From fracture to fragmentation

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ABSTRACT

The nature of fracture phenomena strongly limits engineering solutions to cases, a little bit beyond the regime of linear fracture mechanics. Nevertheless, fracture in brittle disordered materials, dominated by simultaneously growing and dynamically competing cracks is rather ubiquitous [1,2]. From the dynamics of single crack propagation, through the statistics of crack ensembles to the rapid fragmentation of materials, Discrete Element Methods (DEM) helped to enrich the understanding over the past decades. Models of seemingly simple rigid body dynamics with simple contact and cohesive interactions proved to be surprisingly successful for representing dynamic fracture and fragmentation phenomena, emerging from the complex systems dynamics. Today, applications of DEM make a substantial contribution for explaining the mechanical response and breaking phenomena of heterogeneous materials under various types of loading conditions beyond single crack growth [3,4]. Various particle geometries, material response, ways to treat repulsive and cohesive behaviour and of course loss of cohesion, lead to a flexible tool-set of approaches. Strategies for higher order agglomeration, coupling with other simulation techniques for continuum domains or other particle based methods extended the reach of DEM significantly. Ranging from the slowly changing, sub-critical loads to the highly energetic fragmentation, DEM proved to be an indispensable tool for such investigations.

In this talk a brief review on the motivations and basic ideas behind the DEM approach to cohesive particulate matter is given. Different ways of introducing cohesion and its loss are discussed in light of fracture in frictional and non-frictional materials beyond the Griffith length of stable crack growth. Among the widespread applications of DEM for the fracture of heterogeneous materials, focus is given on impact comminution of aggregated matter [4]. By providing an improved understanding of comminution processes e.g. in impact mills, one of the energetically least efficient processes on the global scale could be improved – by the use of particle mechanics. It is shown, that a critical impact velocity v_{cr} exists, separating the fracture from the fragmentation regime. Below the critical velocity, fragmentation by repeated impacts can be described by a Basquin type low cycle fatigue law, above v_{cr} Power-law fragment size distributions emerge. This behaviour is robust even for multi-phase materials. In a comparative study it is finally demonstrated, how the milling efficiency can be increased for the same system only by manipulating the shock wave configurations via vibrating targets.

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