SPECIFIC COMMINUTION ENERGY

General

This model uses the equations published in the following 2 papers which the user is encouraged to read:

MORRELL, S., 2010, Predicting the specific energy required for size reduction of relatively coarse feeds in conventional crushers and high pressure grinding rolls, minerals engineering Volume 23, Issue 2, January, Pages 151-153.
MORRELL, S., 2009.,Predicting the overall specific energy requirement of crushing, high pressure grinding roll and tumbling mill circuits, Minerals Engineering, Vol 22, No 6.

For the users benefit the document "Using the SMC Test® to Predict Comminution Circuit Performance" is also available for download from this website. It summarises the equations contained in the above references and also has worked examples to illustrate how the model can be used Further reading which will assist the user in understanding the evolution of the model is as follows:

MORRELL, S., 2008, A method for predicting the specific energy requirement of comminution circuits and assessing their energy utilisation efficiency, Minerals Engineering, Vol. 21, No. 3.
MORRELL, S., 2004. An Alternative Energy-Size Relationship To That Proposed By Bond For The Design and Optimisation Of Grinding Circuits. International Journal of Mineral Processing, 74, 133-141.

The model predicts the total comminution energy of most types of plant that contain conventional crushers, High Pressure Grinding Rolls (HPGR) and wet tumbling mills such as Autogenous (AG) Semi-autogenous (SAG), rod and ball mills. As well as the total specific energy it will also predict the specific energy of the crushing section, the HPGR section and the tumbling mill section separately. Hence, for example, in the case of an SABC circuit the total specific energy of the entire comminution circuit will be predicted plus the individual specific energies of the primary crusher, pebble crusher and combined SAG/Ball mill stages.

The model was originally developed using 3 data bases of operating comminution circuits to validate and benchmark its accuracy. These 3 data bases cover crushers, HPGRs and AG/SAG/ball mill circuits. In particular the latter data base contains over 120 different operating plants and conditions. To illustrate the accuracy of the model, Figures 1-3 show measured specific energies from these data bases plotted against predicted ones for crushers, HPGRs and total circuits.

How to Use the Model

Inputs to the model are made in three windows, viz:

Ore Characterisation Data – It is necessary for both a SMC Test® and a Bond laboratory ball work index test to have been carried out as the model requires the SMC Test® parameters Mia, Mic, Mih, DWi and the ore specific gravity as well as the Bond ball mill work index (Wib). As the Mia, Mic, Mih, DWi and the ore specific gravity all come from the same SMC Test® and are interrelated, any attempt to enter random values will generate an error message. If you have conducted an SMC Test® and after having entered the values reported to you the error message persists please contact SMC Testing. The Wib value that is input is not directly used by the model. The model uses the Wib value to derive the parameter Mib. Strictly speaking the Mib value is obtained from the raw data generated by the Bond laboratory test using the following equation:

$$M_{ib} = \frac{18.18}{P_1^{0.295}(Gbp)\left(p_{80}^{\;f(p_{80})} - f_{80}^{\;f(f_{80})}\right)} \qquad (1)$$

where

M_{ib}	=	fine ore work index (kWh/tonne)
P_1	=	closing screen size in microns
Gbp	=	net grams of screen undersize per mill revolution
p_{80}	=	80% passing size of the product in microns
f_{80}	=	80% passing size of the feed in microns
$f(x_j)$	=	$-(0.295 + x_j/1000000)$

Quite often users will know the value of the Wib but will not have access to the detailed data of the actual laboratory test that generated it. For this reason it was decided to use an algorithm that initially estimates the relevant Bond laboratory raw data from the Wib then uses these estimates in equation 1 to derive the Mib parameter. This was done by using equation 2, which is Bond's published equation for determining the Wib from his laboratory test raw data. The following assumptions were made concerning equation 2 and are based on the analysis of the raw data from a large number of Bond laboratory tests:

- The 80% passing size of the feed (F) is 2250 microns
- The 80% passing size of the product (P) is equal to the "Tumbling mill circuit product P80-final grind" value that is entered in the "Circuit performance Details" window (see later)
- That to obtain the specified product (P) a sieve size (P1) equal to 1.35 x P was used.

Using the above assumptions and knowing the value of Wib then from equation 2 the value of Gbp can be found. Using this value of Gbp and once again using the above assumptions Mib can be derived from equation 1.

$$W_{ib} = \frac{49}{P_1^{0.23}(Gbp)^{0.82}10\left(\frac{1}{\sqrt{P}} - \frac{1}{\sqrt{F}}\right)} \qquad (2)$$

where

W_{ib}	=	Bond laboratory ball work index (kWh/tonne)
P_1	=	closing screen size in microns
Gbp	=	net grams of screen undersize per mill revolution
P	=	80% passing size of the product in microns
F	=	80% passing size of the feed in microns

Circuit Equipment Configurations – Although the model can be used for a very wide range of flowsheet combinations, it was decided that to keep the spreadsheet as simple as possible but also useful, the spreadsheet was configured to cover the 4 most common flowsheet types viz:

- ABC/SABC
- HPGR/Ball
- Crush/Ball

- Single stage AG/SAG

These are selected by using the drop-down menu. As the flowsheet selected is changed so do the details of what equipment is covered by the calculations as shown in the associated window.

