Microscopic flows of a simple yield stress material in the presence of wall slip

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Preference: ORAL presentation (speaker E. Younes)

A fundamental problem in the hydrodynamics of yield stress fluids relates to the "wall slip" phenomenon. To tackle this, we have performed systematic measurements of flow fields of a simple yield stress fluid (Carbopol Ultrez 10) in a plane acrylic made micro-channel. By using a custom Digital Particle Image DPIV tool developed in the house, times series of velocity fields were measured within a wide range of driving flow rates with an instrumental error that never exceeded 5% of the mean flow speed.

Depending on the magnitude of the constant imposed flow rate, three distinct flow regimes are observed. At low driving flow rates, a full plug flow regime is observed. The entire Carbopol gel is un-yielded and "slides" over a very thin layer of depleted solvent (water) located in the proximity of the channel walls. As the flow rates are gradually increased past this first flow regime, a second flow regime is observed: the Carbopol gel is partially yielded in the proximity of the channel walls (where the velocity gradients are the largest) but a central un-yielded plug may still be observed around the centre-line of the micro-channel. As the flow rates are increased even further, the Carbopol gel is fully yielded across the entire width of the channel. The accurate measurements of the velocity profiles allows one to obtain the wall velocity gradients via the numerical differentiation of a spline interpolant of the velocity profiles. The last missing link is relating the wall velocity gradients to the wall shear stresses and obtain experimentally the scaling law(s) for the wall slip. To do so, we use the dependence between the stress and the rate of shear obtain via classical rotational rheometry and relate the measured wall gradients to the wall stresses. The presentation closes with a comparison of the experimentally found scaling laws for the wall slip with results from the literature.

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