In Detail

**Developed in the laboratory at the JK Centre in 1992, the JK Drop Weight Test measures impact breakage parameter to maximise ore characterisation and increase productivity.**

### The JK Drop Weight Test

The JK Drop Weight Test was developed in the laboratory at the JKMRC as a means of determining the breakage characteristics of a sample of ore in an AG/SAG mill.

In an AG/SAG mill, there are two main mechanisms of breakage: impact (high energy) and abrasion (low energy). The JK Drop Weight Test measures the impact and abrasion parameters for a specific sample of ore using two separate methods:

- The abrasion breakage parameter, $\alpha_a$, is determined by a tumbling test (Note this is NOT the Bond Abrasion Index test).
- The impact breakage parameters, $A$ and $b$, are determined using a high energy impact breakage device called the JK Drop Weight Tester, as shown above.
- These parameters can then be used in the JKSimMet Mineral Processing Simulator software. In JKSimMet, the parameters are combined with equipment details and operating conditions to model SAG/autogenous mill performance. The same test procedure also provides ore specific parameters for use in the JKSimMet crusher model.

A JK Drop Weight Test may be required in a number of cases:

- In greenfield, brownfield or existing operations, to determine the breakage parameters of an ore under AG/SAG milling conditions so that the circuit can be designed, optimised or analysed for a range of operating conditions.
- To determine the parameters for a new or existing crusher, for design or optimisation using the JKSimMet crusher model.
- When a number of SMC tests is to be carried out on an ore body, an SMC Test and a Drop Weight Test on the same sample provide the best correlation for the ore body profile.

The JK Drop Weight Test procedure is comprised of two parts, summarised as follows.

#### Impact Breakage Testing

The 100 kg sample is sized into five size fractions:

-63+53mm, -45+37.5mm, -31.5+26.5mm, -22.4+19mm, -16+13.2mm

For each size fraction, between 10 and 30 particles are broken at each of three energy levels, giving fifteen size/energy combinations. The particles are broken under impact at the required energy level using the JK Drop Weight Tester, which simply involves dropping a weight from a predetermined height on to a particle so that it breaks.

The breakage products of all particles for each size/energy combination are collected and sized. The size distribution produced is normalised with respect to original particle size. For a wide range of energy inputs, particle sizes and ore types, the relative size distributions remain similar in shape and can be described by a single point on the distribution. The JKTech convention is to use the percentage passing one-tenth of the original particle size. This is referred to as the "$t_{10}$".
For the size fractions in the JK Drop Weight Test, the original particle size is estimated by the geometric mean of the size range eg. -63+53 = 57.8mm.

In this way, a set of $t_{10}$ and $E_{cs}$ values are produced for the 15 energy/size combinations. The following equation relates to the amount of breakage, $t_{10}$, to the specific energy, $E_{cs}$ (kWh/t):

$$t_{10} = A(1 - e^{-bE_{cs}})$$

Using the 15 energy/size combination data values, the best fit A and b parameters are calculated using a minimisation of error squared routine. The resulting A and b parameters are related to the resistance of the ore to impact breakage. The product of A by b, which represents the slope of the curve at an $E_{cs}$ of 0 kWh/t, is a measure of the ore impact breakage resistance and is used for comparison with other samples with lower values indicating harder ore in terms of impact breakage.

**Abrasions Breakage Testing**

Low energy (abrasion) breakage is characterised using a tumbling test of selected single size fractions.

The standard abrasion test tumbles 3 kg of -55+38 mm particles for 10 minutes at 70% critical speed in a 305mm by 305mm laboratory mill fitted with 4 x 6mm lifter bars. The resulting product is then sized and the $t_{10}$ value for the product is determined.

The geometric mean particle size of the original size fraction -56+38mm is 45.7 mm.

The $t_{10}$ size is: $1/10 \times 45.7 = 4.57$ mm

The abrasion parameter, $t_a$, is then defined as: $t_a = t_{10} / 10$

A standard JK Drop Weight Test report is issued for every JK Drop Weight Test or set of JK Drop Weight Tests carried out at JKTech. The report details the standard test procedure and background theory, as well as providing the resultant impact and abrasion parameters. Some analysis of the results is provided, including the particle size and density effects for the specific ore type(s) being tested. Further interpretation of the results is available if required.

