The "SCSE" Parameter- Enhancing the Usefulness of the JK Drop Weight A and b Parameters

Background

A and b are parameters which describe the response of an ore to increasing levels of input energy in single impact breakage and are reported outcomes of JK Drop Weight and SMC Tests. A typical t_{10} v E_{cs} curve resulting from a Drop Weight test is shown in Figure 1.

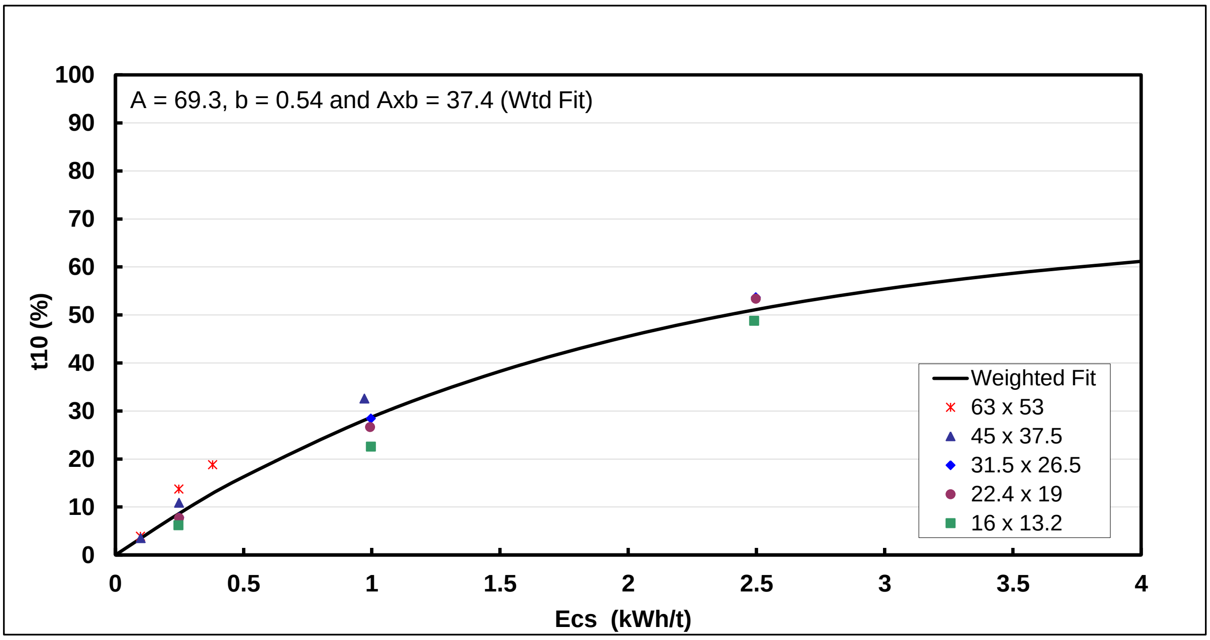

Figure 1: Typical t10 v Ecs curve

The curve shown in Figure 1 is represented by an equation which is as follows:

$$t_{10} = A * \left(1 - e^{-bE_{cs}}\right) \qquad \text{Equation 1}$$

The parameters A and b are generated from analysis of JK Drop Weight and SMC test data. The A and b values are interdependent and although they have no physical meaning in their own right they are indirectly related to ore hardness. They were originally developed for use by the AG/SAG mill model in JKSimMet, which permits prediction of the product size distributions and power draws of AG/SAG mills for a given feed size distribution and feed rate (Morrell and Morrison, 1996). Hence when using JKSimMet in a design situation, the dimensions of the AG/SAG mill are adjusted until the load in the mill reaches 25 % by volume when fed at the required feed rate. The model predicts the power draw under these conditions and, from the power draw and throughput, the specific energy of the mill (kWh/t) is determined. The specific energy is mainly a function of the ore hardness (A and b values), the feed size and the dimensions of the mill (specifically the aspect ratio) as well as to a lesser extent the operating conditions such as ball load, mill speed, grate/pebble port size and pebble crusher configuration.

