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Grain fragmentation in sheared granular flow: weakening effects, energy dissipation, and strain localization CHARLES K.C. LIEOU, University of California, Santa Barbara, AHMED E. ELBANNA, University of Illinois at Urbana-Champaign, JEAN M. CARLSON, University of California, Santa Barbara
— We describe the shear flow of a disordered granular material subject to grain fracture using the shear-transformation-zone (STZ) theory of amorphous plasticity adapted to systems with a hard-core inter-particle interaction. To this end, we develop the equations of motion for this system within a statistical-thermodynamic framework analogous to that used in the analysis of molecular glasses. For hard-core systems, the amount of internal, configurational disorder is characterized by the compactivity $X = \partial V/\partial S_C$, where V and S_C are respectively the volume and configurational entropy. Grain breakage is described by a constitutive equation for the temporal evolution of a characteristic grain size a, based on fracture mechanics. We show that grain breakage is a weakening mechanism, significantly lowering the flow stress at large strain rates, if the material is rate-strengthening in character. We show in addition that if the granular material is sufficiently aged, spatial inhomogeneity in configurational disorder results in strain localization. We also show that grain splitting contributes significantly to comminution at small shear strains, while grain abrasion becomes dominant at large shear displacements.

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