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A robust multigrid preconditioner for two phase gel dynamics

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We develop a computational method for simulating models of gel dynamics where the gel is described by two phases, a networked polymer and a fluid solvent. The models consist of transport equations for the two phases, two coupled momentum equations, and a volume-averaged incompressibility constraint, which we discretize with finite differences/volumes. The momentum and incompressibility equations, which are similar to those arising in Stokes' equations, present the greatest numerical challenges since i) they involve partial derivatives with variable coefficients that can vary quite significantly throughout the domain (when the two phases separate), and ii) their approximate solution requires the "inversion" of a large linear system of equations. For solving this system, we propose a box-type multigrid method to be used as a preconditioner for the GMRES method. Through numerical experiments of a model problem, which exhibits phase separation, we show that the computational cost of the solver scales nearly linearly with the number of unknowns, and performs consistently well over a wide range of parameters. We conclude with results on the parallelization of this new method.