Update on the JKRBT (JKMRC Rotary Breakage Tester)

T. Kojovic and F. Shi

University of Queensland, JKMRC, QLD

Introduction, Background and Objectives

The long history of comminution studies at the JKMRC has included the development of laboratory testing procedures, to provide material characterisation data that are used in conjunction with machine specific data in modelling and simulation (Napier-Munn et al, 1996). The key developments include:

- Twin Pendulum
- Drop Weight tester (DWT)
- Automated Linear Impact Comminution Evaluator (ALICE)
- Short Impact Load Cell (SILC)

The DWT is an established and globally accepted impact characterisation device, and has become one of the standard impact tests for AG/SAG milling ore characterisation. The DWT apparatus and its associated data reduction technique were developed so that the relationship between specific energy input and resultant product size could be determined (see Equation 1):

$$t_{10} = A\left(1 - e^{-b.Ecs}\right) \qquad (1)$$

where t10 is a size distribution 'fineness' index defined as the progeny percent passing one tenth of the initial mean particle size, Ecs is the specific comminution energy (kWh/t), and A and b are the ore impact breakage parameters determined from DWT results. The index A*b has become well known in the mining industry as a reliable indicator of impact ore hardness, and essentially describes the rate at which fines are produced (t10) for a set amount of specific energy (Ecs). The t10-Ecs relationship and A*b parameters are used in size-reduction-modelling for crushers and mills in the JKSimMet mineral processing simulator (Wiseman and Richardson, 1991).

Since all tests using the DWT, SILC (Bourgeois and Banini, 2002), or the Hopkinson bar are conducted on single rock specimens positioned manually on the anvil or flat surface, they are both time consuming and expensive. For the test to remain practical the rock samples being tested are limited to 10 – 30 pieces for each size fraction, which inevitably throws into question the statistical validity of the derived ore characteristics. Recent developments in DEM of milling have revealed that small energy impacts occur much more frequently than high energy impacts (Djordjevic et al, 2004). As such it appears a new requirement in breakage testing will be the characterization of incremental breakage at small impact energies. However, testing of repetitive impacts at small energies using the DW tester is very time-consuming and hence impractical. Research into finding a rapid breakage characterization device was clearly warranted in an effort to overcome these limitations.

The concept of using kinetic energy to crush rocks seemed like a viable alternative for rapid breakage characterization, since it no longer requires the positioning of rock specimens manually on the anvil. Industrial applications of this concept are found in Vertical Shaft Impact (VSI) crushers and laboratory pulverizers, which employ a rotor-stator impacting system. However, both of these devices are employed merely for particle size reduction, not for breakage characterization, as the exact amount of energy applied in the process is not well controlled or measured. However, the JKMRC found that VSI crushers can be modelled from first principles, allowing useful simulations (e.g. effect of rotor speed) to be carried out with only the basic design data on the machine and rock characteristics required (Kojovic, 1996; Djordjevic et al, 2003). This suggests that the rock characteristics may be inferred from the product of the VSI, if the amount of energy applied in the process can be precisely controlled and measured.

In response to the body of evidence supporting the use of kinetic energy, in 2005 the JKMRC comminution research team led by Shi and Kojovic decided to thoroughly investigate the feasibility of using the kinetic energy concept for particle impact breakage characterization. A prototype Rotary Breakage Tester (JKRBT), with a rotor diameter of 360 mm, was designed and manufactured by the JKMRC pilot plant workshop team (Figure 1). The operating system consists of a vibrating feeder, a rotor-stator impacting device with its drive system, and an operation control unit. Like the DWT, the JKRBT also requires the ore particles be pre-sized into narrow fractions. Particles of the selected size are fed into the rotor-stator impacting system via a vibrating feeder.

Figure 1: Photograph of the prototype JKRBT device, with rotor-stator showing through the inspection window.

Methodology / Experimental Technique

The JKRBT uses a rotor-stator impacting system, in which particles gain kinetic energy while they are spun in the rotor. They are then ejected and impacted against the stator, causing particle breakage. The specific energy of each impact in the JKRBT, Ecs, is defined as the kinetic energy Ek per particle mass m:

$$Ecs = \frac{E_k}{m} = \frac{0.5 \times m \times V_i^2}{m} = 0.5 \times V_i^2 \quad (2)$$

Since the particle mass does not affect the specific energy in this type of impact breakage device, the Ecs becomes solely dependent on the impact velocity Vi. The research team has shown that the specific energy of impact can be accurately and precisely controlled in the JKRBT. They also confirmed that the actual impact velocity in practice is less than theoretical, requiring the JKRBT to be calibrated first to achieve precise breakage energy levels. The calibration is machine specific and can be programmed into the JKRBT control system to allow the user to enter the required specific energy directly, or it can be tabulated in the JKRBT Operating Manual as pre-set speeds which can be entered manually to achieve a desired specific energy level.

