Determination of the DWi Using the SMC Test and its Use in Orebody Profiling, Comminution Circuit Design and Optimisation.

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SUMMARY

The SMC test has been developed to provide a cost-effective means of obtaining data that can be used to predict comminution circuit performance in situations where only limited quantities of rock samples are available. It is therefore ideally suited to orebody profiling in greenfield, brownfield and established operations. The SMC test was originally developed to make use of quartered (slivered) core which is cut into a number of identical pieces (Figure 1). Each piece is then broken in an impact device and the broken products used to determine a so-called drop-weight index (DWi). Whole core (Figure 2) and half core (Figure 3) can also be used as can lump material. Original core diameters up to 85mm are suitable. Minimum recommended sample requirement is dependent on ore sg. For rock with an sg of 2.8 the minimum recommended sample weight for 50mm diameter core samples is 2.5 kg of intact core. For rock with a different sg to this, sample requirement is calculated on a pro-rata basis. The samples, once broken in the SMC test, can be used subsequently for Bond ball mill work index or batch grinding tests, therefore limiting overall sample requirements.

The drop-weight index (DWi) can be used to estimate the throughput of AG and SAG circuits through a combination of power- based and model-based approaches. The model-based approach makes use of the direct relationship between the DW_i and the JK breakage parameters A and b. The power-based route uses an approach developed by SMCC Pty Ltd in which it has been shown that the DW_i is correlated with the specific energy of a very wide range of operating AG and SAG circuits. Its usefulness also extends to rock mass characterisation in mining applications, as it is also correlated with the point load index/UCS. It is therefore ideally suited for mine-to-mill studies as it can be simultaneously used to predict comminution circuit performance and to augment input to blast fragmentation models. This versatility makes it a powerful tool for orebody profiling as, in conjunction with a mine's block model, a detailed picture can be built of the blast fragmentation and comminution circuit response.


Figure 1 – Sample Pieces Cut from 50mm Quartered Core


Figure 2 – Sample Pieces Cut from Whole 50mm Core


Figure 3 – Sample Pieces Cut from Half 50mm Core

BACKGROUND

The SMC test was originally designed for breakage characterisation of drill core and generates a relationship between input energy (kWh/t) and the % of broken product passing a specified sieve size. The results are used to determine the so-called drop-weight index (DW_i), which is a measure of the strength of the rock when broken under impact conditions. The DW_i is directly related to the JK rock breakage parameters A and b and hence can be used to estimate the values of these parameters. An example of this is illustrated in Figure 4 where the observed values of the product A*b are plotted against those predicted using the DW_i. Each of the data points in Figure 4 is a result from a different ore type within an orebody.

The SMC test is a precision test, which uses particles that are cut to similar size from drill core using a diamond saw. The particles are broken using a closely controlled range of impact energies. The high degree of control imposed on both the size of particles and the energies used to break them means that the test is largely free of the repeatability problems which plague tumbling mill rock characterisation tests. Such tests usually suffer from variations in feed size, which are not closely controlled, as well as energy input, which although is often assumed to be constant is often highly variable (Levin, 1989).

The relationship between the DW_i and the JK rock breakage parameters makes use of the size-by-size nature of rock strength that is often apparent from the results of full drop-weight tests. This is illustrated for three different rock types in Figure 5, which shows how A*b varies with particle size. In the case of a conventional drop-weight test these values are effectively averaged and a mean value of A and b is reported. The SMC test uses a single size and makes use of relationships such as that shown in Figure 5 to predict the A and b of the particle size that has the same value as the mean for a full drop-weight test.

Where the SMC test is required to estimate A and b values, a number of full drop-weight tests are recommended to ensure that the most accurate correlation between the DWi and these parameters is obtained for the orebody in question. The number of full drop-weight tests required for a given orebody will depend on its variablity and should at least cover the major recognised ore types.

