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ScienceDirect
Minerals Engineering 20 (2007) 303–309
MINERALS ENGINEERING
This article is also available online at: www.elsevier.com/locate/mineng

Modelling of incremental rock breakage by impact – For use in DEM models

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Received 3 August 2006; accepted 15 October 2006
Available online 22 December 2006

Abstract

DEM simulations of AG and SAG mills indicate that breakage in a single impact is almost certainly a rare event. However, there are many events which might cause some damage. Hence it becomes important to be able to model how damage might accumulate and with what severity a particle is likely to break after accumulating sufficient damage.

An investigation of incremental impact breakage of a well characterized ore sample has been carried out by Whyte (2005) [Whyte, R., 2005. Measuring incremental damage in rock breakage by impact. BE (honours) Thesis, The University of Queensland (unpublished)]. The outcomes of this work are encouraging. A modified version of a JKMRC developed equation – which relates severity of breakage to specific energy input – also provides a good description of the degree of incremental breakage for each size range of particles which was tested when breakage does occur.

The other factor of interest for a DEM model is the probability of survival after a number of impact events. The work of Vogel and Peukert (2004) [Vogel, L., Peukert, W., 2004. Determination of material properties relevant to grinding by practicable labscale milling tests, International Journal of Minerals Processing, 74S, S329–S338] provides a useful model for multiple impacts with identical energies. This model has been modified and extended to different input energy levels.

This model proposes a minimum specific impact energy E_0 below which no damage is accumulated by the body of the particle.

Perhaps the most important insight from this work is a way to quantify energy inefficiency of breakage in comminution devices. Each successive impact after the first one fails to utilize E_0 because the particle must be loaded again to E_0 before any further damage can be achieved.

For the ore tested, achieving a similar degree of severity of incremental breakage using multiple impacts typically required substantially more total energy than was required for a single impact. However, even very small interactions will still cause some surface damage and generate fine progeny.

Keywords: Comminution; SAG milling; Discrete element modelling

1. Introduction

Substantial (and continuing) increases in low cost computational power have resulted in several discrete element method (DEM) codes which are sufficiently powerful to be applied to comminution processes. Testing DEM models against experimental data and ore characterization techniques has exposed where our current understanding is adequate – and where it is not.

For devices which comminute rocks in a single event such as conventional crushers or impact crushers, the existing JKMRC energy based breakage and progeny estimation techniques (Whiten and Narayanan, 1988) yield accurate predictions. This condition is satisfied for impact

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0892-6875/$ - see front matter
doi:10.1016/j.mineng.2006.10.015

(Djordjevic et al., 2003) and conventional crushers (Briggs and Bearman, 1995).

However, based on DEM estimates (Morrison et al., 2002; Cleary and Morrison, 2004), the large autogenous and semi-autogenous mills in common use are unable to supply enough energy to break particles larger than a few millimeters in a single event; although there are many low energy events available.

This paper presents the results of a project set up to investigate incremental breakage by low energy impact events.

Low energy breakage by attrition seems to be well correlated with DEM predictions of frictional interactions (Morrison et al., 2006). However, the relationship with impact collisions is more complex.

There are three relationships which are necessary for use in a DEM model:

- The probability of breakage or survival of a rock after a series of impacts of known energies.
- The severity of breakage when it does occur.
- The size distribution of the resultant progeny.

The second and third relationships seem to be similar. However, the severity of breakage is usually modeled by considering a single point on the cumulative size distribution. For this study, we have used the t_{10} – defined as the percentage by weight of the progeny which will pass through an aperture one tenth of the original particle(s). Even though the progeny may have the same t_{10}, there is no necessity for the size distributions to be identical – especially if they were achieved by different comminution processes. Hence, all three relationships must be defined and tested.

With more powerful computers and numerical codes, the shape distribution of the progeny will also become of interest.

2. Experimental work

The JK Drop Weight Tester (DWT) described by Napier-Munn et al. (1996) and shown in Fig. 1 was used to investigate the cumulative effects of impacts at various fractions of the energy required to cause breakage in a single impact.

The standard JK DWT typically uses minimum levels of energy which are high enough to guarantee breakage in a single impact. The DW test was extended to use multiple inputs of energy which were a fraction of the level which would only just cause breakage.

The initial tests were carried out on two size fractions of a well characterized copper gold ore. Each size fraction was divided into randomly selected groups of 30 particles. Particles within one group were subjected to impacts at 20% of the energy which would just cause breakage in a single impact. Particles which were not broken were counted and set aside for another round of impacts. The progeny

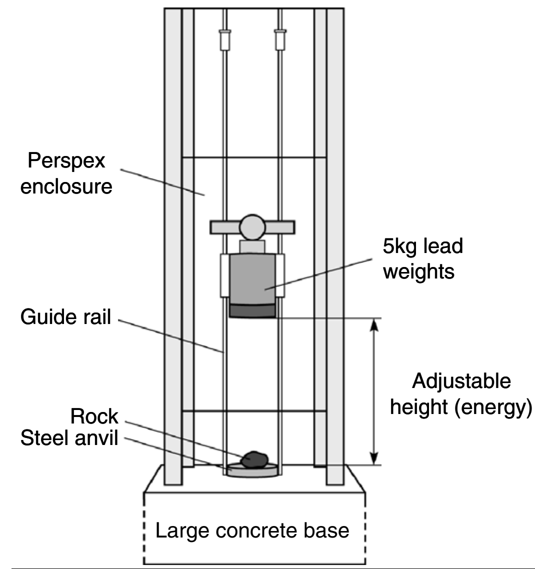

Fig. 1. The JKMRC drop weight testing device.

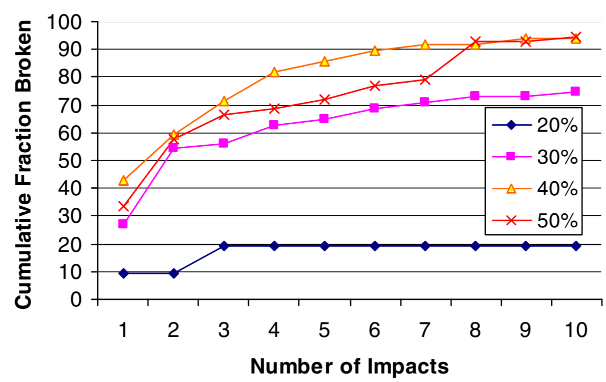

Fig. 2. −19 + 16 mm preliminary test results for breakage caused by successive impacts at various percentages of the minimum energy required to cause breakage in a single impact.

of those particles which were broken after one impact was combined and sized as a measure of severity of breakage (t_{10}) and of the resulting progeny size distribution.

The survivors were subjected to a second set of impacts and the process repeated. Each of the groups of particles was subjected to impacts of 30%, 40% and 50% of the energy which would just cause breakage in a single impact. The results of these repetitive tests (Whyte, 2005) are shown in Figs. 2 and 3. At 20% of the energy required for single impact breakage, only a few particles were broken after 10 impacts. At 50% of that energy, only a few particles survived more than a small number of impacts.

3. Modeling the probability of survival

There is a substantial body of literature concerning the survival of particles after a number of similar impacts – although very few of these researchers have considered the severity of the resulting breakage or the full size distribution of the progeny.