IOWA STATE UNIVERSITY

Materials Science & Engineering Department

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Final Oral Examination
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"Modeling Crack Growth and Phase Separation in Soft Materials: A Finite Strain Phase Field Approach to Microscopic Surfaces and Interfaces"

Elastomers and polymeric gels are soft materials consisting of crosslinked polymer networks. They are highly nonlinear materials capable of undergoing large deformation. In this work, we formulate a finite strain phase field model to study surfaces and interfaces in soft materials considering the coupling between deformation and interface structure for ideal solid and liquid interfaces. The phase field model is combined with visco-poroelastic theory, and implemented into finite element code using a rate based variational principle. The model is first applied to viscous fracture of elastomers using a non-conserved phase field variable to track the stress-activated damage of polymer networks. Crack surface is modeled as a coherent diffusive interface between intact material and vacuum. The model provides a thermodynamically consistent way of calculating arbitrary crack growth. By examining the numerical results of steady state viscous crack, we explain viscous toughening mechanism and the rate dependency of fracture energy via the extrinsic viscoelastic dissipation. In the second example, we study phase separation of gels using conserved phase field model which serves as a general model for the effect mismatch strain of coherent phase boundary on morphology of coexisting phases. Our numerical results reveal formation of sponge structures, which consist of compartment of majority phase embedded in thin network of connected minor phase. A theory is proposed for mechanism of sponge structure formation as the consequence of competition between minimizing interface energy and strain energy from nonlinear deformation of curved phase boundary.