3D XFEM Modeling of Composite Failure Combining Discrete and Diffuse Damage

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For a consistent lightweight design the consideration of the nonlinear macroscopic material behavior of composites, which is amongst others driven by damage effects and the strain-rate dependent material behavior of typical polymeric matrices, is required. To this end, the authors developed a numerical modeling approach that combines the extended finite element method (XFEM) with suitable constitutive relations for the individual constituents.

The XFEM is a well recognized technique for the modeling of heterogeneous material structures. It allows for the modeling of both, weak and strong, discontinuities independent of the underlying FE mesh. In combination with a cohesive zone law it can be utilized to model discrete damage phenomena. In the present contribution the method is applied to model the interface failure between fibre and matrix material on the microscale of composites. Further failure mechanisms, such as the degradation of the matrix material, are incorporated by a continuum damage approach. In addition to these approaches, which account for the material structure and its failure mechanisms, viscoelastic and viscoplastic material models have been developed for the inelastic behavior of the polymeric matrix [3]. The structure of the overall approach allows for the description of the effective material behavior on both the micro and the meso scale.

The modeling of composites often requires the description of complex material structures. To this end, the XFEM is commonly linked to a level-set function, which is utilized to locate the discontinuity within the model domain. Since a closed analytical expression of such function is only available for special cases, e. g. for a cylinder or a sphere, the description of complex geometries can become challenging. Therefore, the authors developed a so called local level-set representation, where the the discontinuity is localized elementwise [1]. The nodal level-set values are calculated corresponding to an elementwise parametric function which is again defined by a set of discrete points of the actual interface. Such points can be easily obtained from a CT scan or a micrograph. The overall method has been extended to model curved, three dimensional structures. The usage of higher order shape functions reduces the discretization error and interelement discontinuities [2]. However, curved discontinuities require consistent integration techniques. To this end, different integration techniques have been examined regarding their error and convergence rate.

References

[1] M. Kästner, G. Haasemann, V. Ulbricht, Multiscale XFEM-modelling and simulation of the inelastic material behaviour of textile-reinforced polymers, Int J Numer Meth Eng 86 (2011) 477–498.

[2] M. Kästner, S. Müller, J. Goldmann, C. Spieler, J. Brummund, V. Ulbricht, Higher order XFEM for weak discontinuties level set representation, quadrature and application to magneto-mechanical problems, Int J Numer Meth Eng 93(13) (2012) 1345-1454.

[3] S. Müller, M. Kästner, J. Brummund, V. Ulbricht, On the numerical handling of fractional viscoelastic material models in a FE analysis, Comput Mech (2012).