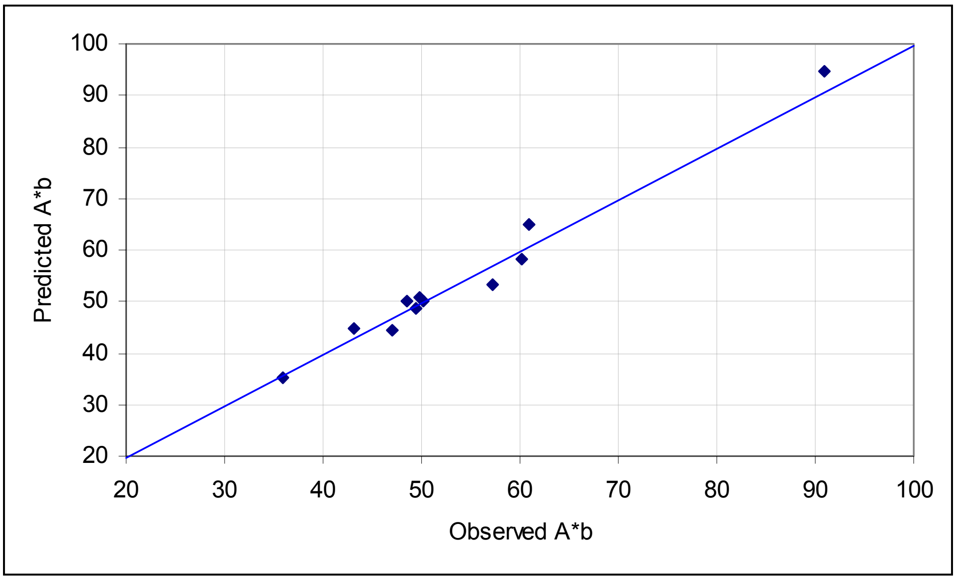

Figure 4 – Observed vs Predicted A*b Values Using the DWi

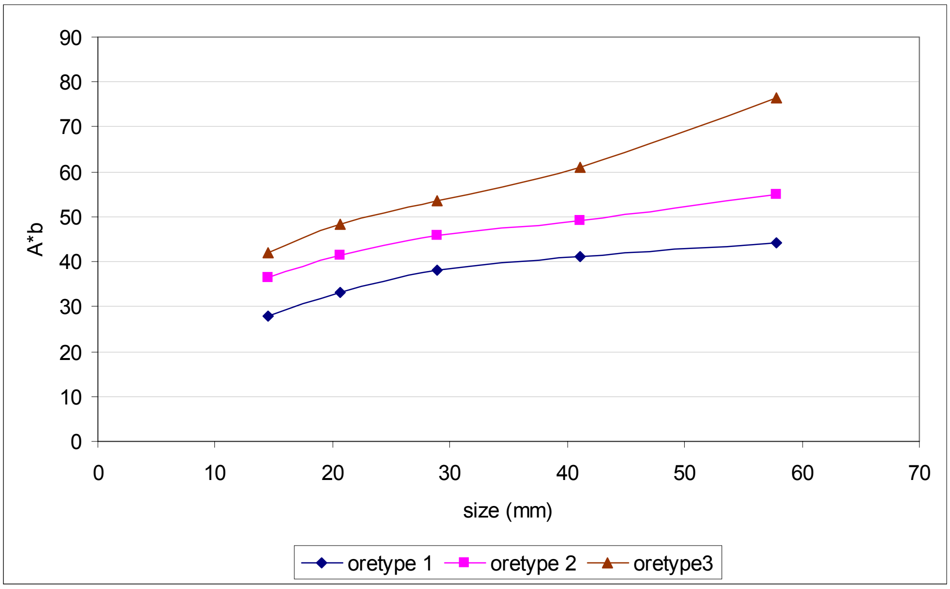

Figure 5 – Relationship Between Particle Size and the Product of A and b

USING THE DW_I IN MODELLING/SIMULATION

The DW_i can be used to estimate the JK rock breakage parameters A and b. These parameters are ore specific and relate the t_{10} (a size distribution index) to the applied specific energy (Ecs). They are normally determined from a full drop-weight test. The equation describing the relationship between the t_{10} and Ecs is given below. A typical plot of t_{10} vs Ecs from a drop-weight test is shown in Figure 6. The relationship is characterised by a two-parameter equation where t_{10} is the dependent variable:

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

The specific comminution energy (Ecs) has the units kWh/t and is the energy applied during impact breakage. As the impact energy is varied, so does the t_{10}. Higher impact energies produce higher values of t_{10}, which is reflected in products with finer size distributions.

The t_{10} can therefore be interpreted as a "fineness index" with larger values of t_{10} indicating a finer product size distribution. The value of parameter A is the limiting value of t_{10}. This limit indicates that at higher energies little additional size reduction occurs as the Ecs is increased beyond a certain value. A*b is the slope of the curve at 'zero' input energy and is generally regarded as an indication of the strength of the rock, lower values indicating a higher strength.

The A and b parameters can also be used with equation 1 to generate a table of Ecs values, given a range of t_{10} values. Such a table is used in crusher modelling to predict the power requirement of the crusher given a feed and a product size specification.

