NEW CONCEPTS FOR THE DESIGN OF FUTURE FRACTURE RESISTANT AND DAMAGE TOLERANT COMPOSITES

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ABSTRACT
In this presentation, it is tried to transfer the idea of enhancing the fracture resistance by introducing compliant interlayers to technical composite materials where both, the matrix and the interlayer material, behave elastic-plastic. In a first step, it has been shown that spatial variations of the yield stress \( \sigma_y \) in materials with constant elastic modulus \( E \) can also improve the fracture resistance (Kolednik et al. 2010, Sistaninia and Kolednik 2014). Experiments have been conducted to validate the computational results on composites with various types of interlayer exhibiting inhomogeneity of the yield stress \( \sigma_y \) alone and inhomogeneity of both \( \sigma_y + E \), (Zechner and Kolednik 2013).

Keywords: Composites, fracture resistance, biological material

INTRODUCTION
Certain biological materials, such as deep-sea glass sponges (Fig. 1a), have a microstructure consisting of layers made of hard and brittle bio-glass and thin, compliant protein interlayers.

Fig. 1 - (a) Skeleton of the deep sea sponge *Euplectella Aspergillum*. (b) A thin, compliant layer in a material with high Young’s modulus \( E \) leads to a strong decrease of the crack driving force \( J_{tp} \) when the crack enters the interlayer.
It has recently been revealed by numerical investigations applying the concept of configurational forces, see e.g. Gurtin 2000, that the multi-layered structure with strong spatial variation of the Young’s modulus between the stiff bio-glass and the compliant protein is the dominant reason for the high fracture resistance and damage tolerance of the glass sponge. The reason is that the crack driving force strongly decreases when the crack grows into the soft interlayer (Fig. 1b), which leads to crack arrest (Kolednik et al. 2011). These compliant interlayers may lead also to considerable enhancement of the fracture strength of the composite, if the architecture of the composite fulfills certain criteria (Kolednik et al. 2014). A problem, however, is that these design rules can be applied only for elastic materials.

RESULTS AND CONCLUSION

From the results of numerical studies with the configurational force concept, optimum interlayer configurations are deduced for the different types of composites so that the interlayers work as effective crack arresters. It is shown that yield stress and thickness of the interlayer have to fulfill certain criteria, as well as the distance of the interlayers. Via fracture mechanical considerations, these criteria shall be used to work out design rules for future, especially fracture resistant and damage tolerant multilayered materials and components.

REFERENCES


