FIELD-RESPONSIVE RHEOLOGY OF MAGNETORHEOLOGICAL SUSPENSIONS IN AN AGING, YIELD-STRESS MATRIX FLUID

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Magnetorheological (MR) fluids are field-responsive materials that exhibit fast, dramatic, and reversible changes in properties when subjected to a magnetic field. They consist of a suspension of microscopic magnetizable particles which, upon application of the external field, form domain–spanning chains and clusters, leading to large and reversible growth in the apparent viscosity and a field-induced yield stress. The tunability of these fluids over a large range of viscosities makes them attractive for a number of engineering applications, including precision damping of mechanical parts, prosthetics, robotics and oilfield applications.

The vast majority of investigations on MR suspensions involve Newtonian carrier fluids; however, due to the typically large density difference between the magnetic particles and the suspending fluid, particle sedimentation is problematic. This is especially the case in situations where the magnetic actuation occurs only periodically and re-suspension of the fluid is infeasible, such as for downhole drilling fluids and earthquake damping systems. Though various stabilizing additives have been explored to prevent sedimentation, yield-stress carrier fluids have the potential to offer significant improvements to long-term stability. Ideally, the background yield stress prevents particle sedimentation while still allowing the formation of field-induced microstructure. In this work, we study the field-responsive rheology of MR suspensions in a yield-stress carrier fluid consisting of an aqueous dispersion of Laponite clay. As model thixotropic fluids, aqueous Laponite dispersions exhibit a rich array of non-Newtonian properties, including rheological aging. Drawing from our previous work on the linear and nonlinear rheology of aqueous Laponite dispersions at both bulk and microscopic length scales, we investigate the effects of aging and non-Newtonian carrier fluid behavior on the field-responsive rheology and sedimentation stability of this composite material. In particular, the field-induced yield stress and apparent viscosity are explored as functions of carrier fluid age, and the consistency of the response after a long off-state time is examined. A wide range of clay-based thixotropic drilling fluids are already deployed in the field and this work provides guidelines for the formulation of novel field-responsive drilling fluids.