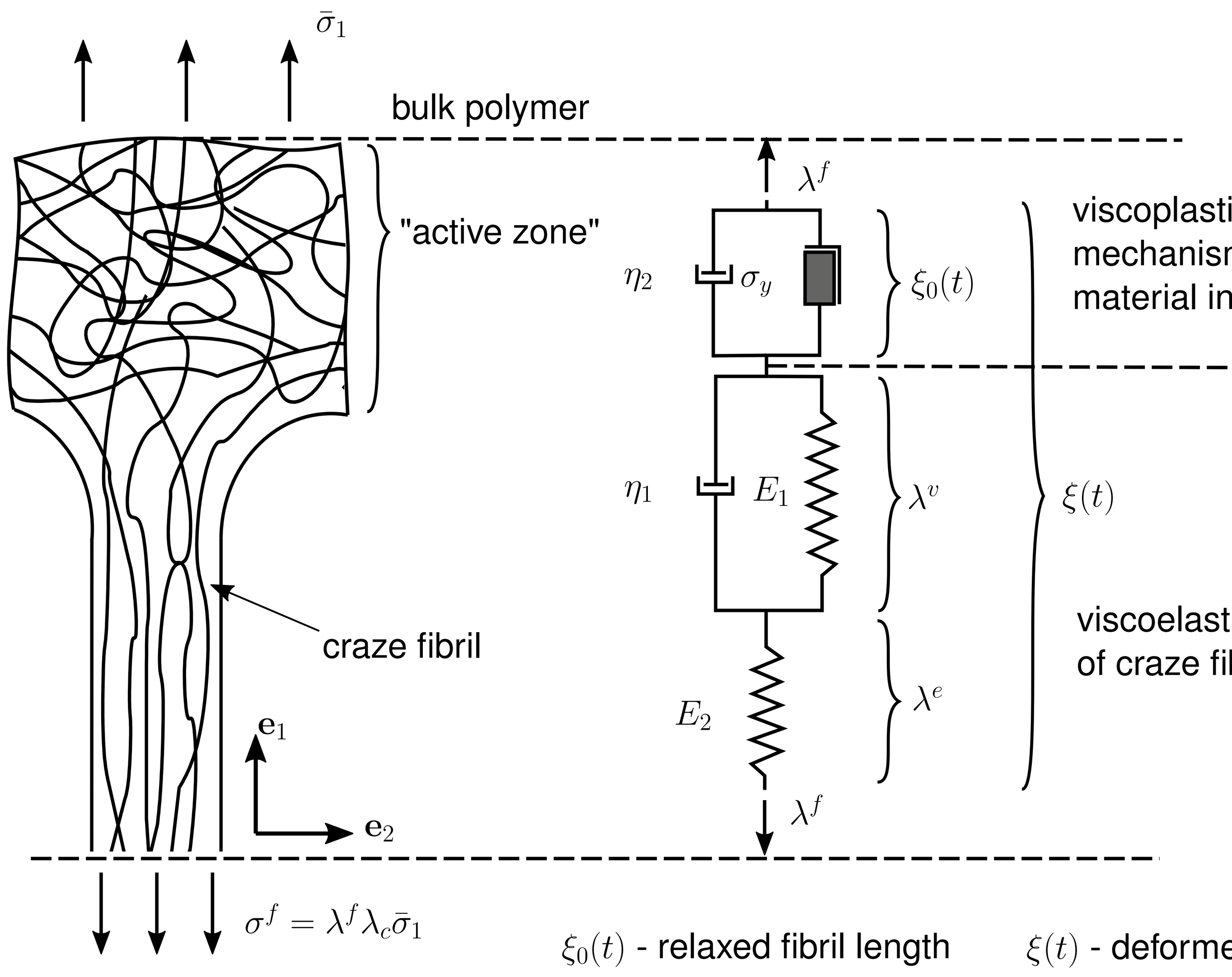
Fatigue crack propagation (Könczöl et al. [2])

Constitutive model

Model encompasses:

- craze initiation
- continuous morphology change via extension ratio $\lambda_c = \lambda_c(\xi_0)$ from craze initiation (i.e. $\lambda_c = 1$) up to fully developed craze (i.e. $\lambda_c = \lambda_{c,max}$)
- thickening due to
  - viscoelastic stretching
  - viscoplastic drawing mechanism: $\dot{\xi}_0 = \frac{h_0}{\eta_2} < \sigma^b - \sigma_y >$
- loose hanging fibrils during unloading: $\sigma^f \geq 0$
- craze breakdown when primordial thickness h_0 is consumed



