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Numerical simulation of desiccation crack nucleation and propagation by a variational phase-field model

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Clay formation is a prominent candidate for barrier rock in radioactive waste management. Thus we must assess its integrity (or lack thereof) under varying conditions such as drying around excavations or heat sources. As the porous rocks dry, the moisture gradient alters the effective stress and may initiate cracks at the exposed surface. Unlike cracks driven purely by mechanical loading, desiccation cracks can form in a geometrically complex pattern. When one of the drying material's dimensions is much larger than the other, cracks tend to develop parallel to each other. Otherwise, a more complex, polygonal crack distribution may develop. Although material heterogeneity contributes to crack nucleation and complexity, we also observe complex cracks in a dried homogeneous plaster.

When stress concentration is not clearly present such as for cooling or drying cracks, the classical fracture mechanics framework struggles to determine the crack initiation and propagation path. To overcome these challenges, a variational approach, also known as a phase-field model, for fracture has been proposed and successfully applied to simulate complex fracturing including desiccation cracks without prescribing heterogeneities in the domain. However, as phase-field modeling of desiccation crack is still at its infant stage, there are various and ambiguous ways to treat crack nucleation or define the effective stress.

In this study, we compare several available phase-field models implemented in an open-source code, OpenGeoSys, in terms of crack nucleation and propagation. We investigate the model in two- and three-dimensional settings and the influence of the material properties. We find that, unlike some reported studies, crack nucleation induced by drying does not need to be instigated by material heterogeneity or mesh irregularity, but shows a dependency on the chosen phase-field model. We also show that the onset of crack is largely dependent on the definition of the effective stress, which couples the hydraulic, mechanical crack fields, and on the choice of the phase-field model. Furthermore, we discuss the application of the phase-field model in experiments at larger spatial and temporal scales.

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References

Time Block Preference

Time Block A (09:00-12:00 CET)

Participation

In person

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