KUNSTSTOFF TECHNIK LEOBEN

MATERIALS SCIENCE AND TESTING OF POLYMERS
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Biomimetic concepts for toughness optimization

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Transfer of fracture mechanical concepts from the skeleton of the deep-sea sponge Euplectella aspergillum to mineral reinforced polymers

For a multitude of technical applications, the material toughness is essential to prevent critical failure of structural parts. Inspired by biological concepts, ongoing research now tries to enhance the toughness of brittle polymeric materials by introducing soft interlayers. A single interlayer of soft PP was introduced into a matrix of highly mineral reinforced PP.

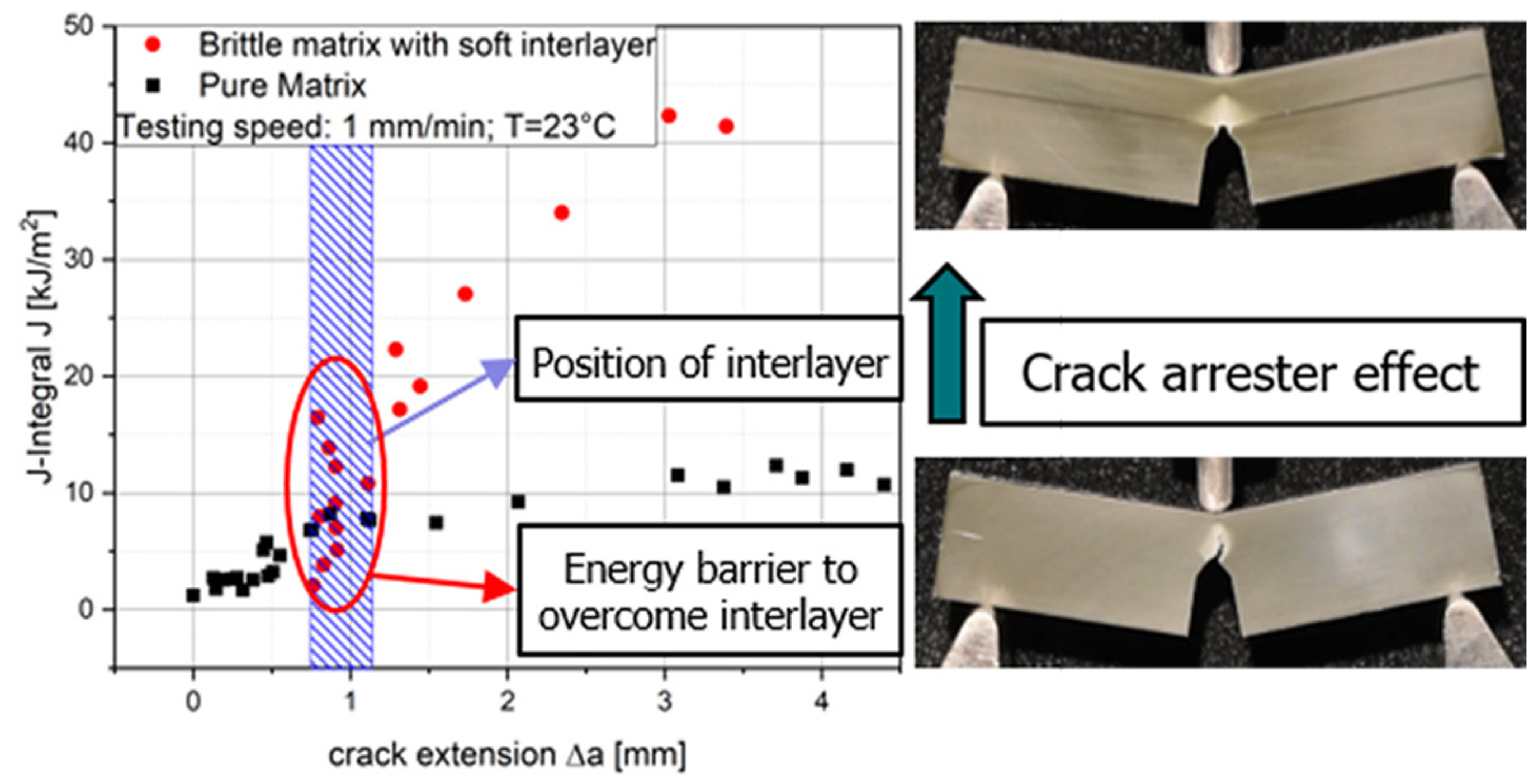


Fig.2: Thoughness increase in SENB specimens due to the material inhomogeneity effect.