Key Results / Findings

The JKRBT overcomes some of the limitations of existing impact tests such as a lack of precision of the energy input, the amount of time required to run individual tests and the difficulties in testing the smallest particles. To date, comparative breakage tests using the prototype JKRBT device and the traditional JKMRC Drop Weight Tester showed that the two devices generate the identical breakage–energy relationship for the same ore of the same size, as shown in Figure 2.

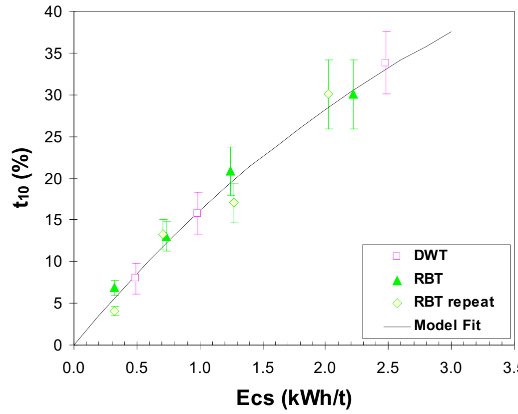

Figure 2: Comparison of t10 vs. Ecs relation determined by the JKRBT and DWT.

Statistical analysis indicates that the two testing methods can generate statistically similar breakage parameter A*b values, as illustrated in Figure 3 which compares the A*b values of 16 ore types determined by industrial JKRBT and DWT respectively. This analysis accounts for the difference in contact points and strain rates between the DWT and JKRBT.

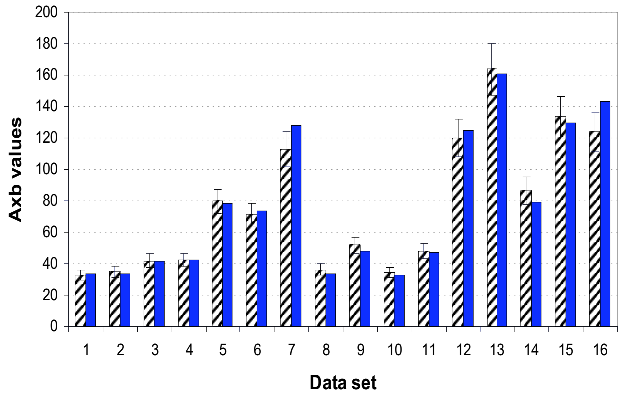

*Figure 3: Comparison of breakage parameters A*b determined by the JKRBT and DWT (10% error bars on DWT result).*

The very positive feedback received from mining companies to the JKRBT has prompted the JKMRC to further validate the device through a formalized experimental test program on professionally designed and manufactured JKRBT machines. The validation project started in March 2007 with the first industrialised unit installed and commissioned at Anglo Research in Johannesburg, South Africa. Barrick, BHP Billiton, Rio Tinto and Teck Cominco have also signed up to participate in the project. The current status and site deployment is as follows:

- Anglo Research (Crown Mines, South Africa) x 2 machines

- Barrick Gold (JKtech, Brisbane) - 12 months agreement
- BHP-Billiton (Newcastle Technology Centre, Australia)
- Rio Tinto (Kennecott, USA)
- Teck Cominco (Trail, Canada)

Figure 4 shows a diagram of the industrialised JKBRT, designed and manufactured by Russell Mineral Equipment (RME).

Figure 4: *The first industrialised JKRBT installed at Anglo Research in South Africa.*

Unlike the prototype device, the industrialised JKRBT can be opened for easy access to clean the breakage chamber. The lid is operated by an electronically driven linear actuator. The counter-weight at the back of the lid is designed to prevent the lid from falling down by gravity should the electronic system fail while the lid is opening or closing. The industrialised JKRBT employs a rotor 450 mm in diameter, and can treat particles from 1 to 45 mm, at specific energy levels from 0.001 to 3.8 kWh/t. The use a rotary feeder has provided a simple feeding system that also offers an effective noise suppression mechanism, reducing the noise to below 85dB at the highest operating speed.

