VISCO-PLASTIC FORMING AND EXTRUSION

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ABSTRACT

Yield stress fluids have the property that they do not deform unless a given yield stress is exceeded. While in some flows this leads to unwanted features, this property can also be exploited in order to produce novel flow features. One example of such flows are visco-plastically lubricated (VPL) flows, in which a yield stress fluid is used to stabilize the interface in a multi-layer flow, far beyond what might be expected for a typical viscous-viscous interface. Here we extend this idea in the following directions. We study multi-layer VPL flows in which we experiment with oscillating the flow rates of the individual phases. According to the flow rate variations we succeed in freezing in a range of different interfacial patterns. Experiments performed with Carbopol™ as lubricating fluid, and with xanthan and polyethylene oxide (PEO) as core fluid, serve to illustrate the potential of the method. For the PEO, repeated oscillation leads to strings of elegant diamond shapes, for which we can control the frequency and amplitude. Numerical simulations extend the range of shapes achievable and give us interesting insights into the forming process. This process is similar to the cleaning process when the visco-plastic lubricant is totally unyielded and the cleaning fluid replaces the core fluid. This study gives us better understanding in estimating and decreasing the required time of cleaning, which strongly depends on the relationship between the interfacial patterns and the states of stresses in the residual layer. We also consider the encapsulation of droplets within a visco-plastic fluid, for the purpose of transportation, e.g. in pipelines. The main advantage of this method, compared to others that involve capillary forces is that significantly larger droplets may be stably encapsulated, governed by the length scale of the flow and yield stress of the encapsulating fluid. We explore this computationally. We show that sufficiently small droplets are held in the unyielded plug of the Poiseuille flow. As the length or radius of the droplets increase the carrier fluid eventually yields, potentially breaking the encapsulation. We study this process of breaking and give estimates for the limiting size of droplets that can be encapsulated.