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Computational modeling of fingering in stretched hydrogel cylinders

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Recent experiments on hydrogels subjected to large elongations have shown elastic instabilities resulting in the formation of geometrically intricate *fingering* patterns. In this talk, we present a robust computational framework to simulate this complex material response from the onset of instability to the post-bifurcation behavior. We discuss the numerical challenges stemming from the non-convexity of the strain energy density in the near-incompressible, large-deformation regime, which is responsible for the coexistence of multiple equilibrium paths with vastly-different, sinuous deformation patterns immediately after bifurcation. We show that these numerical challenges can be overcome by using high order of interpolation in the finite element approximation, an arc-length nonlinear solution procedure following the equilibrium path of the system, and a parallel implementation enabling large-scale simulations. The resulting computational approach provides the ability to conduct highly-resolved, truly quasi-static simulations of complex elastic instabilities. Finally, we present numerical results demonstrating the ability of the path-following approach to describe the full evolution of fringe and fingering instabilities observed experimentally. Importantly, we observe that the robustness of the static solution procedure enables complete access to the multiplicity of solutions occurring immediately after the onset of bifurcation, as well as to the settled post-bifurcation states.

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