The evolution of fragment shapes in repeated sub-critical impact

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ABSTRACT

The shape of rocks in mountain boulder fields and of pebbles in river beds observed today are all results of a long evolution of abrasion and spallation processes [1]. The initial configuration of these types of geomorphic evolution is freshly fractured rock which is mainly generated by energetic fragmentation processes occurring in earthquakes, volcanic eruptions, cliff collapses, landslides, and stone avalanches [2]. Fractured rock pieces have a polyhedral shape with sharp edges and corners which then undergo a complex degradation process resulting in a smooth and rounded shape. The typical mechanism of this process is sub-critical impact where the imparted energy is not sufficient to give rise to breakup of the body instead small pieces are gradually removed from the surface in a sequence of events [1,2].

Here we investigate the evolution of fragment shapes caused by repeated sub-critical impact using a discrete element modelling (DEM) framework. We constructed a three-dimensional model of heterogeneous brittle materials by sedimenting spherical particles in a container. The particles are coupled by beams which represent breakable cohesive contacts of material elements [3,4]. Starting from a cuboid shape the repeated impact of the sample with a hard wall was studied. First we determined the critical impact velocity of fragmentation which results in complete breakup then simulations were performed by varying the impact velocity in the sub-critical range down to the threshold velocity where no beam breaking occurs at all. In a single impact a small fraction of mass is removed from the sample surface creating some debris and a large residue which is then retained and subject to further impacts at the same velocity.

We show that our DEM approach reproduces the generic experimental observation that the shape evolution has two stages, i.e. first the sharp edges and corners are removed and a nearly spherical shape is attained which is then followed by an isotropic shrinking where the radius of the sphere gets reduced. Varying the velocity and number of impacts our simulations revealed interesting scaling laws which describe the gradual evolution of the mass, surface area, internal damage, and overall shape parameters of the sample.

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