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ERROR-CONTROLLED ADAPTIVE MULTISCALE ANALYSIS FOR CRACK INITIATION AND PROPAGATION IN BRITTLE MATERIALS

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Abstract. The addressed research is based on linear elastic fracture mechanics for the macro-scale, so far, and on non-local continuum damage mechanics with linear kinematics until micro-cracking on micro-scale. The material considered is alloyed ceramics (Yttria (3Y) stabilized (with 2%-3%) tetragonal Zirconia-Oxide -- a polycrystalline ceramic 3Y-TZP). The main goals are: error-controlled adaptive modeling and numerical approximations on both scales, including error estimators for quantities of interest. This also needs energy consistent projections from micro- to macro-scale and backwards. The final objective is defined as coupled micro-macro damage and crack propagation processes for technologically interesting problems. This is scheduled in an overall adaptive scheme, trying to realize step by step verification and validation of this coupled process.

Our current results are based on new explicit and implicit residual error estimators for the eXtended Finite Element Method (XFEM), including goal-oriented error estimation [1,2]. Special features of singular enrichment functions within XFEM are also discussed. In particular, it is shown that a significant reduction of the discretization error in crack tip element is achieved by using a statically admissible asymptotic displacement field in the XFEM discretizations. Alternative to XFEM, the adaptive Singular Function Method (SFM) is considered, including new explicit residual (constant-free) error estimator for low order triangles [3], yielding very good effectivity indices between 1 and 2.

Modeling of microcrack nucleation and coalescence in ceramic specimen is realized within the framework of Continuum Damage Mechanics (CDM), in particular in terms of a non-local damage model using the enhanced gradient formulation [4]. Error estimation analysis for this coupled problem and results of adaptive mesh refinements are presented. A major point is the transition from continuous damage to equivalent micro-cracks, using energetic equivalence between damage and fracture [5].

A two-scale coupling of the above two processes is presented. The transition between the two scales is realized by the multiscale projection method.

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