Transition in a dense granular flow.

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The effect of base roughness on the flow down an inclined plane is studied using the discrete element method (DEM), in which the interaction force between particles is modeled using a spring-dashpot model in which the force due to deformation consists of a spring force proportional to the relative displacement of the surface of contact between the both parallel and perpendicular to the surfaces, and a damping force proportional to the relative velocity. The simulations are carried out using the open source code, LAMMPS (Large-scale Atomic Molecular Massively Parallel Simulator). The base consists of a random configuration of frozen particles, and the base roughness is varied by varying the ratio of the diameters of the frozen and moving particles. As the base particle diameter is decreased, a discontinuous change is observed in both the relative arrangement of particles and in the flow dynamics at a critical base particle diameter. Above the transition particle diameter, the relative particle arrangement is disordered, the flow is less dense (volume fraction 0.59 or less), whereas below the transition diameter, the particles flow in the form of layers sliding past each other, with hexagonal ordering within the layers, and the flow is more dense (volume fraction in the range 0.62-0.64). In both regimes, it is found that Bagnold law is valid, and the stress is proportional to the square of the strain rate. However, the Bagnold coefficients (ratio of stress and square of strain rate) are higher, by more than an order of magnitude, in the disordered state in comparison to the ordered state. The physical basis for the transition will be discussed using both theories for flow instabilities in homogeneous fluids, as well as the instability of a layered flowing structure.

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