Isotropic and anisotropic Eikonal gradient-enhanced damage models: thermodynamics derivation and simulation of quasi-brittle materials

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Quasi-brittle materials are often modeled using strain-softening continuum damage models. This implies using the so-called regularization techniques to obtain mesh-independent results in a finite element context. Non-local models of integral [1] and gradient [2] type, introduce an internal length in the analysis and may recover mesh objectivity in terms of structural response but are not capable of reproducing realistic "pseudo-crack" paths. In these approaches, non-local interactions are assumed isotropic and constant. This induces some drawbacks, such as boundary effects and damage spreading, leading to nonphysical damage evolution and propagation.

The Eikonal approach [3] considers that the damage field is responsible for modifying the interactions. A damage-dependent Riemannian metric is introduced in the formulation, such as damage is considered to curve the space where the interactions occur. Material points separated by damaged zone thus progressively reduce their interactions and no longer interact for very high damage levels. Consequently, the behavior becomes local, allowing for a better modeling of strain localization and the progressive transition from diffuse micro-cracking to fracture [4, 5].

The present contribution first provides a thermodynamics derivation of a gradient-enhanced Eikonal damage model (ENLG). Contrary to the usual developments for non-local models, this paper derives the problem from the micromorphic framework proposed in [6]. A purely geometric (using differential geometry concepts) modification of the free-energy potential introduced by [7] for the classic implicit gradient model is proposed. Both isotropic and anisotropic ENLG damage models are derived.

Then, numerical simulations of a few well-known problems (four point bending, shear band, etc.) using the ENLG model and a standard implicit gradient formulation are illustrated to highlight advantages and drawbacks of considering damage-dependent non-local interactions.

References

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