Fluidisation of yield-stress material under vibrations

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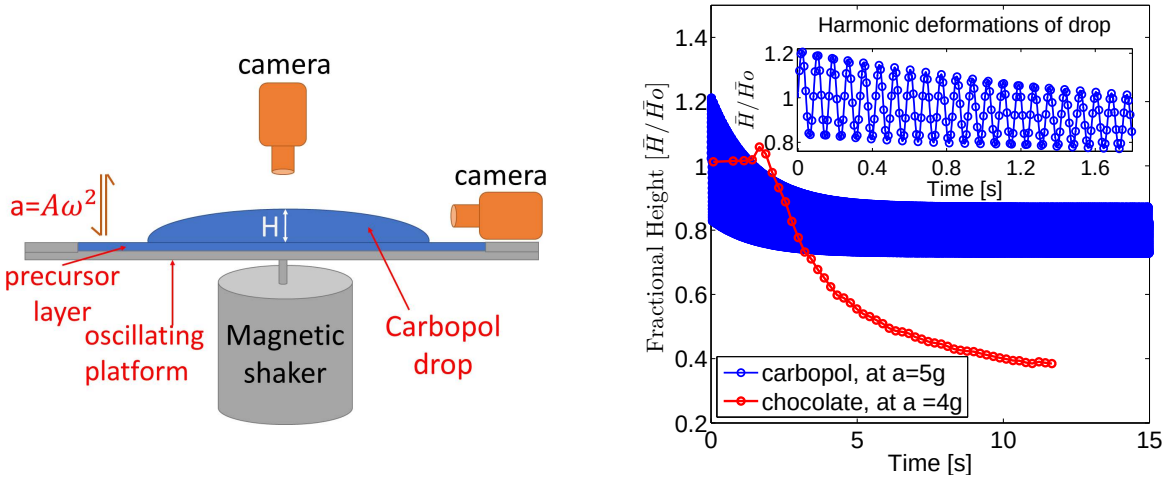
The rheology of yield-stress fluids has been the subject of extensive research in recent years. However, the mechanics of fluidisation of such materials due to external forcing remains poorly understood. Using a combination of experiments and theory, we investigate the fluidisation of a sessile drop of a yield-stress fluid on a pre-existing layer of the same fluid due to vertical sinusoidal oscillations (see experimental set-up in figure 1(a)). We find that molten tempered chocolate and a microgel solution of carbopol exhibit different fluidisation behaviours despite having the same yield stress. The experiments show that the carbopol drop deforms harmonically with the driving frequency for low values of the driving acceleration unlike chocolate, which remains rigid. Above a critical value of the acceleration, transient axisymmetric spreading occurs. Chocolate spreads viscoplastically whereas the carbopol drop exhibits large amplitude harmonic deformation with the drive and spreads significantly less (see figure 1(b)). The time scale of spreading is significantly reduced in carbopol where the drop rapidly reaches a new stable state of harmonic deformation. The carbopol drop requires fourfold accelerations to spread to similar footprints as a chocolate drop. Informed by rheological measurements, we model chocolate and carbopol as a viscoplastic and an elastoviscoplastic fluid, respectively. We derive a depth-averaged model for the dynamics of the drop in the limit of a shallow axisymmetric drop and compute solutions using finite-difference methods. We find that the harmonic deformations of the carbopol drop are associated with elastic deformations and that the yield-stress controls the critical acceleration at which spreading is initiated. However, the spreading of the fluidised drop is controlled by viscoelastic effects.



(a) (b)

Figure 1: (a) Schematic of the experimental set-up (b) Temporal evolution of central height of carbopol and chocolate drops (Bergemann, N., PhD thesis, 2015) while spreading.

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