Calibration and Simulation of Breakage by using DEM

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ABSTRACT

This work presents a methodology to simulate a pilot-scale milling application with the use of an advanced breakage model and the calibration of its Discrete Element Methodology (DEM) parameters. The presented model is based on the DEM [1] and the previous work from Tavares (2009), Tavares and King (2002). It focuses on demonstrating the capabilities of the model in capturing the different breakage mechanisms of a brittle material and is validated using data from Drop Weight Tests (DWT) performed by ME Elecmetal laboratories.

Particle breakage and subsequent size reduction is a perpetual problem across a wide range of industries including the food, chemical, mineral and pharmaceutical sectors which encompass an even wider range of processed materials [2, 3]. The phenomenon of breakage includes different mechanisms, starting with abrasion (or degradation, weakening, damage) by repeated low energy stressing events and resulting to final body breakage. This is an important subject that range from materials handling to comminution. There are many applications where undesirable degradation can take place such as cyclones, fluidized beds, centrifuges, stirred vessels; and in transport equipment, such as pneumatic, screw and hydraulic conveyors and chutes [4, 5]. For instance, degradation is of relevance from materials such as coal and iron ore lumps, used in steelmaking, to fine powders that are processed in the chemical, food and pharmaceutical industries [6-8]. Another example in which degradation is actually desirable is the case of crystallization processes as it is used to provide a consistent size distribution, which would not be achieved through controlled crystal growth alone [9, 10].

Research has shown that particles are often loaded using insufficient energy to cause breakage inside comminution equipment, being fractured only after repeated low-energy stressing. This has been particularly well-known for autogenous and semiautogenous mills, where rock lumps are broken by a combination of attrition and self-induced impact-fracture [11]. Breakage by repeated stressing is also the major mode of breakage for coarse particles used in the mining and mineral processing sectors. Therefore, this mode of particle fracture is likely to be of significance for applications that use crushers too. This has led to an increased demand in the simulation of particle breakage and degradation to better describe the fracture of particles subjected to repeated loading.

This work describes a suitable calibration process and analyses the simulation of an industrial pilot-scale milling application in order to assess the performance of the equipment and the resulting material after the end of the process. The material used is copper ore and is being processed through fully-autogenous (AG) and semi-autogenous (SAG) tests. The presented work includes the calibration of the DEM parameters through DWTs and the replication of the AG and SAG tests with relevant analysis. The model discusses both the catastrophic breakage and the replacement of original particles with its fragments and also the surface damage due to low stressing events. Furthermore, the size distribution of the fragments is defined by using a combination of a t_{10} parameter and a clever algorithm that provides realistic representation of real-life scenarios. The presented breakage model is based on previous work of Tavares (2009) reflecting the latest advances in research thus provides information on the final particle size distribution, the mass loss that the particle suffers due to abrasion, the new fracture energy per particle type, as well as the average power mill.

The calibration results were in very good agreement with the DWTs and showed that the model was able to capture the behaviour of the material in detail. Also, they suggested that the majority of the breakage and the creation of fines occurs at the perimeter of the mill, while providing important information regarding the mass loss in the system, such as the presence of steel balls increased the abrasion by 3.5%. Finally, an important and novel observation was that the material reached a plateau between 30-80 secs of simulation showing minor breakage for the intermediate particle sizes, agreeing with real-life observation in SAG mills. This type of analysis highlights the importance of the presented model and brings great benefits to a wide range of industries as it provides information regarding the material behaviour and operating conditions that would be impossible to gain otherwise.

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