Despite the lack of physical meaning, the product of A and b, referred to as A*b, has been universally accepted as the parameter which represents an ore's resistance to impact breakage. However, there are a number of drawbacks to the use of A*b for this purpose. Firstly it is a qualitative measure, secondly it is inversely related to impact resistance, and lastly its relationship to impact resistance in non-linear. This last factor is particularly important when comparing the A*b values of different ore samples and gives rise to the somewhat counter-intuitive phenomenon that the difference in hardness between two samples with A*b values of, say 25 and 29 (15% difference), may be statistically different from a specific energy perspective, yet in the case of two samples with A*b values of 250 and 350 (40% difference) they may not be significantly different. The only way to tell is through simulating the influence that the different A and b values have on the AG/SAG mill specific energy.

Development of the SCSE

To overcome these shortcomings, JKTech Pty Ltd and SMC Testing Pty Ltd have developed a simulation methodology to predict the AG/SAG mill specific energy (SCSE) required for an ore with a given A and b when treated in a "Standard" circuit comprising a SAG mill in closed circuit with a pebble crusher (see Figure 2).

The specifications for the "Standard" circuit are:

- SAG Mill
  - inside shell diameter to length ratio of 2:1 with 15 ° cone angles
  - ball charge of 15 %, 125 mm in diameter
  - total charge of 25 %
  - grate open area of 7%
  - apertures in the grate are 100 % pebble ports with a nominal aperture of 56 mm
- Trommel
  - Cut Size of 12 mm
- Pebble Crusher
  - Closed Side Setting of 10 mm
- Feed Size Distribution
  - F_{80} from the t_a relationship given in Equation 2

The feed size distribution is taken from the JKTech library of typical feed size distributions and is adjusted to meet the ore specific 80 % passing size predicted using the Morrell and Morrison (1996) F_{80} – t_a relationship for primary crushers with a closed side setting of 150 mm given in Equation 2.

