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PHASE-FIELD MODELS FOR BRITTLE AND COHESIVE FRACTURE

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The modelling of discontinuities, including interfaces, is of a growing importance in the mechanics of materials. Basically, two methods exist to capture discontinuities: one can either distribute them over a finite width, or handle them as true discontinuities, i.e. in a discrete sense.

When a discontinuity has a stationary character, such as in grain boundaries, it is fairly straightforward to describe it in a discrete manner, since it is then possible to create a conforming mesh such that the discontinuity, either in displacements or in displacement gradients, is modelled explicitly. An evolving or moving discontinuity is more difficult to capture. One possibility is to adapt the mesh upon every change in the topology. Another approach is to model fracture within the framework of continuum mechanics. A fundamental problem then emerges, namely that standard continuum models do not furnish a non-zero length scale which is indispensable for describing fracture. To remedy this deficiency, regularisation methods have been proposed, including nonlocal averaging, the addition of viscosity or rate dependency, or the inclusion of couple stresses or higher-order strain gradients. The effect of these strategies is that the discontinuity is transformed into a continuous displacement distribution. The internal length scale is set by the constitutive model, and for a sufficiently fine discretisation, the numerically calculated results are objective with respect to mesh refinement.

Not unrelated to gradient damage approaches are the phase-field models for fracture. However, the point of departure is completely different. In gradient damage models an intrinsically mechanical approach is adopted, and the damage model is regularized by adding gradients to restore well-posedness of the boundary value problem in the post-peak regime. The basic idea in phase-field models, on the other hand, is to replace the zero-width discontinuity by a small, but finite zone with sharp gradients in a mathematically consistent manner. Indeed, the latter requirement inevitably leads to spatial derivatives in the energy functional, similar to gradient damage models. The first attempts to apply phase-field models to fracture have focused on brittle fracture.

In this contribution we will first review some basic concepts in brittle and cohesive fracture, and in phase-field modelling. Next, we will assess the performance of some recently proposed brittle phase-field models at the hand of elementary and established examples. We will investigate a number of factors that can critically affect the performance of phase-field models in brittle fracture.

Models for brittle and cohesive fracture rely on very different concepts, and the development of a cohesive phase-field model is a non-trivial task. A contribution on how to apply phase-field models to propagating cohesive cracks follows next, accompanied by one-dimensional and two-dimensional examples.