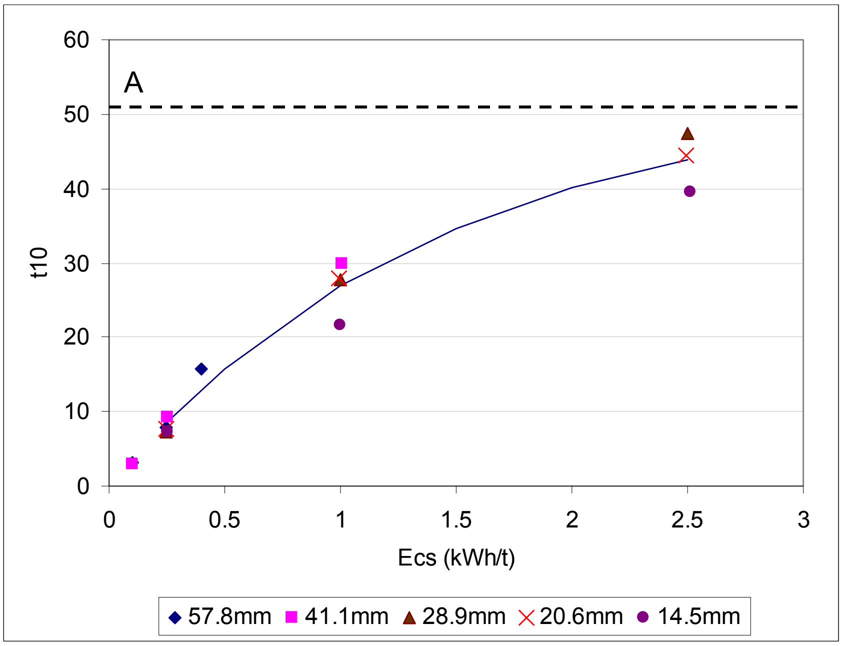

Figure 6 – Typical Plot of Raw t_{10} vs Ecs Data from a JK Drop-weight Test

The A and b parameters are used in AG/SAG mill models, such as those in JKSimMet, for predicting how the rock will break inside the mill. From this description the models can predict what the throughput, power draw and product size distribution will be (Napier-Munn et al (1996)). Modelling also enables a detailed flowsheet to be built up of the comminution circuit response to changes in ore type. It also allows optimisation strategies to be developed to overcome any deleterious changes in circuit performance that are predicted from differences in ore type that are indicated by the SMC test. These strategies can include both changes to how mills are operated eg ball load, speed etc but also changes to feed size distribution through modification to blasting practices and primary crusher operation (mine-to-mill).

These models require information on rock mass competence such as provided by the point load index. The DW_i is correlated with the point load index and hence can also be used in blast fragmentation modelling where direct measurements of point load index are not available.

USING THE DW_I IN POWER-BASED CALCULATIONS

The DW_i is related to the resistance of a rock to break under impact. SMCC has developed a series of equations that relate the DW_i to the specific energy (kWh/t) of AG and SAG mill circuits. These equations take into consideration factors such as ball charge, feed size, aspect ratio, whether the mill is operated with or without a pebble crusher and whether it is closed with a fine classifier such as a cyclone. The ability of these equations to predict AG/SAG mill circuit specific energy is illustrated in Figure 7. The data shown cover 19 different operations and include Cu, Au, Ni and Pb/Zn ores.

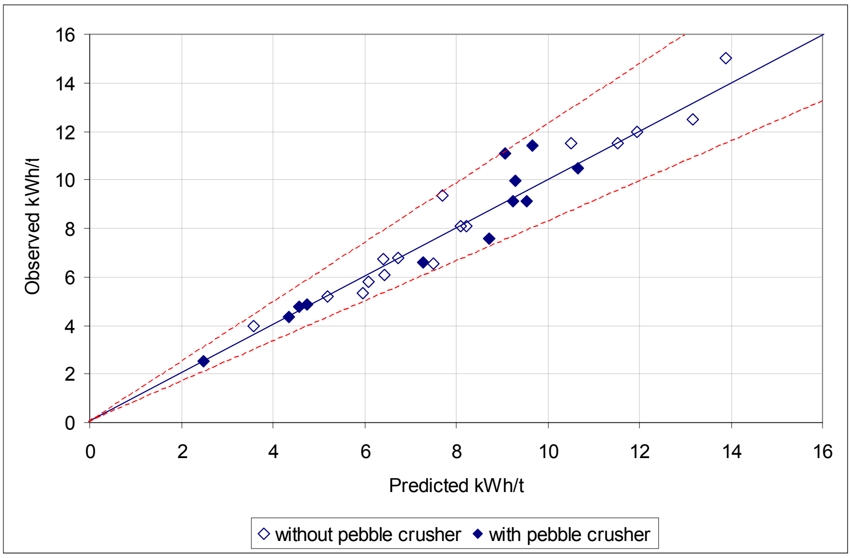

Figure 7 – Predicted AG/SAG Mill Specific Energy Using the DWi (+/- 2 s.d. envelope is shown)

CONCLUSIONS

The SMC Test is a cost-effective technique for determining the impact breakage characteristics of rocks using very small quantities of sample. It is therefore ideally suited for use with quartered (slivered) drill core. The SMC test generates a competence index (DW_i) which, via modelling and power based techniques, can be used to predict the specific energy of AG and SAG mills.

The usefulness of the DW_i extends to rock mass characterisation in mining applications, as it is also correlated with the point load index/UCS. It is therefore ideally suited for mine-to-mill studies as it can be simultaneously used as an input to both blast fragmentation and comminution circuit models.

REFERENCES

Levin, J., 1989. Observation on the Bond Standard Grindability Test, and a Proposal for a Standard Grindability Test for Fine Materials. SAIMM, vol 89, n0.1, pp13-21.

Napier-Munn, T.J., Morrell, S., Morrison, R.D. and Kojovic, T., 1996, Mineral Comminution Circuits Their Operation and Optimisation. JKMRC Monograph Series.