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An enriched phase-field method for the efficient simulation of fracture processes, part 2: displacement-field approximation

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Nowadays a widely used method for the simulation of fracture processes in continuum mechanics is the phase-field method [1]. Herein the crack is represented in a regularized manner by a scalar field $\phi(\mathbf{x})$, interpolating between sound ($\phi = 0$) and broken material ($\phi = 1$). The width of the transition zone depends on a length parameter l. For $l \to 0$, the crack surface Γ converges to the sharp crack. Thereby high gradients in the phase-field as well as in the displacement-field occur. To capture these gradients accurately applying the standard Finite Element Method, an extremely fine mesh around the crack is necessary.

Within the framework of the eXtended Finite Element Method (XFEM) [2] it is possible to introduce enrichment functions, which contain information about the solution of the underlying minimization problem. It becomes apparent, that an exponential enrichment function for the approximation of ϕ leads to accurate results for Γ, independently of the mesh size. Using coarse meshes standard polynomial shape functions are not able to correctly represent the displacement jump corresponding to regions where $\phi = 1$. Therefore, also an enrichment of the displacement field approximation is desirable. Based on a 1D-solution for the fully developed crack, a sigmoid-like enrichment function for the displacement-field can be extracted directly from the solution of the phase-field. The enrichment function is chosen in a way such that it can represent a jump (in regions with a fully developed crack) and the transition between the jump and the intact material at the crack front. Several examples show the main features of the proposed enriched phase-field approach and its reduced numerical effort compared to a standard phase-field approach.

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