International mining Technology

HALL OF FAME 2015

COMMINUTION

Fred Bond

Fred Bond is the posthumous 2015 inductee in Comminution. The word Bond is synonymous with grinding circuit design, e.g. Bond Grindability and Bond Work Index. Bond's work on circuit design occurred from the late 1930s to the mid 1960s and it changed the method of design completely. In the pre-Bond era the prediction of the power required per tonne to grind material to a known product size was based on experience and judgment, in the post Bond era the method of prediction had become engineering practice which was based on measurement and calculation. Bond's work defined the relationship between ore hardness, tonnage processed, size reduction achieved and power required. It set the standard for circuit design in the 1950s and it is widely used today, although modifications have been made to handle the large increases which have occurred in mill sizes, feed sizes and feed rates.

Fred Bond in 1932

Ball milling replaced stamp milling as the major method of grinding in the early years of the 20th century and from then until the 1950s mill manufacturers devised methods of designing ball mill circuits. The approach was for their sales engineers to collect data from operating ball mill circuits and their laboratory staff to carry out grindability tests on the ores being processed. Processing of new ores involved use of this information to produce a "ball park" design for a grinding circuit which indicated the mill power required. This was refined according to the experience of company staff. The data were kept confidential.

Bond worked for Allis Chalmers from 1930 and he knew the limitations of design techniques which were current at the time. During the late 1930s and the 1940s he studied the relationship between energy and size reduction and in 1952 he proposed a "Third" theory of comminution to define this relationship. Rittinger and Kick had proposed the first two. To apply it he defined "Work Index" (W_i) for an ore as the specific energy (kWh/tonne) required to reduce the ore from infinite grain size to 100 µm and he showed that for any ore the Work Index can be calculated from plant data and determined in a laboratory test.

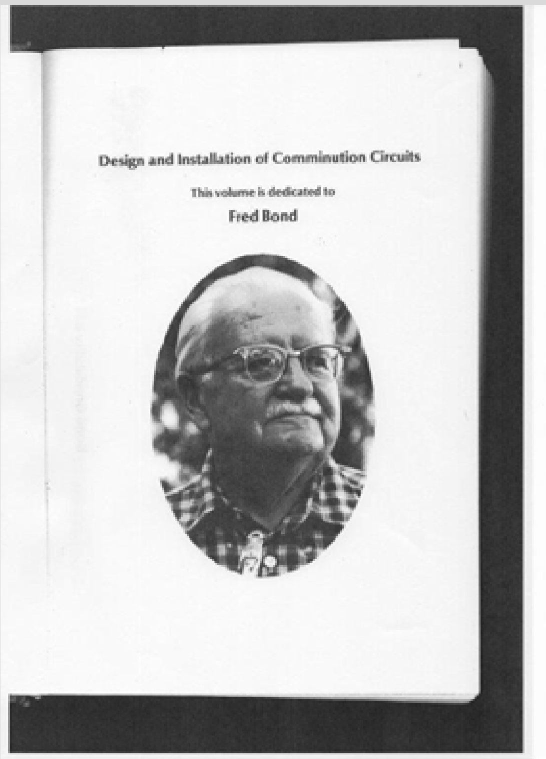
Plant data $W = W_i \cdot \left(\frac{10}{\sqrt{P}} - \frac{10}{\sqrt{F}}\right)$ where W is the energy consumption of the mill in kWh/short ton; W_i is the Work Index; and P and F are the 80% passing sizes of the product and feed in µm.

Laboratory data $Wi_b = \frac{44.5}{P_1^{0.23}\, G_{bp}^{0.82} \left(\frac{10}{\sqrt{P}} - \frac{10}{\sqrt{F}}\right)}$ where Wi_b is the ball mill Work Index in kWh/short ton; P_i is the test sieve aperture size in µm; G_{bp} is the ball mill grindability in grams/rev; and F and P are the 80% passing sizes of the feed and product.

Fred Bond and Allis Chalmers colleagues

Having developed the equations Bond's procedure for mill selection was

1 - Determine the grindability of the ore in the standard Bond laboratory test,
2 - Calculate the laboratory W_i from the grindability and use it as the plant W_i to which it is equivalent,
3 - Knowing W_i and F_{80} calculate W (kWh/t) for the required value of P_{80}.
4 – Knowing W calculate the power required for the feed rate and select the mill which delivers the power required.



Design and Installation of Comminution Circuits

This volume is dedicated to

Fred Bond

The methodology Bond developed for mill selection is widely used. When high capacity ball mills were installed from the late 1970s (5.5 m diameter and larger) it was found that throughput predictions for large mills with high feed rates of coarser particles were greater than those achieved. Correction factors based on the new data were required. SAG mill-ball mill circuits using large diameter mills became common from about 1980 and the difference between actual and predicted capacities using the decades-old equations highlighted the importance of accurate correction factors. Design companies with large data bases have determined correction factors which are not disclosed.

The Bond Work Index approach is the standard method of selecting ball mills to grind from about 3 mm to 25 µm provided that correction factors are used if necessary. The power prediction is fairly accurate for devices that produce a product with a size distribution parallel to that of the feed. It does not work well for devices such as the AG/SAG mill and high pressure grinding rolls where the product size distribution is not parallel to that of the feed.