Large amplitude oscillatory shear of wormlike micellar solutions: shear-banding and vortex like instabilities

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The shear rheology of the wormlike micellar solution CPyCl-NaSal (100/60) mM is well described by a viscoelastic Maxwell model at low shear rates but it exhibits strong shear-thinning above a critical shear rate. We experimentally explore the non-linear rheological behaviour of this solution in two different geometries using time-resolved Particle Image Velocimetry (PIV).

In the cone and plate geometry we use a Rheo-PIV device that incorporates the PIV visualization technique into a cone-plate rheometer, providing simultaneously bulk rheological data, represented in terms of Lissajous figures (stress vs. strain), and local velocity fields in the sample. By performing steady shear as well as large amplitude oscillatory shear (LAOS) experiments, we observe the transition from linear to shear banded velocity profiles as we progressively increase the applied shear rate, further into the non-linear regime. The shear banded profiles show three different bands, with two low sheared bands at the boundaries and a highly sheared band at the center[1]. Analogous measurements done with the more diluted, but yet strongly shear-thinning micellar solution CPyCl-NaSal (66/40) mM show qualitatively different steady flow curves and velocity profiles, elucidating the influence of the micellar concentration on the shear-banding formation.

We also make the (100/60) mM solution to oscillate in a vertical straight cylinder of large aspect ratio. We characterize the fluid flow by measuring the velocity and vorticity fields within a meridional plane of the tube. The laminar flow is known to resonate at well defined driving frequencies[2]. For increasing amplitudes of the applied forcing it becomes unstable against the formation of several toroidal vortices distributed along the tube with a well defined spatial and temporal structure. The transition from the laminar to the unstable flow exhibits hysteresis when the forcing amplitude is ramped up and down, elucidating the subcritical nature of the bifurcation. Although this transition occurs well into the non-linear regime, the role of shear banding on the onset of the instability is not yet clear.

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[2] Casanellas, L. & Ortín, J. 2012. Experiments on the laminar oscillatory flow of wormlike micellar solutions. *Rheol. Acta* in press, DOI 10.1007/s00397-012-0620-3.