$$F_{80} = 71.3 - 28.4 * ln(t_a)$$ Equation 2

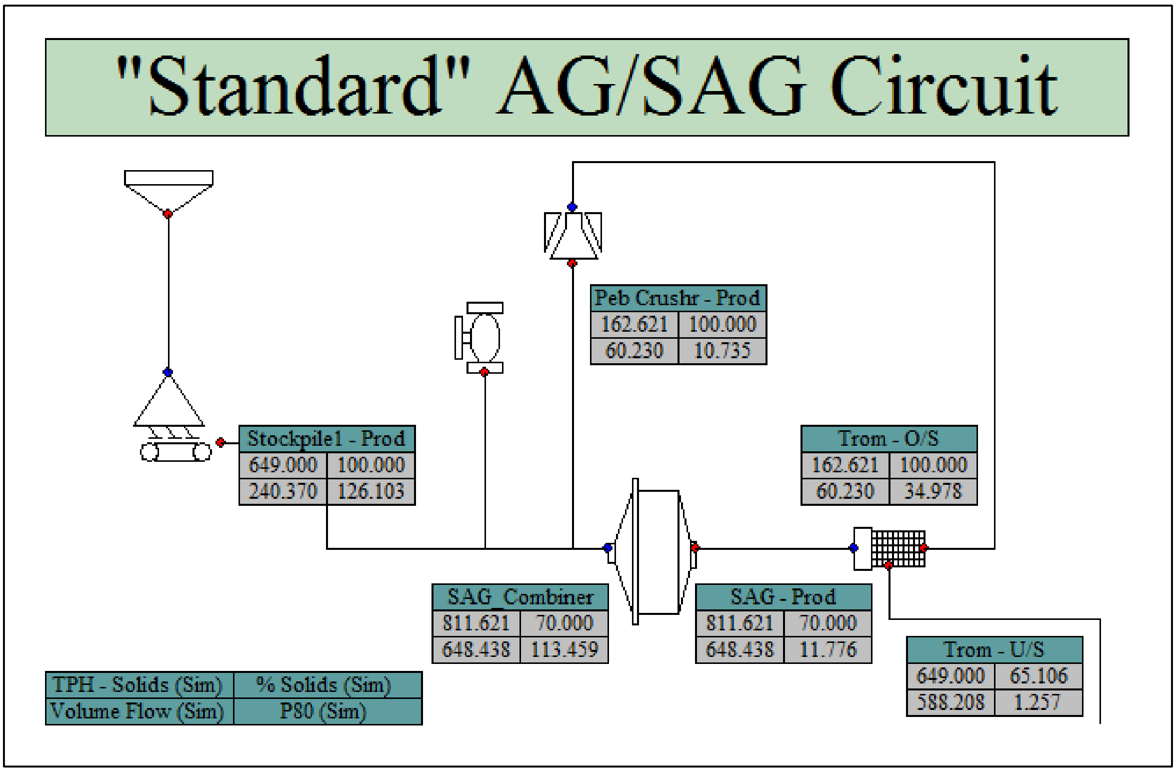

Figure 2: Flowsheet used for "Standard" AG/SAG circuit simulations

Simulations were conducted with A*b values ranging from 15 to 400, t_a values ranging from 0.145 to 3.866 and solids SG values ranging from 2.5 to 3.7. For each simulation, the feed rate was adjusted until the total load volume in the SAG mill was 25 %. The predicted mill power draw and crusher power draw were combined and divided by the feed rate to provide the specific energy consumption. The results are shown in

Figure 3. It is of note that the family of curves representing the relationship between Specific energy and A*b for the "standard" circuit is very similar to the specific energy – A*b relationship for operating mills published in Veillette and Parker, 2005 and reproduced here in Figure 4.

The specific energy value for the "standard" circuit is termed the "SCSE" (SAG Circuit Specific Energy) and will now be included in JKTech reports of JK Drop Weight and SMC Test® results in addition to the usual A, b, ta and crusher matrices which are currently reported. Of course, the SCSE quoted values may not necessarily match the specific energy required for an existing or a planned AG/SAG mill due to differences in the many operating and design variables such as feed size distribution, mill dimensions, ball load, ball size, grate/pebble port size, trommel aperture and pebble crusher configuration. However, the SCSE is an effective tool to compare in a physically meaningful manner the expected behaviour of different ores in AG/SAG milling in exactly the same way as the Bond laboratory ball mill work index can be used to compare the grindability of different ores in ball milling (Bond, 1961 and Rowland and Kjos, 1980). The reported A and b parameters which are associated with the SCSE values will still be required in JKSimMet simulations of a proposed circuit to determine the AG/SAG mill specific energy required for that particular grinding task. Guidelines for the use of JKSimMet for such simulations were given in Bailey *et al*, 2009.

