

IFPRI Research Project Brief

Rheology of Suspensions at High Solids Content: Bridging the Gap from Colloids to Grains

Pumping, flow, conveyance, and the long-term flow stability of highly concentrated particle systems remain an industrial challenge. Advancements in understanding surface turnover and chemistry-mediated particle interactions have improved our understanding of highly concentrated colloidal systems. Improvements in understanding of jamming phenomena, particle shape and inertial streams have similarly improved understanding of granular systems. A recent revolution has taken place in understanding the rheology of high-solid-content dispersions (HSCDs), viz., that at sufficiently high stress, particles are pressed into contact, so that many ideas from granular flow may become transferable to suspension flow in this regime. This project aims to explore how this new paradigm can be applied to optimize the processing of HSCDs by understanding how their rheology is controlled by many of the classic variables (e.g. morphology and size distribution) viewed under the new paradigm, and by some of the variables made relevant by these recent advances themselves (e.g. roughness, friction).

A key idea from recent advances is that HSCDs jam at a packing fraction ϕ_m substantially below random close packing, so increasing solid content involves increasing ϕ_m . *The overall objective is therefore to understand what controls ϕ_m .* Research themes under this heading may include:

- The friction coefficient matters, but how this can be systematically modified on the micro to nano scales is not yet mastered.
- Roughness almost certainly matters on some scale, but again, no systematic study yet exists.
- Badly packed aggregates lower ϕ_m , so that it may be fruitful to study wet milling in this context. In particular, wet milling applies stress to an HSCD at $\phi > \phi_m$ to break up aggregates, thereby lowering ϕ_m in the process; the new paradigm should give insight into how best to do this.
- Polydispersity is known to affect random close packing; how it affects ϕ_m is largely unknown.
- Identify key/dominant particle characteristics (e.g., morphology, surface friction, modulus, size distribution) that impact particle assembly, jamming and overall rheological behavior across the transition zone between low and high particle Peclet number concentrated (>40% vol) slurry systems for predictive modeling applications.
- Explore the link between system level and particle level characteristics on the packing/jamming transitions and corresponding rheology of concentrated suspensions across the transition regime between surface dominated interactions and inertially dominated particle systems.

To make progress, the contractor should be able to perform studies in well characterized systems using one or more of the following methodologies: monitor structure and dynamics under flow using a mixture of real-space and scattering methods; develop framework linking measured structure and dynamics to constitutive properties of suspension; develop toolkit for systematic variation of relevant parameters (friction, roughness, etc.).