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Continuum modeling of size effects in dense granular flows: numerical solutions and comparison to experiments

Henann, David, david_henann@brown.edu, Brown University, United States; Kamrin, Ken, MIT, United States

ABSTRACT

Dense granular materials display complicated deformation phenomenology, which differentiate them from ordinary solids or fluids. For example, slowly flowing granular media form shear bands, which can have a variety of possible widths and which decay nontrivially into the surrounding quasi-rigid material. Furthermore, when a shear band exists at one point in a granular medium, creeping mechanical behavior is induced far outside the region of the shear band. Despite the ubiquity of granular flows, no model has been developed that captures or predicts these complexities, posing an obstacle in industry. We present a three-dimensional, continuum-level constitutive model and numerical simulation capability for well-developed, dense granular flows aimed at filling this need. The key ingredient of the theory is a grain-size-dependent nonlocal contribution, in which flow at a point is affected by both the local stress as well as the flow in neighboring material. With a single new material parameter, we show that the model is able to quantitatively predict experimental dense granular flows in an array of different geometries.