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Investigations on comminution of sheared prismatic granular materials using the discrete element method

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The comminution (or breakage) of granular materials under shearing loads is conjectured to strongly influence dynamics of both natural processes (such as fault zone evolution and landslides) and man-made processes (such as underground cave mining and minerals processing). Previous laboratory [1] and numerical studies [4] have demonstrated that two distinct breakage mechanisms contribute to the comminution of granular materials under shear. The first mechanism is that of abrasion in which grinding or chipping removes small volumes of material from the surface of larger blocks. The amount of abrasion has been found to be dependent both on the total shear strain and the confining pressure applied to the granular material. The second breakage mechanism is that of bulk-splitting, in which a single block is broken into two or more smaller blocks. The degree of bulk-splitting has been shown to be largely dependent upon confining pressure, and only to a lesser extent the total shear strain.

Common to previous laboratory and numerical studies is that the granular material is typically initially mono-disperse and often of a contrived shape (cylindrical [1] or spherical [4]). This approach has two adverse consequences. Firstly, the initial granular material has a porosity much higher than a similar volume of compacted prismatic material. The higher porosity results in less dilation of the granular material as shear commences, which may inhibit breakage via builk-splitting. Secondly, there are fewer edges or corners, the sites most amenable for abrasion both during confinement and shear.

This study extends previous studies using the Discrete Element Method (DEM [2]) to investigate the breakge mechanisms of sheared prismatic granular materials whose initial porosity is near zero. The granular prismatic material is constructed by first filling a volume with large spheres of variable size. These spheres are then replaced by convex polyhedra forming planar surfaces between adjacent spheres. Finally, the convex polyhedra are filled with bonded spherical particles to simulate the brittle-elastic response of the granular material.As in previous studies, the granular assembly is then compressed to various confining pressures and sheared to large total shear strains.

During these so-called annular shear-cell experiments, each breakage event is analysed to determine whether it qualifies as an abrasion event or bulk-splitting event. The size-distribution of fragments within the shear-cell is also monitored throughout the experiments. Preliminary results confirm the qualitative relationships between applied loads and breakage mechanisms described above. Quantitative comparisons with previous DEM studies will be presented at the meeting.

These experiments were conducted using ESyS-Particle, an Open Source DEM simulation package for multi-core PCs or supercomputers [3].

References

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[4] Mair, K. and Abe, S. (2011), Breaking up: comminution mechanisms in sheared simulated fault gouge, *Pure Appl. Geophys.*, **168**, no. 12, 2277–2288.