Large Amplitude Oscillatory Extension (LAOE) of polymer solutions

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Oscillatory shear tests are frequently used for the characterization of soft matter and complex fluids such as polymer melts and solutions, biological fluids, and food products. These materials often undergo large and rapid deformations in practical applications and processing environments, making the quantification of nonlinear material properties essential for predicting system responses under such conditions. Large Amplitude Oscillatory Shear (LAOS) tests are pivotal in providing rheological fingerprints that detail the behavior of soft materials under nonlinear shear deformations. Despite advances in characterizing nonlinear material properties in shear flows, the potential of using oscillatory flows for elucidating the extensional properties of complex fluids is largely unexplored. However, extension-dominated and mixed flows are crucial for a wide range of industrial applications, including fiber spinning, ink-jet printing, and blow molding. In this work, we introduce a new experimental method to examine the fluid response to Large Amplitude Oscillatory Extension (LAOE). For this, we use a microfluidic Optimized Shape Cross-slot Extensional Rheometer (OSCER) device that generates a homogeneous planar extensional flow. Programmable syringe pumps are used to drive the flow through the OSCER geometry by two different modes: an oscillating sinusoidal mode or a pulsatile sinusoidal mode with a constant background flow. We analyze the time-dependent flow field inside the OSCER by means of micro-particle image velocimetry and measure the simultaneous pressure drop to evaluate the fluid's elastic stress response. We examine the time-dependent flow of viscoelastic dilute polymeric solutions during LAOE, covering a broad range of Weissenberg and Deborah numbers. This investigation advances our understanding of non-Newtonian fluid dynamics and extensional rheometry, and leads to a potentially promising new methodology for characterizing complex fluids under extremely nonlinear flow conditions.