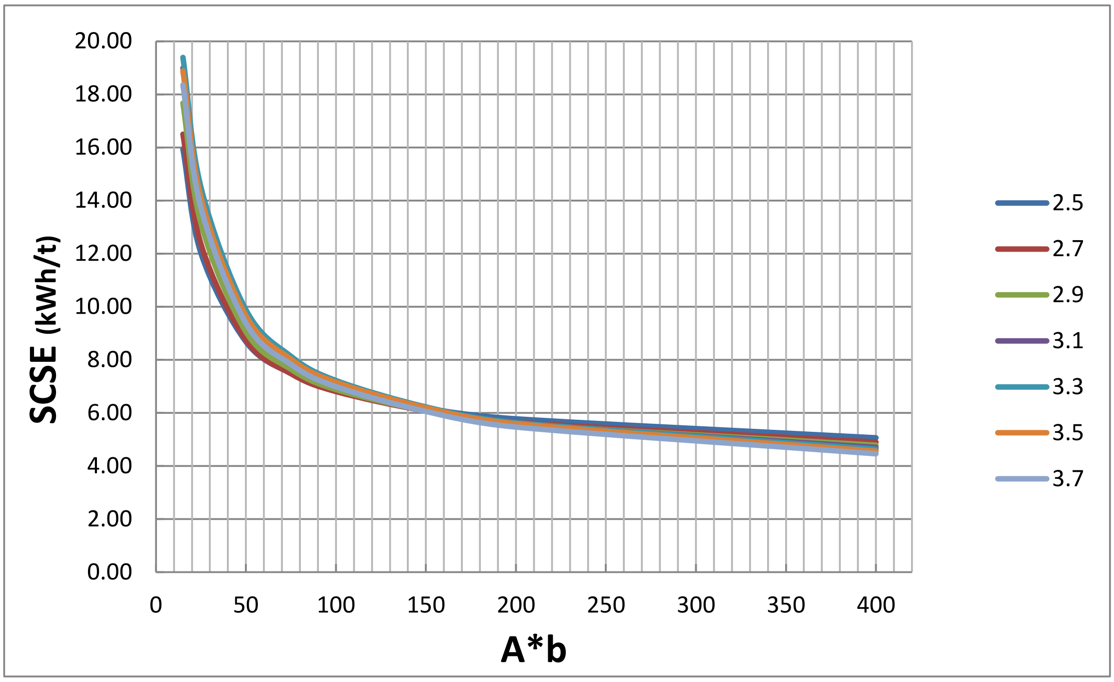

Figure 3: The relationship between A*b and SCSE with varying SG

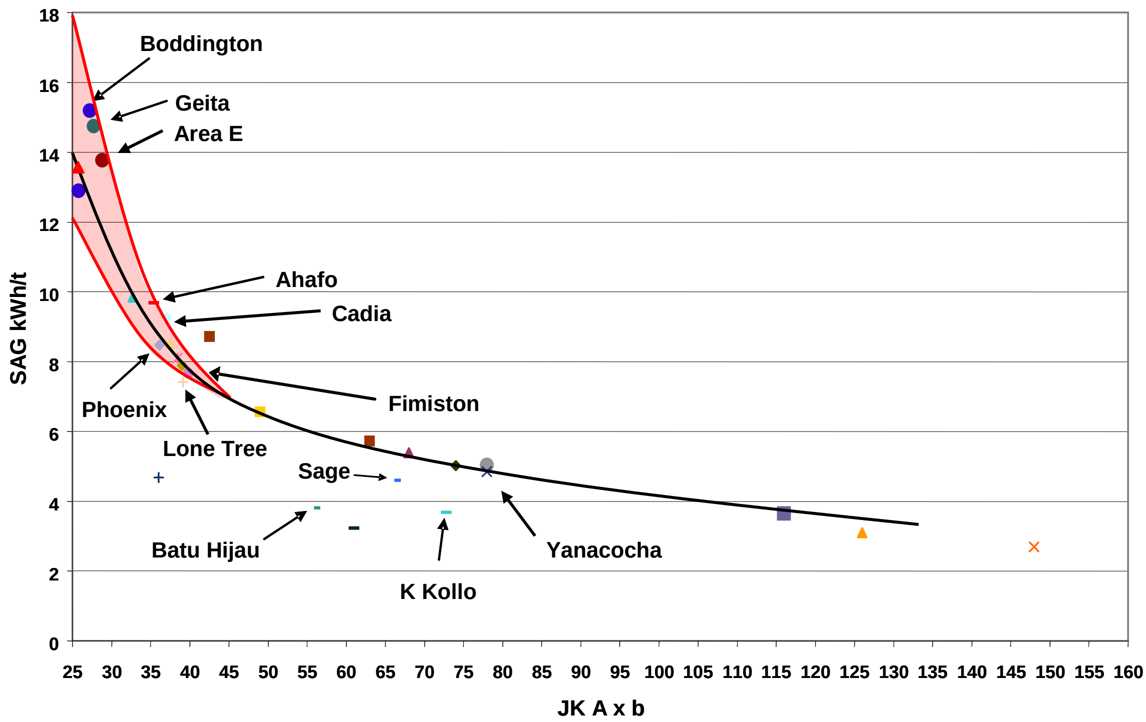

Figure 4: A*b vs SAG kWh/t for operating AG/SAG mills (after Veillette and Parker, 2005)

Relationship to the DWi

The SCSE is the output in kWh/tonne from a simulation of a particular SAG mill circuit configuration using the variable rates model in JKSimMet, one of which inputs is the A and b value. The DWi is a hardness parameter (kWh/m3) which comes from the SMC Test. Conceptually they are therefore different and cannot be interchanged or substituted for one another. However, the DWi can be used as the input to a power based equation to predict the kWh/t of a SAG mill circuit. If the ore is hard the DWi will be relatively high and hence the predicted specific energy will be relatively high. For the same ore the A*b will be relatively low and hence the SCSE will be relatively high, reflecting the same fact that the ore is hard and that the expected SAG mill specific energy will be relatively high. In this respect, therefore, it is expected that there will be a broad correlation between the DWi and the SCSE, as they both indicate hardness from a AG/SAG mill perspective, though they use very different equations/routes to get to their respective end-points.

References

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