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A variational phase-field model for subcritical fracture

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We present a variational phase-field framework for modeling subcritical crack growth in geological materials. Also known as static fatigue, this phenomenon is characterized by the occurrence of crack extension at stress levels substantially below those associated with the critical energy release rate, G_c. We assume that this is brought about mainly by stress corrosion, in which highly stressed material at crack tips is weakened due to chemical reactions in the presence of an environmental agent. Prior studies in the literature point to the existence of a nominal value of the energy release rate, G_0, below which subcritical crack growth does not occur. Above this threshold, the speed of crack extension can be related to the crack tip energy release rate via a power relation known as Charles' Law.

Following recent phase-field approaches for modeling fracture due to cyclic fatigue [1, 2], we incorporate the aforementioned behavior in the variational phase-field framework by scaling G_c with a function whose time rate of change depends on a quantity analogous to the energy release rate. Apart from the displacement and phase-field variables already present in the standard model for brittle fracture, no additional field unknowns are introduced in connection with static fatigue. Instead, an ordinary differential equation must be solved to determine the critical energy release rate evolution at each material point. The coupled system is solved numerically using a hybrid discretization that utilizes classical finite elements for the linear momentum conservation and cell-centered finite volumes for the energy balance governing phase-field evolution [3, 4].

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