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Unifying grain shape effects in granular flows down a rough incline

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Abstract

Granular materials in nature are nearly always non-spherical, but particle shape effects in granular flow remain largely elusive. Here we use the discrete element method (DEM) to simulate dense granular flows down a rough incline with varying microscopic parameters and particle shapes. For each particle type, we vary the flow thickness h and slope angle θ to extract the $h_{\mathrm{stop}}(\theta)$ curves (below which flow ceases) and the $Fr = h/h_{\mathrm{stop}}$ relations following Pouliquen's approach [1], where $Fr = u/\sqrt{gh}$ is the Froude number, u is the mean flow velocity, and g is the gravitational acceleration. For microscopic parameters, we find that the friction coefficient (μ_s) has a significant impact on the flow, saturating at around $\mu_s = 0.5$, for spherical and non-spherical particles. Other parameters (particle stiffness with linear and Hertz models, Poisson's ratio, and restitution coefficient) have a minor influence. For non-spherical particles, we first focus on the particle length-to-diameter aspect ratios (AR). The Fr-h/h_{stop} curves show an intriguing nonlinear dependence on AR, with two plateaus at small and large AR, respectively [2]. Similar behaviors are observed for other particle shapes (flatness and angularity), indicating that Pouliquen's flow rule is not universal across granular materials. Finally, we show that a recent velocity scaling [3] based on a shear stress argument can collapse data for all flow conditions and particle shapes, including cubes, pyramids, elongated particles, flat particles, and realistic sand-shaped particles, which represents a promising grain-shape-unifying flow rule for granular avalanches.

References

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