Spreading of dense granular suspension drops

Alice Pelosse, Élisabeth Guazzelli, and Matthieu Roché
Université Paris Cité, CNRS, Matière et Systèmes Complexes (MSC), Paris, France

Abstract:

This work addresses the flow of suspensions confined by free interfaces, with a focus on the spreading of dense suspension drops on solid substrates. Our results show that the spreading dynamics of suspension drops can be described by classical spreading laws both at the local drop scale (i.e. in the vicinity of the advancing contact line) and at the global drop scale (i.e. by recording the time evolution of their radius), provided that effective viscosities (which are different from the bulk viscosities of the suspensions and can depend on different parameters) are employed. However, it is also shown that the continuum description can fail when particle confinement is significant.

Keywords: suspension, wetting

Introduction:

In this study, we examine the constraining effect of a free surface and contact line on a fundamental capillary flow of suspensions, specifically the spreading of a drop deposited on a solid substrate. The topic of capillary effects in particle-laden flows has yet to be explored in any depth. This represents a significant avenue of inquiry for several reasons. Primarily, there are numerous applications wherein suspension flows are bounded by a free surface. These include coating processes for surfaces utilized in industry. Secondly, it enables a more comprehensive understanding of both dense suspensions and dynamic wetting. This is achieved by modulating particle confinement and probing dissipation mechanisms. The primary objective is to examine whether the spreading laws established for a pure fluid remain valid for a complex fluid such as a suspension.

Experimental Methods:

We study the spreading of viscous density-matched suspensions on a solid surface, as illustrated in Figure 1. The investigation focuses on dense granular suspensions, comprising large particles for which Brownian motion and colloidal forces can be considered negligible. The spreading law is examined at both the local drop scale [1, 2], where the advancing contact line is tracked, and the global drop scale [3], where the time evolution of the radius is recorded. These observations are made using highly resolved imaging techniques.

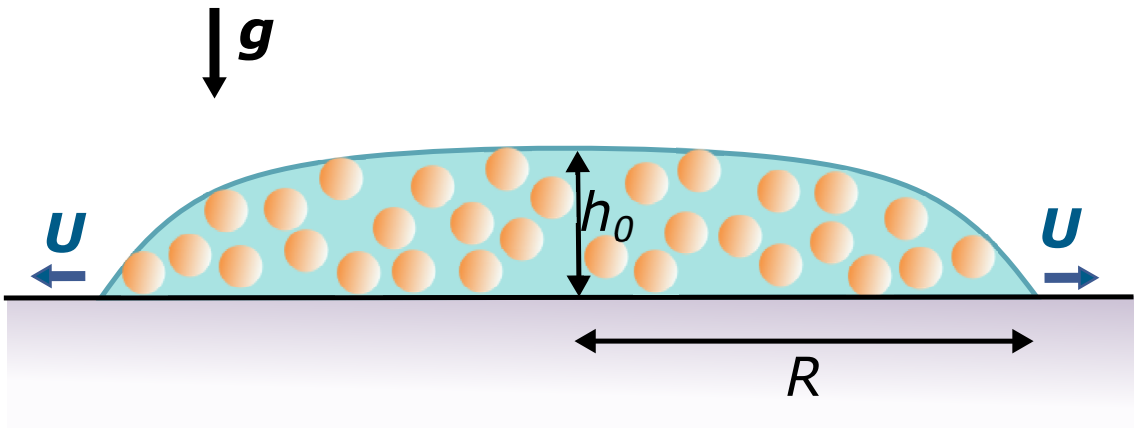

Figure 1: Sketch of a suspension droplet spreading on a rigid substrate.

Results and discussion:

The essential outcome of this investigation is that the classical spreading laws remain valid, contingent upon the utilization of effective viscosities that differ from the bulk viscosities of the suspensions and can be influenced by various parameters. In the vicinity of the contact line [1, 2], the relation between the dynamic contact angle and the contact line velocity is analogous to the classical Cox-Voinov law observed in the case of a pure liquid. However, the wetting viscosity involved in this law differs from that of the bulk, as it depends not only on the particle volume fraction but also on particle size. This observation is linked to the ability of the particles to approach the contact line at a sufficient distance to affect dissipation at the local level. On a global scale [3], the power law that describes the growth of the drop radius for large drops (i.e., when gravity dominates capillary forces) remains valid when an effective viscosity that is independent of particle size but much smaller than the bulk suspension viscosity is employed. However, when the drop height is of the order of the particle size, the power law is no longer applicable, as the particles freeze while the contact line continues to advance.

References

[1] Menghua Zhao & Mathieu Oléron & Alice Pelosse & Laurent Limat & Élisabeth Guazzelli & Matthieu Roché *Spreading of granular suspensions on a solid surface.* Physical Review Research. **2**, 022031(R) (2020).

[2] Alice Pelosse & Élisabeth Guazzelli & Matthieu Roché *Probing dissipation in spreading drops with granular suspensions.* Journal of Fluid Mechanics. **955**, A7 (2023).

[3] Alice Pelosse & Élisabeth Guazzelli & Matthieu Roché *Success and failure of the spreading law for large drops of dense granular suspensions.* Journal of Fluid Mechanics. in press (2024).