Complex fluids under vertical vibrations: a birefringence study of wormlike micelles

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A layer of simple fluid under vertical vibrations undergoes the well-known Faraday instability: above a critical acceleration a_c, the surface becomes unstable and ripples organize into patterns characterized by a critical wavelength λ_c [1]. In this work, we investigate the effect of vertical vibrations on a layer of a *complex fluid*. Our fluid is a semi-dilute solution of surfactant molecules that self-assemble into elongated cylindrical micelles known as "wormlike micelles" or "living polymers."

More precisely, we study the system composed of cetylpyridinium chloride (CPCl) and sodium salicylate (NaSal) at various concentrations in brine. Classical rheological measurements have shown that this system is very viscoelastic and behaves as a Maxwell fluid in the small deformation regime [2]. At large deformations, it displays a strong flow–microstructure coupling characterized by micelle alignment [3].

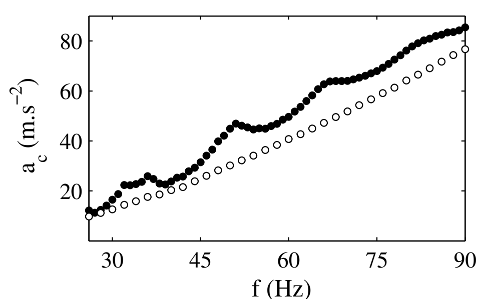

Figure 1: a_c vs f in 4% wt. wormlike micelles (•) and in a simple viscous fluid (water–glycerin mixture, ◦).

In a recent work [4], we have found that the onset of the Faraday instability is strongly affected by the viscoelasticity of the micellar network: elastic waves between the surface of the fluid and the bottom of the container may enhance or hinder the instability depending on the vibration frequency f and on the elastic modulus of the fluid G_0. Figure 1 shows the signature of viscoelasticity on the measurement of the critical acceleration a_c as a function of the vibration frequency f: in the wormlike micelles, a_c displays oscillations that are not observed in a simple fluid. The characteristic frequency of these oscillations is given by [4]:

$$\delta f = \frac{1}{h}\sqrt{\frac{G_0}{\rho}}, \tag{1}$$

where G_0 is the elastic modulus, ρ the density, and h the depth of the fluid layer.

In order to better demonstrate such an elastic effect, we performed birefringence experiments to access the deformation and stress fields locally under vibrations. Our measurements unveil the existence of "elastic rolls" that reflect the surface wave pattern over the whole depth of the fluid. Figure 2 shows an example of birefringence image recorded under vibrations.

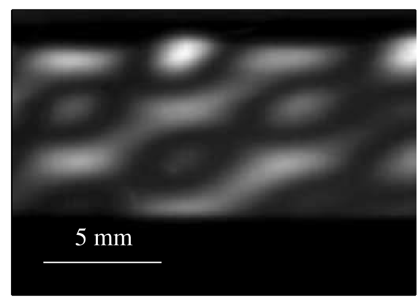

Figure 2: Birefringence image at f = 75 Hz in 5% wt. wormlike micelles

In this talk, we will describe in details the measurement technique and our latest results. We will show that the number of "elastic rolls" is linked to the oscillations observed in a_c vs f. A question underlying this work is whether micelles (or other supramolecular aggregates) could get locally aligned under vibrations, leading to a macroscopic order imprinted by the surface wave pattern.

References

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