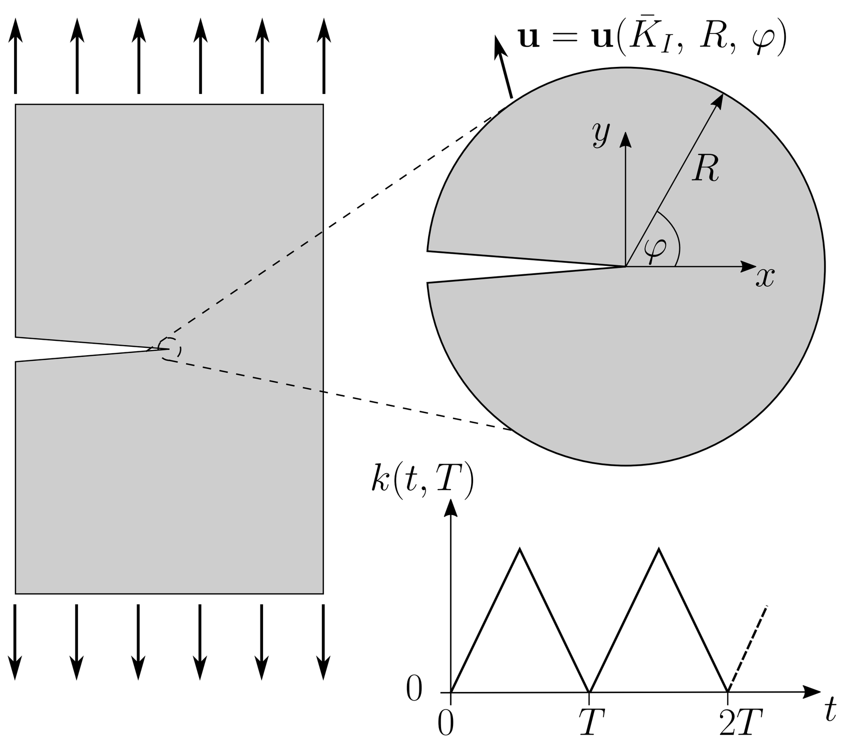


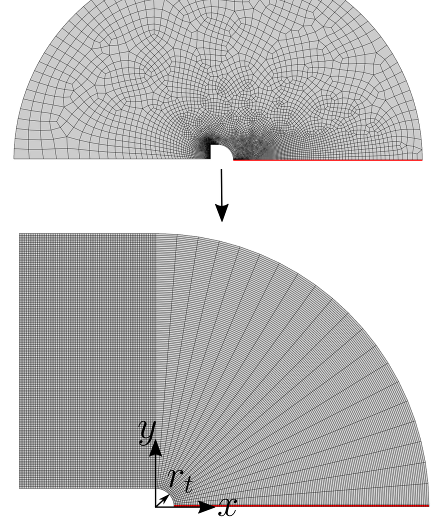
$\xi_0(t)$ - relaxed fibril length
$\xi(t)$ - deformed fibril length
η_1 - fibril viscosity
η_2 - drawing viscosity
σ_y - "yield" stress
λ_c - extension ratio

Three characteristic times related to:

- fibril defo $\tau_1 = \eta_1/E_1$, drawing $\tau_2 = \eta_2/E_2$ and loading period T