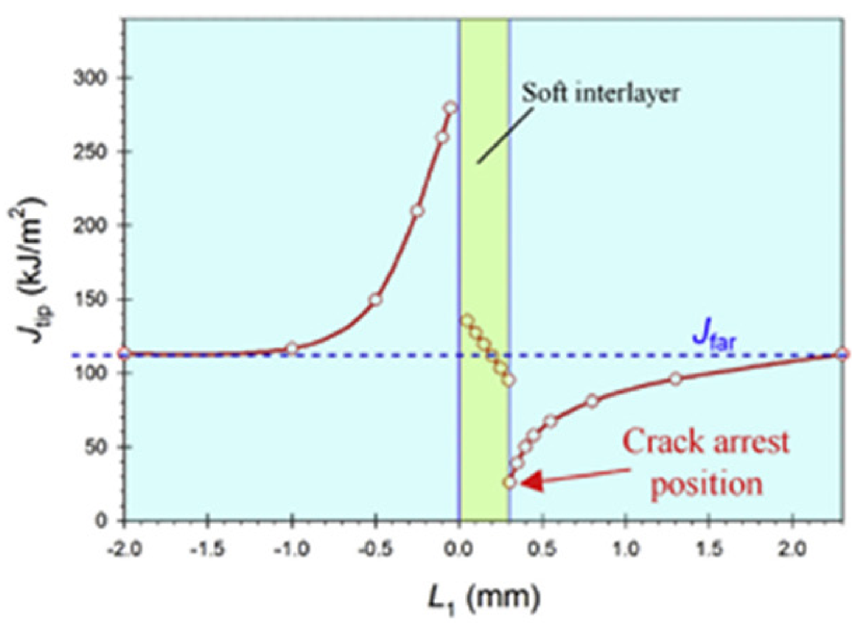
Fig.1: Creation of a crack arrest position by introducing a single soft interlayer.

$$\frac{J_{tip}}{J_{far}} = 1 + \frac{C_{IL}}{J_{far}} = 1 + \frac{C_{inh1}}{J_{far}} + \frac{C_{inh2}}{J_{far}}$$

Most influential parameter: mismatch in elastic properties between the two phases

$$\frac{C_{inh1}}{J_{far}} = \frac{1}{2\pi}\left\{\mathrm{Re}\left(\mathrm{arctanh}\sqrt{1-\left(\frac{L_1}{r_y^{IL}}\right)^2}\right) - \mathrm{Re}\left(\mathrm{arctanh}\sqrt{1-\left(\frac{L_1}{r_y^{IL}}\right)^2\left(\frac{\sigma_y^M}{\sigma_y^{IL}}\right)^4}\right)\right\}$$

$$\frac{C_{inh2}}{J_{far}} = \frac{1}{2\pi}\left\{\mathrm{Re}\left(\mathrm{arctanh}\sqrt{1-\left(\frac{L_2}{r_y^{IL}}\right)^2\left(\frac{\sigma_y^M}{\sigma_y^{IL}}\right)^4}\right) - \mathrm{Re}\left(\mathrm{arctanh}\sqrt{1-\left(\frac{L_2}{r_y^{IL}}\right)^2}\right)\right\}$$



J_{tip}...near-tip J-integral
J_{far}...far-field J-integral
C_{IL}, C_{inh1}, C_{inh2}...inhomogeneity terms
L_1, L_2...distance between the crack tip and interface 1 and 2
r_y^{IL}...radius of the crack tip plastic zone
σ_y^M...yield stress of the matrix
σ_y^{IL}...yield stress of the interlayer

Sistaninia and Kolednik, 2017

The process of cracking in such inhomogeneous materials can be described using elastsic plastic fracture mechanics (Fig. 1). More specifically, the local crack driving force J_{tip} in the vicinity of an interlayer can be drastically different from the global loading parameter J_{far}. This material inhomogeneity effect can be utilized to tailor a local minimum of J_{tip} which serves as crack arrester. On a macroscopic scale, this translates to an energy barrier that has to be overcome by a growing crack. For tested SENB specimens, the total amount of consumed energy J exhibits a significant increase after the crack reaches the interlayer (Fig. 2).

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RESEARCH FOCUS: biomimetic polymers, applied fracture mechanics with specific focus on optimizing fracture toughness

PROJECT: BioMimic Polymers
PROJECT PARTNERS: Erich-Schmid-Institut für Materialwissenschaft der österreichischen Akademie der Wissenschaften, Materials Center Leoben Forschung GmbH
FUNDING: Austrian Research Promotion Agency (FFG)