

CM 2200, Fall 2007

Grinding Energy Calculations Using the Bond Equation

Theory:

In grinding calculations using the Bond equation, the 80% passing size is used as the measure of particle size. This is determined as shown in the graph below. The advantage of using the 80% passing size instead of the top size (or 100% passing size) is that the 80% passing size is less affected by variations in the number of very coarse particles. For example, adding only a few 1000 μm particles to the size distribution shown in Figure 1 would increase the top size to 1000 μm , but would not alter the rest of the curve and would not have any significant effect on the 80% passing size.

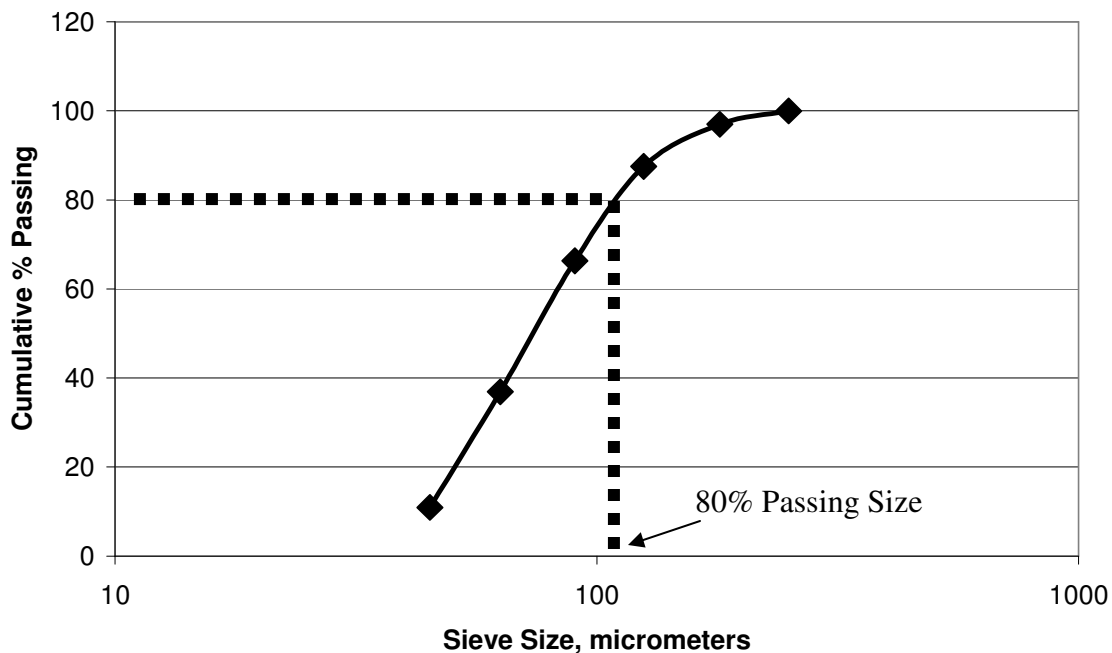


Figure 1: Determination of the 80% passing size for a size distribution.

The energy required to crush and grind particles depends on the following factors:

1. The size of the feed particles
2. The size of the desired product
3. The grindability of the material
4. The dimensions and operating conditions of the mill

The grindability of the material is given by the work index, W_i . This is defined as the energy that would be required to break particles of infinite size, to a powder that is 80% passing 100 micrometers. This has the units of kilowatt-hours per ton. As the work index increases, the amount of energy needed to grind the material increases.

It has been determined empirically that the energy needed for grinding is inversely proportional to the square root of the particle size, and so the Bond equation is:

$$W = 10W_i \left(\frac{1}{\sqrt{P}} - \frac{1}{\sqrt{F}} \right)$$

where P = 80% passing size of the mill product, in micrometers

F = 80% passing size of the mill feed, in micrometers

W_i = Work index, kilowatt-hours/ton

W = Power consumption of the mill, in kilowatt-hours/ton

The constant 10 is derived from the fact that the reference size for determining the work index is 100 μm. The 80% passing sizes ***must be expressed in micrometers*** for the equation to work.

The work index will vary somewhat for the same material depending on the feed particle size and the type of comminution machine, so there are separate work index values for crushers, rod mills, and ball mills. If a circuit has several different types of machine, each stage should be calculated separately and then the results added together.

Some typical values for the average work index for different minerals are as follows (please note that work indexes will vary from these values depending on the source of the ore, and whether the work index is for rod milling or ball milling):

Basalt:	20.4
Cement Clinker:	13.5
Limestone:	11.6
Gypsum:	8.16
Hematite:	12.7
Magnetite:	10.2
Silicon Carbide:	26.2
Coal:	11.4
Coke:	20.7

When used for ball mills, the procedure for determining the work index assumes that the ore will be ground in a mill that is 8 feet in diameter inside the liners. If a mill has a different diameter, the mill power consumption should be multiplied by the diameter efficiency factor:

$$EF_D = (8/D)^{0.2}$$

where EFD = diameter efficiency factor (dimensionless)

D = mill diameter inside liners (feet)

Example:

A material has a ball mill work index of 15.6 kW-hr/ton, and a particle size of 80% passing 1 mm. How much energy is needed to grind 100 tons per hour to 80% passing 100 μm in a mill 8 feet in diameter? How much energy will be needed per ton if the mill diameter is increased to 10 feet in diameter?

Solution: $W_i = 15.6$, $P = 100 \mu\text{m}$, $F = 1 \text{ mm} = 1000 \mu\text{m}$

$$W = 10W_i \left(\frac{1}{\sqrt{P}} - \frac{1}{\sqrt{F}} \right) = 10(15.6) \left(\frac{1}{\sqrt{100}} - \frac{1}{\sqrt{1000}} \right) = 10.67 \text{ kW-hr/ton for an 8 foot diameter mill.}$$

Since the feedrate is 100 tons/hour, the mill must draw $(100\text{tons/hr})(10.6 \text{ kW-hr/ton})=106 \text{ kilowatts}$.

If the mill is increased to 10 feet, the correction factor is:

$$EF_D = (8/D)^{0.2} = (8/10)^{0.2} = 0.9564$$

and so the power consumption becomes $(10.67 \text{ kW-hr/ton})(0.9564) = 10.20 \text{ kW-hr/ton}$

Note that increasing the mill diameter also increases the capacity of the mill, and so the mill diameter should be matched to the feedrate.

Name _____

CM 2200, Fall 2007, Homework #5

Homework Problem:

A comminution circuit for silicon carbide for ceramics consists of an 8 foot diameter rod mill followed by a 18 foot diameter ball mill, as shown below. The rod mill work index for the silicon carbide is 28.2 kW-hr/ton, and the ball mill work index is 30.5 kW-hr/ton. The rod mill feed is 80% passing 8 mm, and the rod mill product is 80% passing 1 mm. The ball mill feed is the rod mill product, and the ball mill grinds to 80% passing 15 μm . How much energy is required per ton to grind the silicon carbide?