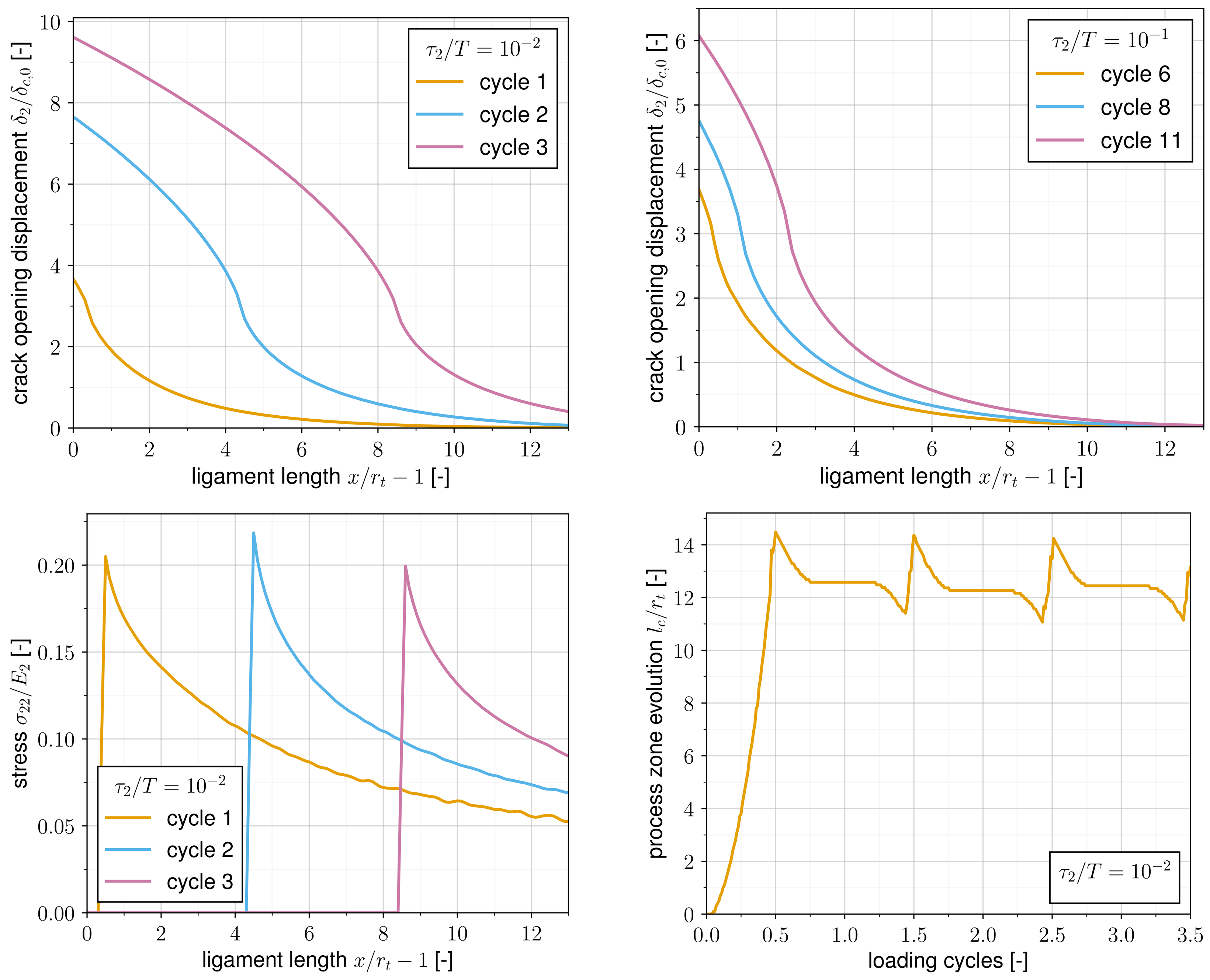
Mode I crack tip - small scale yielding





- K-controlled loading with linear-elastic bulk material
- Investigated parameter: τ_2/T

Results



- Higher drawing viscosity yields smaller crack growth rate
- Stress distribution without second stress peak (cf. Kambour [1])
- Variation of process zone length l_c due to different rates of craze tip and crack tip advance in the course of load cycle

Outlook

- Extension ratio as function of stress in active zone (cf. Lauterwasser and Kramer [3])
- Pinching of fibrils during crack tip closure
- Viscoplastic bulk material model (e.g. Boyce) to account for interaction between crazing and shear yielding

[1] Kambour, R. P. Stress-strain behavior of the craze. In: *Polymer Engineering and Science*, 8(4): 281–289, 1968. ISSN: 0032-3888.
[2] Könczöl, L., Döll, W., and Bevan, L. Mechanisms and micromechanics of fatigue crack propagation in glassy thermoplastics. In: *Colloid & Polymer Science*, 268(9): 814–822, 1990. ISSN: 0303-402X.
[3] Lauterwasser, B. D. and Kramer, E. J. Microscopic mechanisms and mechanics of craze growth and fracture. In: *Philosophical Magazine A*, 39(4): 469–495, 1979. ISSN: 0141-8610.
[4] Takemori, M. T. Fatigue fracture of polycarbonate. In: *Polymer Engineering and Science*, 22(15): 937–945, 1982. ISSN: 0032-3888.