Circuit performance Details – In this window the P80 product values are entered for each of the comminution stages covered by the circuit option chosen by the user. The ROM P80 is the feed to the circuit (primary crusher feed) and this has been fixed at 450mm. The reason for fixing this is that often users do not know what the value is and hence it was decided to use a typical value from SMC Testings data base.

Three model output windows are shown on the right hand side of the page:

The **Total Comminution Specific Energy** window at the top of the page gives the specific energy for the entire circuit. It is made up of the sum of any crusher/HPGR net specific energies plus the tumbling mill circuit specific energy at pinion.   The associated 95% confidence levels are also shown and are based on the accuracy of model as indicated by the data base (see Figure 3). This indicates that the standard deviation of the relative error of the model is approximately 6.5%.

The **Circuit Performance Details** window gives the specific energies of the individual crushing/HPGR/tumbling mill circuits that go into generating the total comminution circuit specific energy

The **Mib Estimate from Bond Wib** window gives the Mib value that the model has estimated from using equations 1 and 2.

“Cautionary Tales”

Bond, in his published papers specified that the Bond ball mill laboratory test should be carried out such that it produces a product P80 with a similar value to that which the full scale plant produces. This is because the Wib value often varies with as the closing screen size (and hence final product P80) is varied. Rules for the Mib are no different. Hence it is explicitly assumed that the Wib value that is used has come from a Bond ball mill work index test that has generated a similar value to that input to the “Tumbling mill circuit product P80- final grind” field. If this is not the case the resultant specific energy prediction accurate might be compromised.

