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In this work, we used the Contact Dynamics - Discrete Element Method (CD-DEM) to investigate the effect of material and system parameters on the grinding process in a 2D rotating drum. To model breakable particles we implemented the Bonded Cell Method (BCM) [1], in which the particles are discretized into bonded polygonal cells (figure 1a). A debonding criterion consistent with the classical framework of fracture mechanics (both in terms of yield stress and fracture energy) was employed [2]. We used a smooth drum without grinding media in which particle breakage is a consequence of granular flow. In this self-grinding or autogenous process (figure 1b), each particle breaks into fragments composed of unbreakable primary cells with different shapes and sizes depending on grinding time, surface energy, rotation speed and other mechanical properties.

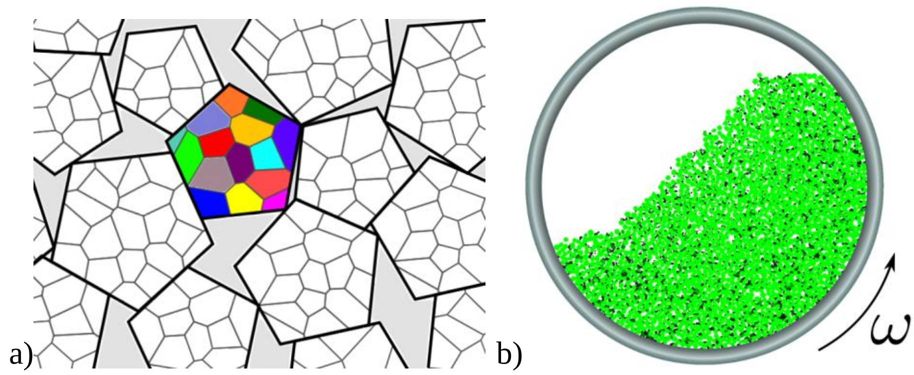

Figure 1. a) Voronoï tessellation applied to polygonal breakable particles. Each cell is presented in a different color. b) Snapshots of a rotating drum simulation. The color is proportional to damage, defined as the number of cells detached from a particle, represented on color scale from bright green for intact particles to black for highly-damaged particles.

For an extensive parametric study [3] we performed long lasting simulations with large number of particles and cells in order to get meaningful statistics of fracture events. We varied system parameters such as drum size, rotation speed, filling degree and initial particle shape. The effect of each parameter on the granular flow and evolution of grinding in terms of the mean particle size and specific surface of the material was quantified. We show that the specific surface (defined as the sum of the surface areas of all particles divided by their total weight) increases almost linearly with time up to a transition point to a nonlinear regime where many unbreakable fragments are generated, and thus the probability of breakage declines. For all values of system parameters, this point corresponds to the same amount of specific surface equal to slightly more than half the maximum specific surface that can be generated in the simulations. This transition was used to define a characteristic time associated to the grinding efficiency. For all system parameters, when the times are scaled by this characteristic time, the rate of particle breakage collapses on a master curve. Finally, we show that the rate of particle breakage can be expressed as a linear function of a general scaling parameter that incorporates all system parameters. This scaling behavior provides a framework for the upscaling of drum grinding process from laboratory to industrial scale.

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