**The JK Drop Weight Test Parameters**

The three parameters relevant to AG/SAG milling are A, b and $t_a$. A and b are used to characterise the impact breakage of the ore. $t_a$ is a measure of the resistance of the ore to abrasion. In both cases, the lower the value the greater the resistance of the ore to that type of breakage.

A and b are the high energy impact breakage parameters in the equation which relates $t_{10}$ (the % of broken product passing 1/10 the original particle size) to $E_{cs}$ (the specific energy of comminution), as follows:

$$t_{10} = A(1 - e^{-bE_{cs}})$$

Typically, the curve looks something like the one below. A is the maximum $t_{10}$ value achieved. This is significant for higher energy breakage. The absolute value of A is not critical in a SAG mill because it is a measure of the breakage of the ore at energy levels higher than those that are usually achieved in a SAG mill. However, A is important in the part it plays in characterising the overall breakage curve. The parameter b is related to the overall slope of the $t_{10}$ vs $E_{cs}$ curve at the lower energies. A and b are interdependent, since the value of one will directly affect the other. As A and b are related, it is usual to report A*b as the single value indicating the hardness of the ore in terms of impact breakage. The A*b parameter is the slope of the $t_{10}$ vs $E_{cs}$ curve at its origin and it is a measure of breakage of the ore at lower energy levels. This is particularly applicable to SAG mill breakage, which mostly occurs at lower energy levels.

The abrasion parameter $t_a$ is defined as:

$$t_a = t_{10} / 10$$

A lower value of $t_{10}$ (and thus $t_a$) indicates that there is a lower percentage of material passing 1/10th the original particle size, or greater resistance to abrasion breakage.

The following table indicates some typical figures for the JK Drop Weight Test parameters, and a relative measure of what they mean.
**Frequently Asked Questions**

**How long does a JK Drop Weight Test take?**
The usual turnaround time is two to three weeks from the start of testing until preliminary results are available. Please contact Laboratory Services Manager to determine the current status, or if there are any special requirements associated with handling the sample or delivering the results.

**What are the limitations of the JK Drop Weight Test?**
1. JK Drop Weight Tests are good for predicting AG/SAG milling characteristics of an ore using JKSimMet, provided the ore is brittle and does not experience much plastic deformation before breaking. Ores which do undergo plastic deformation, such as those with high clay content, may not be reliably characterised by a JK Drop Weight Test.

2. The JK Drop Weight Test is limited by the size of the particle that can be tested. Results for larger particles are extrapolated from the data for the size ranges tested. If an ore is weaker at particle sizes larger than the top size range tested (-63+53mm), then the results from a JK Drop Weight Test will be conservative.

**What if the ore sample is not brittle, has a high clay content?**
The results from the JK Drop Weight Test for this type of ore may not accurately characterise the AG/SAG milling properties of the sample. Effective AG/SAG milling requires some competent material in the larger size ranges, and therefore it is possible that this ore type is unsuited to AG/SAG milling. A JK Drop Weight Test will identify where AG/SAG milling may be a problem for a given ore type and may therefore still be a useful exercise.

**Why is the variation of resistance to impact breakage with particle size reported in a standard JK Drop Weight Test report?**
The effect of particle size on impact breakage is important in AG/SAG milling. Some ores indicate a decrease in impact resistance with increasing particle size, whereas others show little or no variation. It is important in AG/SAG milling to have some competency in the larger particle sizes, so that these particles can act as media in the impact breakage mechanism. Reporting the variation of impact breakage resistance with particle size is important in identifying ore types where media competence for AG milling may be a problem.

**Why is ore density reported in a standard JK Drop Weight Test report?**
The densities of 30 randomly selected particles in the 31.5 x 26.5mm size fraction are measured in a JK Drop Weight Test, in order to determine the distribution. Of particular interest in AG/SAG milling is whether there is a heavy component in the ore which is also resistant to impact breakage and is also liberated at coarse size. Such a component has the potential to concentrate in the mill and cause power draw problems. The presence of such a component will be indicated by a bimodal density distribution.

The JKTech Mineral Comminution Circuits monograph includes detailed information about the JK Drop Weight Test plus information on comminution circuit equipment, operation and modelling.