FROM TRANSIENT TO STEADY STATE RHEOLOGY IN SIMPLE YIELD STRESS FLUIDS

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In this work we revisit the case of a simple yield stress fluid (YSF), namely a carbopol "gel". Indeed, in spite of a huge body of rheological work, no thorough temporally and spatially resolved study has been conducted on simple YSF. In particular, it is generally assumed that the flow remains homogeneous during its evolution towards steady state. Here we investigate the fluidization for both shear-rate and shear-stress controlled experiments using ultrasonic speckle velocimetry [Manneville (2004)] simultaneously to standard rheological measurements.

On the one hand, shear-rate controlled experiments show that (i) the transient regime from solidlike to liquidlike behavior involves a shear-banded flow; (ii) the duration of this transient regime decreases as a power law of the imposed shear rate and (iii) the flow always turns out to be homogeneous after this transient shear banding. This fluidization scenario is very robust and the exponent of the power law does not depend on the gap width or on the boundary conditions. Our results not only confirm the idea that one cannot observe steady-state shear banding without thixotropy but also demonstrate that a simple YSF can present shear banding in a transient regime that can last surprisingly as long as 10^5 s [Divoux (2010)].

On the other hand, shear-stress controlled experiments show that (i) the transient regime from solidlike to liquidlike behavior also involves a shear-banded flow; (ii) the duration of this transient regime decreases as a power law of the reduced shear-stress: the applied stress minus the yield stress of the fluid; and (iii) the flow always turns out to be homogeneous after this transient shear banding. This fluidization scenario is very robust and rules out any analogy between the stress induced fluidization process of simple YSF and the rupture of elastic solids as recently suggested [Caton (2008), Benmouffok (2010)]. Indeed, spatiotemporal diagrams of ultrasonic speckle signals show a fluidization involving the whole bulk of the gel without any fracture-like events.

Finally, we will discuss the link between imposed shear rate and shear stress experiments. In particular, we will show how the fluidization process involving a transient shear banding phenomenon gives a physical interpretation of the Herschel-Bulkley model that describes the rheology of carbopol.