Drops and jets of complex fluids
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Summary

In the first part of this thesis we explored wetting and its dynamics for small droplets. First, we showed how a simple feature of water droplets on a surface, i.e. Laplace pressure, can be exploited to build a micropump. We investigated capillary pumping in microchannels both experimentally and numerically. Putting two droplets of different sizes at the in/outlet of a microchannel, will generally produce a flow from the smaller droplet to the larger one due to the Laplace pressure difference. We show that an unusual flow from a larger droplet into a smaller one is possible by manipulating the wetting properties, notably the contact line pinning. In addition, we propose a way to actively control the flow by electrowetting. The dynamics and velocity of the contact line of the drops does not play an important role in this chapter. Instead, we show that wetting properties are the key to controlling the flow.

In the next chapter, sliding drops on an inclined plane are studied to investigate the dynamics of wetting. ‘Shaped drops’ were made by adding ferrofluid to small magnets (∼1 cm). The important feature of these drops is that the magnet preserves the shape of the drop and the contact line. Therefore, we can impose the shape of the contact line and observe the consequences on the dynamics of sliding drops on an inclined plane. In this chapter, we observed a situation where a liquid object, submitted to its weight and viscous forces, adopts a different direction than the steepest descent. The main reason is a left/right dissymmetry of our systems. An asymmetric perimeter leads to a total viscous force that is not collinear with the velocity, this effect arises from the simple dynamics we have proposed. But, as we have seen with the half-disc geometry, even symmetric shapes can deviate from the steepest descent (even if, in average, the line of the largest slope remains a symmetry axis). Another issue has then to account for: the total torque of the viscous forces has to play a stabilizing role for the drop. In our case, the half-disc has to be tilted. This is a new approach for studying contact line dynamics. More systematic measurement of the force acting on a moving contact line, while the velocity is not normal, can be performed.

The subsequent chapters made a study of 3 scenarios which can occur for a falling liquid jet. The breakup of viscous threads of silicone oil, the spread of a non-Newtonian liquid jet (dilute polymer solutions) over a horizontal plate and the coiling of yield stress fluids (foam and gel) were studied, respectively. Thin jets of viscous fluid like honey falling from capillary nozzles can attain lengths exceeding 10 m before breaking up into droplets via the Rayleigh-Plateau (surface tension) instability. Using a combination of laboratory experiments and WKB
analysis of the growth of shape perturbations on a jet being stretched by gravity, we determined how the jet’s intact length $l_b$ depends on the flow rate $Q$, the viscosity $\eta$, and the surface tension coefficient $\gamma$. In the asymptotic limit of a high-viscosity jet, $l_b \sim (gQ^2\eta^4/\gamma^4)^{1/3}$, where $g$ is the gravitational acceleration. The agreement between theory and experiment was good except for very long jets.

A brief review of hydraulic jump for viscous and inviscid flow. Expressions for the radius of the jump $R_j$ (from the impact point of the jet) were derived. Correction to the viscous expressions due to the surface tension was also presented. The same approach was pursued for the case of non-Newtonian power law fluids. Some data for the hydraulic jump of dilute polymer solutions were also shown, however, the experiments of this chapter were still incomplete.

Finally, we present an experimental investigation of the coiling of a filament of a yield stress fluid falling on a solid surface. We use two kinds of yield stress fluids: shaving foam and hair gel, and show that the coiling of the foam is similar to the coiling of an elastic rope. Two regimes of coiling (elastic and gravitational) are observed for the foam. Hair gel coiling, on the other hand, is more like the coiling of a liquid system; here we observe viscous and gravitational regimes. No inertial regime is observed for either system because of instabilities occurring at high flow rates or the break up of the filament in large heights.