Interplay of wall slip and shear banding in wormlike micelle solutions

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Shear banding, the separation of flow into distinct regions of shear rate, is well studied in wormlike micelles (WLMs) and often accompanied by some degree of wall slip, a phenomenon where the velocity of a fluid at a moving surface is less than the surface velocity. Despite being observed simultaneously, the relationship between wall slip and shear banding is still not fully understood. A significant complication is the inconsistent manifestation of wall slip; sometimes wall slip is observed near the onset of flow while sometimes wall slip is observed after shear-banded flow has developed. Additionally, wall slip is difficult to quantify in shear-banding experiments because of large shear-rate gradients near the solid-liquid interface. To investigate the interplay between these phenomena, the evolution of shear-banded flows with and without wall slip is simulated using the Germann-Cook-Beris (GCB) model of WLMs. Motivated by the few datasets that quantify wall slip with shear banding, simple shear-rate and stress-dependent slip laws are postulated and applied at the moving boundary. Wall slip is found to delay the onset of shear banding to higher applied shear rates, consistent with experimental observations. In shear startup, wall slip dampens the magnitude of shear-rate gradients, which extends the time for shear-banded flow to develop. However, the evolution of the flow field is sensitive to the type of slip law; the magnitude of flow reversal—a phenomenon where portions of the fluid move opposite to the imposed wall velocity—is enhanced with shear-rate-dependent slip and dampened with stress-dependent slip. The steady and transient shear flows predicted in this study suggest that inclusion of some type of wall slip in models is needed to qualitatively reproduce certain experimental observations. This work emphasizes the need for new experiments to quantify wall slip and to connect microstructure at the solid-liquid interface to both shear banding and wall slip.