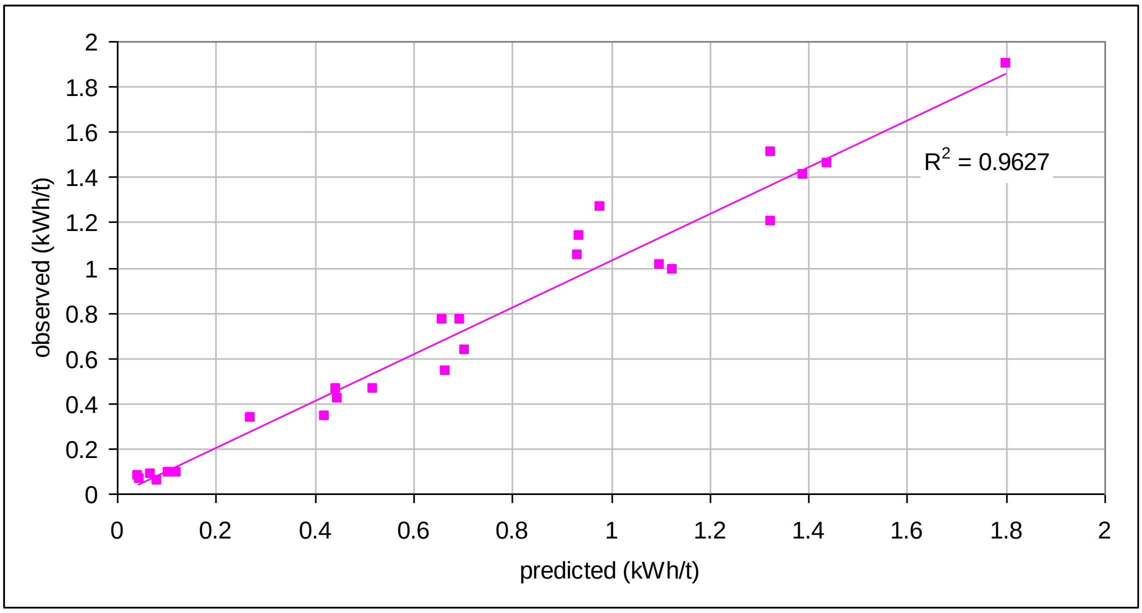

Figure 1 – Measured vs Predicted Specific Energy for Crushers

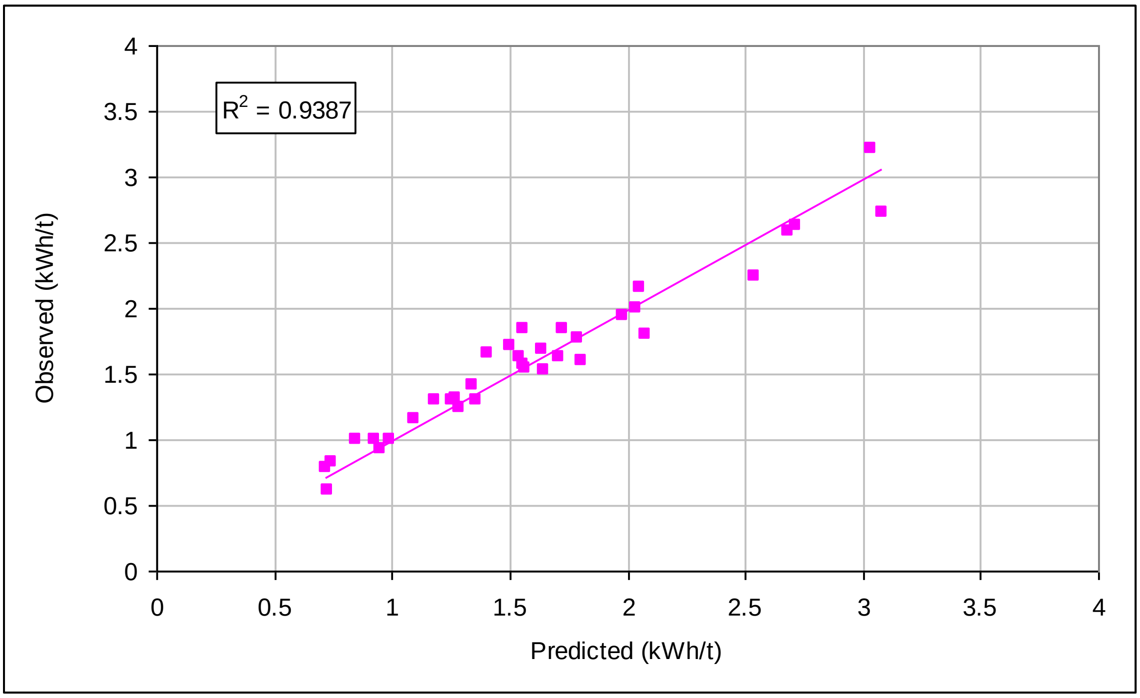

Figure 2 – Measured vs Predicted Specific Energy for High Pressure Grinding Rolls

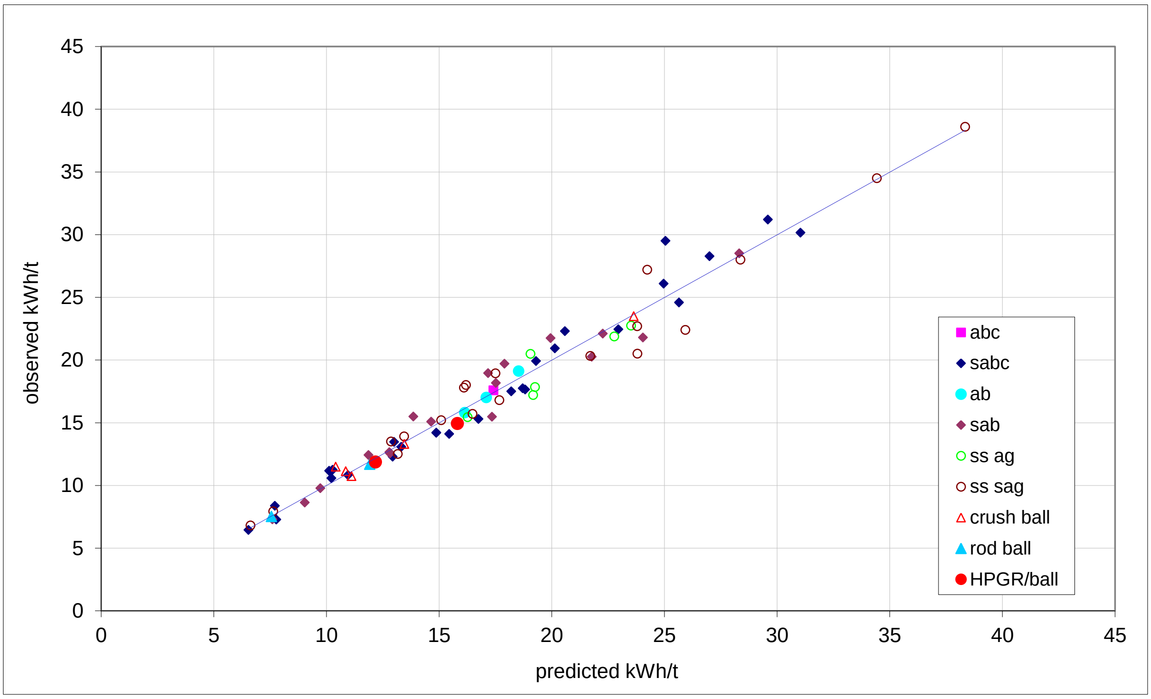

Figure 3 – Measured vs Predicted Specific Energy for Total Comminution Circuit