Aging and flow in a complex fluid

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Understanding the physical mechanisms governing the interplay between aging dynamics and shear flow is crucial to both elucidating the nature of slow dynamics in soft materials and controlling their complex rheological behavior.

We investigate the evolution of the density autocorrelation function of an aging colloidal suspension subject to a steady shear flow. The competition between the structural relaxation time and the inverse shear rate gives rise to a complex dynamical behavior that we could quantitatively analyze studying the detailed shape of the particles density autocorrelation function.The sample is an aqueous suspension of Laponite, a highly thixotropic liquid which undergoes structural arrest on a timescale which strongly depends on concentration and ionic strength and that can be as long as few months. We found that the aging dynamics displays two different regimes whose boundary is marked by the condition $\tau\dot{\gamma} = 1$. As long as the characteristic relaxation time τ is small on the time-scale $1/\dot{\gamma}$, aging is unaffected by the presence of shear. During aging dynamics slows down, and when τ becomes of the order of $1/\dot{\gamma}$, the system enters a shear dominated regime where aging is strongly reduced and the structural relaxation time is very sensitive to $\dot{\gamma}$ (see Fig. 1). The intermediate scattering functions, characterizing the slow non-equilibrium dynamics of the sheared sample, are well described assuming an heterogeneous scenario where the complex dynamics results from the superposition of relaxing units each one independently coupled to shear rate.

At the same time we monitor velocity profiles by means of heterodyne dynamic light scattering. Shear localization is observed at the lower rates of shear. An un-sheared gel band coexists with a uniformly sheared fluid band whose relaxation time is fixed by the shear rate.

We also study the aging process after rejuvenation of the sample with an high shear rate. The t_w dependence of τ after rejuvenation is substantially different from that observed in normal aging. We found that $\tau \approx t_w^\alpha$, with $\alpha \approx 1.5$.

We discuss these results in relation to recent theoretical work and present a simple phenomenological model based on Langevin dynamics which is capable of reproducing many of the observed features.

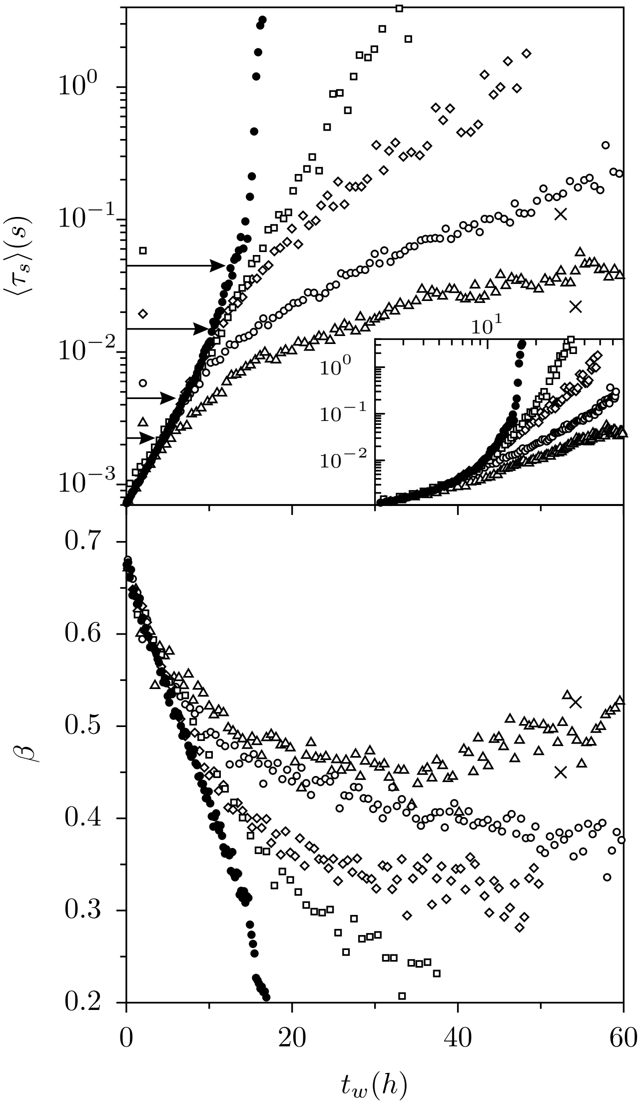

Figure 1: Average slow relaxation timeτ and stretching exponent β as a function of waiting time t_w during aging under different shear rates $\dot{\gamma}$: 446, 223, 67, 22 s^{-1} Solid symbols refer to aging without shear. Arrows in top frame indicate the $\dot{\gamma}$ values corresponding to each curve. Inset in top frame shows the same data in a double-logarithmic scale.