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Acoustic Emissions Characteristics During Shearing of Granular Media

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Stresses in granular materials are focused along grain networks called force chains. During deformation, microscopic reorganizations of grains cause these chains to fail and reform. Changes in distribution of energy release and stress drops are used to quantify progressive failure and identify precursors indicative of imminent global failure. Here we use acoustic emissions to monitor the energy released by failures of force chains during shear deformation of glass beads. Using a specially-designed shear frame, we performed systematic studies of statistics of shear stress drops and associated acoustic emissions as functions of normal load, shear velocity, and grain size. The apparatus consists of sand or glass-bead filled rectangular enclosures that move horizontally relative to each other with fixed gap forming a well-defined shear zone within the granular material. A fixed normal load is applied by means of a pneumatic piston pressing the top surface of the enclosure. We measure the shear forces exerted on the enclosure, the vertical motion of the piston, and the carriage horizontal motion at rates of 150 Hz. Acoustic emission sensors buried in various places in the granular material record high frequency (kHz) elastic waves produced by grain motion and collision. During strain-controlled tests, the shear stress exhibits a saw-tooth shape with exponentially distributed stress drops. These stress drops are attributed to force chain failures. Acoustic emissions amplitude-frequency distributions closely follow the distribution of stress drops. Moreover time series analysis indicate correlations between certain acoustic emissions and stress drops confirming that force chains liberate measurable high frequency elastic waves. The combination of acoustic emissions and stress fluctuations provides a framework to study acoustic emission source mechanisms during shear deformation of granular materials with the potential to predict time and location of failure by careful monitoring of evolving statistics. These measurements also identify parallels with simple conceptual models of failure such as the fiber bundle model proposed to simulate force chain failures.