Derivation and Validation of a Mechanically Consistent Continuum Damage Model for Brittle Composite Materials

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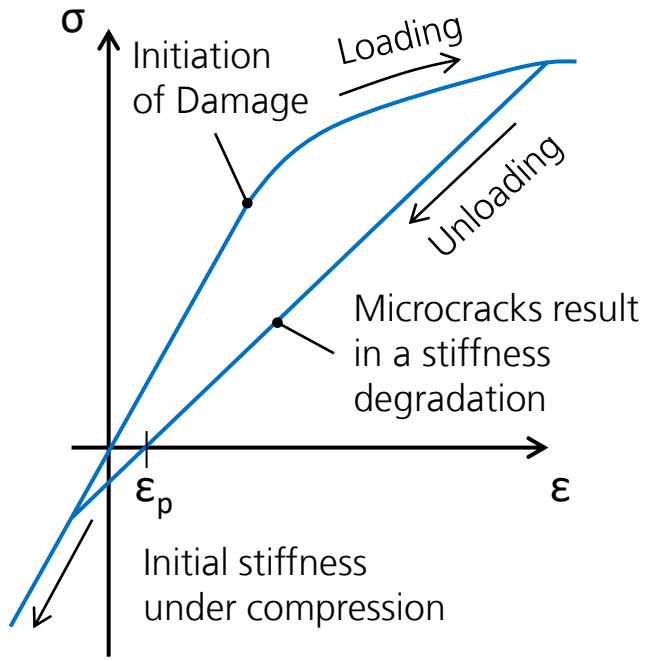
Continuum Damage Mechanics of Brittle Anisotropic Materials

Motivation

- Damage modeling of brittle Ceramic Matric Composites (CMCs)
  - Stiffness degradation caused by microcracks due to mechanical or thermal loading
  - Due to the (woven) microstructure anisotropic damage evolution and effect
  - Damage effect is deactivated due to crack closure for "compressive" loading
  - Small amount of plastic deformation possible
- Damage deactivation with a continuous stress-strain relation [Chaboche 1993]
- Mechanically consistent if stiffness decreases by damage [Wulfinghoff2017]:

$$\varphi(\varepsilon, D) \geq \varphi(\varepsilon, D + dD) \quad \text{for all admissible } \varepsilon, D, dD$$

→ For most Models not fulfilled [Lemaitre 1996, Chaboche 2001,…]



Stress-strain behavior of a damaged brittle composite material

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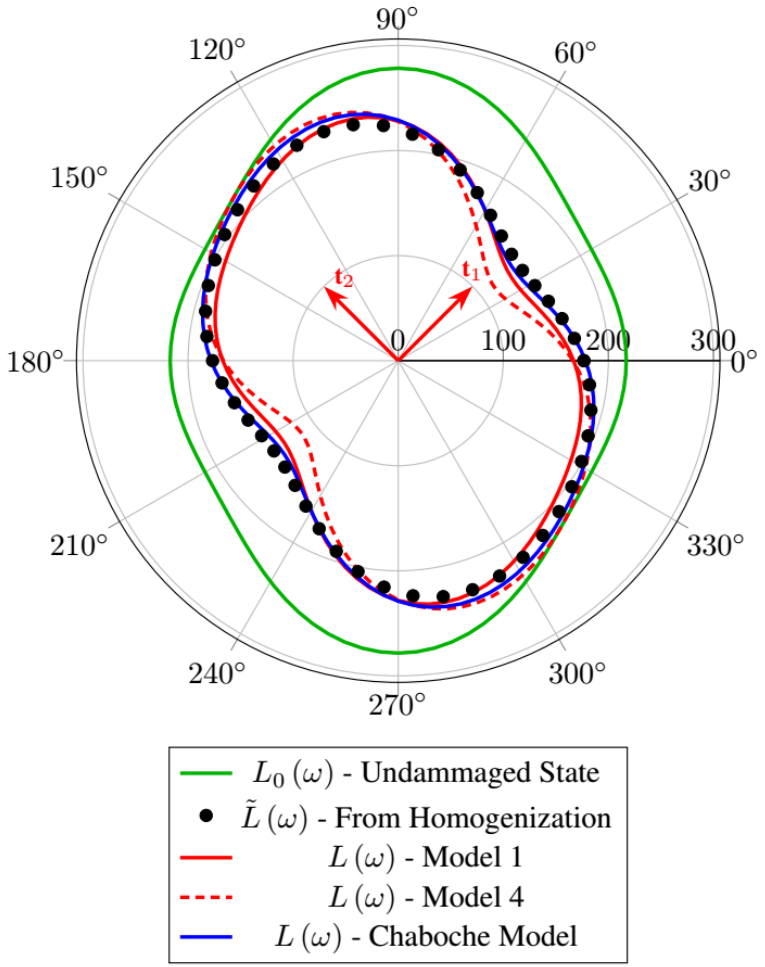
Model Formulation

- Model formulation
  - Neglects plastic deformation (1. Step)
  - Linear damage effect
  - Based on an invariant representation with orthotropic Invariants $I_1, \dots, I_{18}$
  - Reduction by restricting the damage state D to in-plane damage
  - Reduction by the damage growth criterion
  - → Mechanically consistent damage effect model with 6 Material Parameters
  - → Damage deactivation that results in a continuous (C^0) stress-strain relation
- Model validation by virtual test data using simple homogenization approach (dilute crack distribution in anisotropic matrix)

Model Validation by Homogenization Results



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Damage Deactivation by closed microcracks