DENSE GRANULAR FLOWS DOWN INCLINES

MICHEL LOUGE

Dense granular flows down inclines continue to defy understanding. However, the last three decades have witnessed progress in techniques and approaches that have moved the field closer to achieving ab initio predictions of practical relevance.[1]

Difficulties arise for three principal reasons. First, because granular flows dissipate mechanical energy on the particle scale, regions featuring a substantial net gain in agitation have limited extent, unless the flow is relatively dilute [1], and are generally established near boundaries where slip can produce fluctuation energy by the working of the mean shear. Any such excess in agitation quickly dissipates farther afield, condensing grains into a flow with correlated interactions among several particles [2, 3]. Recent calculations have predicted the corresponding correlation length with dense gas kinetic theory [4], established its role near boundaries [5, 6], or have acknowledged their presence by introducing a dissipation length scale [7].

Second, while steady, fully developed flows over bumpy boundaries originally elicited much attention [8, 9], progress has been made on situations that are relevant to natural or manufactured systems, such as dense flows over a flat base confined between side walls [10, 11], which are common in industrial and agricultural applications, and flows over an erodible base with [12, 13] or without natural levies [14], which arise in geophysical systems. In such flows, the underlying granular bed dissipates agitation, but it can feature minuscule grain jumps down to surprising depths [15, 16]. Theories of particle segregation in inclined flows have also advanced significantly [17].

Third, because microscopic interactions at grain contacts, such as friction and cohesion, ultimately determine the rate of particle dissipation, their understanding is a prerequisite for quantitative predictions. Although contact dynamics is progressing [18], and there is evidence that certain inclined flows can be independent of contact models [19], challenges remain in implementing realistic contact models in numerical simulations.

An approach inspired by observations in several granular systems [20], and rooted in simply sheared flows [21], introduced an inertial number making the local shear rate dimensionless with normal stress, suggesting that granular flows would conform to a universal rheology relating effective friction and bulk density to the inertial number. Despite successes such as dense flows over bumpy boundaries [22], limits of this convenient approach arise, for example, with accelerating flows [23] or flows down flat walls, which feature a thin

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basal layer of spinning grains [24] and bifurcate into a remarkable variety of regimes [25], suggesting that stability analyses of theoretical solutions would lend useful insight [26, 27].

1. BIOGRAPHY

Michel Louge has taught at Cornell University since 1985, with visiting appointments at the Université de Provence, the Université de Rennes 1, and the École Centrale de Paris. He hold a Ph.D. in Mechanical Engineering from Stanford University. He has worked on combustion kinetics, circulating fluidized beds, granular flows, particle impact, heat transfer in gas-solids systems, powder snow avalanches, internal processes in sand dunes, and instrumentation for dense suspensions.

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