Multi-axial loadings in phase field model of fracture: Part 2

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Phase field modeling of fracture is gaining popularity in the fracture mechanics community, particularly for its ability to generate cracks with arbitrarily complex geometries and topologies in two and three dimensions without the need for ad hoc criteria. The model first introduced in [1] has a clear connection with Griffith's propagation criterion via Gamma convergence tools and further results [2] have shown that, in addition to propagation, it can quantitatively predict crack nucleation for mode-I loading. However, the initial model cannot reproduce with flexibility the experimentally measured strengths under multiaxial loads. Moreover, a modification is necessary to avoid the interpenetration of crack surfaces in compression and reflect the physical asymmetry of fracture behavior between tension and compression [3]. New models are often validated through different case studies that show specific potentials, making their comparison not immediate and analysis of limitations not straightforward. Among these contributions, some preserve the variational nature of the phase field model [3, 4, 5, 6] while others seek flexibility by stepping outside the variational framework [7]. The most popular variational solutions [3, 4] are based on elastic energy decompositions. This idea is adopted in [5, 6], justified through structured deformation theory.

In light of the criteria defined in the first part of the presentation, we examine the influence of different softening laws on the volumetric and deviatoric components of the strain energy density. We then evaluate a new model that is based on distinctive volumetric-deviatoric softening behaviors, using the benchmarks established in the previous part of the study.

References

[1] B. Bourdin, G. A. Francfort and J. J. Marigo, Numerical experiments in revisited brittle fracture, Journal of the Mechanics and Physics of Solids 48 (2000) 797–826.

[2] E. Tanné, T. Li, B. Bourdin, J. J. Marigo and C. Maurini, Crack nucleation in variational phase-field models of brittle fracture, Journal of the Mechanics and Physics of Solids 110 (2018) 80–99.

[3] H. Amor, J. J. Marigo and C. Maurini, Regularized formulation of the variational brittle fracture with unilateral contact: Numerical experiments, Journal of the Mechanics and Physics of Solids 57 (2009) 1209–1229.

[4] C. Miehe, F. Welschinger and M. Hofacker, Thermodynamically consistent phase-field models of fracture: Variational principles and multi-field FE implementations, International journal for numerical methods in engineering 83 (2010) 1273–1311.

[5] F. Freddi and G. Royer-Carfagni, Regularized variational theories of fracture: a unified approach, International journal for numerical methods in engineering 58 (2010) 1154–1174.

[6] L. De Lorenzis and C. Maurini, Nucleation under multi-axial loading in variational phase-field models of brittle fracture, International Journal of Fracture 237 (2022) 61–81.

[7] A. Kumar, B. Bourdin, G. A. Francfort and O. Lopez-Pamies, Revisiting nucleation in the phase-field approach to brittle fracture, Journal of the Mechanics and Physics of Solids 142 (2020) 104027.