Forced spreading and evaporation of films and droplets of colloidal suspensions

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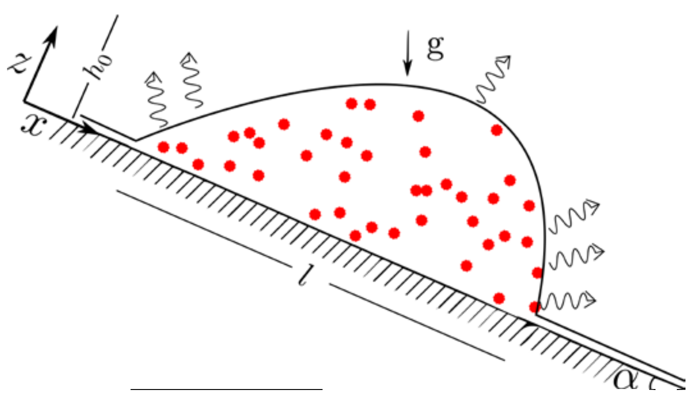
After an inclined surface has been covered with a thin liquid film, the film will tend to flow under the effects of gravity. This can lead to undesired effects in liquid-applied coatings, such as thickness variations (sag) and, in the case of colloidal suspensions, the formation of patterns due to the uneven distribution of the suspended particles. Evaporation often occurs simultaneously as well, which tends to raise the liquid viscosity and lead to the locking-in of defects. Similar issues arise with droplets, which appear in spray coating operations. Although colloidal suspensions appear in numerous coating processes, relatively little is understood about how they influence the flows of thin films and droplets. This a complex problem because as a suspension begins flowing, particle concentrations can vary in space and time, leading to variations in viscosity. Our overall interest is to develop models that provide a bridge between the physical properties of a colloidal suspension (e.g., viscosity, surface tension, particle size and loading) and coating quality when flow and evaporation are present.

To begin addressing these issues, we study the dynamics of films and droplets of colloidal suspensions flowing down an inclined plane. Lubrication theory and the rapid-vertical-diffusion approximation are used to derive a coupled pair of one-dimensional partial differential equations which describe the evolution of film height and particle concentration. Our results indicate that in the case of spreading forced by gravity, the presence of colloidal particles, which modify the dynamics through a concentration-dependent viscosity, modify the propagation of the wave front at the leading edge of the flow. In particular, the front evolves continuously in time instead of traveling without changing shape as happens in the absence of colloidal particles. We also find that at high enough particle concentrations, Brownian diffusion can lead to the formation of long-lived secondary flow fronts. These observations suggest a mechanism for the onset of patterns that are observed experimentally in flowing films of colloidal suspensions. The influence of evaporation on this process will also be discussed. The model is expected to provide insight into which combinations of physical properties of a colloidal suspension minimize coating defects (*L. Espín and S. Kumar, Journal of Fluid Mechanics 742 (2014) pp 495)*.



Sketch of a droplet of a colloidal suspension spreading on an inclined, heated substrate.