Nonlinear Microrheology of wormlike micelle solutions using gerromagnetic nanowire probes

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Abstract: We describe the application of high-aspect-ratio ferromagnetic nanowires as microrheological probes of wormlike micelle solutions composed of equimolar cetylpyridinium chloride/sodium salicylate (CPCl/NaSal). Employing high-speed video microscopy to track the rotation of suspended nanowires in response to external magnetic fields, we access both the linear and nonlinear rheology of the fluid. The linear viscosity at low rotation rates is strongly temperature dependent as expected from macroscopic rheometry. At high rotation rates the viscosity exhibits pronounced shear thinning that is surprisingly independent of temperature. The onset of the nonlinear response is characterized by a thickening that has no apparent counterpart in the macroscopic rheometry. Further, the fluid in the nonlinear state generates an out-of-plane torque on the wire whose magnitude varies as a power law with the rotation rate, with a power-law exponent of approximately 0.4. From time-resolved measurements tracking the motion of the wire in response to this torque we extract an effective viscosity for drag perpendicular to the nonlinear flow. The values of this viscosity are remarkably large, providing evidence for the anisotropic nature of shear-thinned fluid's viscoelasticity.