It is worth noting that the new breakage model developed by the JKMRC (Shi and Kojovic, 2007) enables the user to accurately match the DWT derived breakage parameters, A and b, from JKRBT data on four (13.2 to 45 mm) instead of the standard five DWT size fractions (13.2 to 63 mm). The model and application of JKRBT concept to ore testing has been patented by The University of Queensland.

Highlights / Benefits

Feedback from Anglo Research has indicated higher productivity and better repeatability by the first commercial JKRBT when compared with the Drop Weight Tester. The results to date look very promising and suggest the JKRBT will provide a powerful and easy to use tool for rapid ore breakage characterisation to the mining industry. Tests have confirmed the device offers a rapid method for determining the hardness of drill core samples within the context of the AMIRA P843 geometallurgical project. For comparative testing, Walters and Kojovic (2006) found the JKRBT appears to be the best choice, followed by SMC and PLT.

Some of the key features of the JKRBT are:

- Treats many more particles – hence can generate statistically more valid results
- Wide particle size range (1.4 – 45 mm), wide energy range (0.001 – 3.9 kWh/t)
- Rapid characterisation (1/8 - 1/10 of DWT time confirmed by Anglo Research)
- Accurately and precisely control energy
- Excellent reproducibility

Conclusions and Future Direction

A new rapid breakage characterization testing device, the JKRBT, has been developed by the JKMRC. A detailed study using a prototype machine confirmed the concept of using controlled kinetic energy to characterize ore particle breakage, prompting a comprehensive validation using an industrialized JKRBT, professionally designed and fabricated by Russell Mineral Equipment (RME). The validation project will be completed in 2008, with commercial release expected in early 2009.

Application of the prototype JKRBT in geometallurgical testing with the AMIRA P843 GeM project has confirmed the JKRBT device offers a rapid and consistent method for determining the hardness of drill core samples.

The JKRBT has the potential to revolutionize ore testing, with applications in laboratory impact breakage characterisation of rock samples, drill cores, coal and other materials. Automation with lab image sizing technology like the Camsizer would further enhance its productivity. It also stands poised to significantly advance the process control of comminution circuits since it is readily adaptable to on-line ore hardness measurement. This concept will be explored in the current P9O project.

Acknowledgements

The research and development of the JKRBT has been funded by The University of Queensland, JKMRC, JKTech, AMIRA/P9N Project, and Centre for Sustainable Resource Processing (CSRP). In-kind support from Anglo Research staff during the commissioning of the first industrial JKRBT unit is greatly appreciated.

References

1. Bourgeois, FS and Banini, GA, 2002. A Portable load cell for in-situ ore impact breakage testing. Int. Journal of Mineral Processing. 65, 31–54.
2. Djordjevic, N, Shi, F and Morrison, RD, 2003. Applying discrete element modelling to vertical and horizontal shaft impact crushers. Minerals Engineering 16: 983-991.
3. Djordjevic, N., Shi, F. and Morrison, R., 2004. Determination of lifter design, speed and filling effects in AG mills by 3D DEM. Minerals Engineering, 17, 1135-1142.
4. Kojovic, T., 1996. Vertical shaft impactors: predicting performance, Quarry Aust Jrnl, Vol 4, No 6, pp35-39
5. Napier-Munn, T.J., Morrell, S., Morrison, R.D., and Kojovic, T., 1996. Mineral comminution circuits: their operation and optimisation. ISBN 0 646 28861. Julius Kruttschnitt Mineral Research Centre.
6. Shi, F. and Kojovic, T. 2007. Validation of a model for impact breakage incorporating particle size effect. Int. Journal of Mineral Processing, 82, 156-163.
7. Van Latum, LA, 1985. The evaluation, conceptualization and development of single particle breakage testing apparatus. Masters Thesis (unpublished), Technical University of Delft, Netherland.
8. Walters, S., and Kojovic, T., 2006. Geometallurgical Mapping and Mine Modelling (GEMIII) – the way of the future. Proc SAG 2006, Vancouver, Vol IV, pp411-425.
9. Wiseman D.M. and Richardson J.M., 1991. JKSimMet - the mineral processing simulator. Proceedings 2nd Can Conf on Comp Applications in the Min Ind, (Eds Paulin, Pakalnis and Mular), Univ B.C. and CIM, Vol II, pp427-438.