Multi-scale fracture mechanics using the FEM^2/IGA^2 method

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In this contribution, we present a multi-scale fracture framework, allowing us to consider individual fracture behaviour on multiple scales. We utilize the well-known FEM^2/IGA^2-method for macroscopically modeling complex materials with heterogeneities on the micro-scale, see Schmidt et al. [1]. In this talk we address additionally the established phase-field method for fracture mechanics, see Hesch et al. [2].

To be specific, we apply the macroscopic deformation at a given point to a representative volume element via suitable boundary conditions and superimpose the macro-phasefield in this point onto the micro-phasefield of the $\mathcal{RVE}$. Introdcing a suitable homogenization technique including different fracture dissipations on the micro- and macro-scale, we obtain an energy preserving formulation. Moreover, we are able to derive consistent linearization of macroscopic stresses, the phase-field driving force and multi-field contributions for the Newton-Raphson iteration.

For the presented framework, we demonstrate its behaviour and accuracy applying a variety of benchmarks, e.g. two-dimensional fracture mode tests for the macro-scale. We investigate different crack growth behaviours, from pure micro- or macro-fracture to combined and accumulated fracture.

References

[1] F. Schmidt, M. Krüger, M.-A. Keip and C. Hesch, Computational homogenization of higher-order continua, International Journal for Numerical Methods in Engineering, 123 (2022) 2499–2529.

[2] M. Dittmann, J. Schulte, F. Schmidt and C. Hesch, A strain-gradient formulation for fiber reinforced polymers: Hybrid phase-field model for porous-ductile fracture, Computational Mechanics 67 (2021) 1747–1768.