Lab #4 – Grinding Assessment

Name: ________________________________ Grade: ____________ Feedback:

Group Name: ___________________________ Day:

Pledge: "On my honor as a Virginia Tech student, I have neither given nor received unauthorized assistance on this assignment." Initial_____

By participating in this class, all students agree to abide by the Virginia Tech Wellness principles:

https://ready.vt.edu/well.html

If you answer yes to any questions in the Hokie Health survey (questions can be posted in the syllabus), you must not attend class in person. Notify me by email and contact Schiffert Health Center for testing and quarantine protocol.

Introduction

Figure 1. Standard Bond mill.

Comminution is one of the most important processes in mineral processing and also one of the most energy intensive. Of all the various comminution steps, ball mill grinding is the most energy intensive and the least efficient. Therefore, it is very important to understand how the ball mill works and how to design large-scale ball mills from laboratory data. One important piece of information needed for ball mill scale-up is the Bond Work Index. The Bond Work Index is usually determined using a 12 x 12 inch Bond mill, which runs at 70 RPM and contains a standard ball charge consisting of 25 - 1.50” balls, 39 - 1.25” balls, 60 - 1.00” balls, 64 - 0.88” balls and 97 - 0.75” balls. The feed to the Bond mill is stage-crushed to minus 6 mesh and the product is usually screened at 70 or 100 mesh. All grinding and screening are carried out dry. If the Bond Work Index (W_i) is known, the grinding energy E can be determined from the 80% passing size of the product and feed (P and F, respectively) by:

$$E = W_i\left[\frac{10}{\sqrt{P}} - \frac{10}{\sqrt{F}}\right]$$

Unfortunately, the standard Bond Grindability Test is quite laborious and requires several iterative stages until the process comes to steady state. Any deviation from the standard mill properties (mill size, ball size distribution, rotational speed, etc.) or any physical abnormalities due to mill wear can introduce considerable error that will invalidate the test. Given these issues, many plant metallurgists instead choose to do comparative tests using a reference ore with a known Bond Work Index. While this approach only provides an approximation of the work index, the speed and simplicity of the test make it much more suitable for diagnostic evaluations.

For a comparative grinding test, a representative sample of ore with known mass and known work index is ground for a set period of time to produce a desired product size. Next, the same mass of the test material is ground in the same mill under the same conditions of feed size, mill and charge size, and grind time. Finally, the feed and product size distributions are determined for both samples, and the F_{80} and P_{80} values are evaluated. Since the mill conditions in both grinds are the same, the energy input in both tests should be identical. As a result, the work index of the new ore can be readily calculated using the Bond equation solved simultaneously for both cases. Since the test results are analyzed comparatively, the specific mill conditions are not significant, and a non-standard mill can be utilized, provided that it can be operated identically in both tests.

The objective of this laboratory exercise is to determine the Bond Work Index of the chalcopyrite ore used in your previous laboratory exercises by using a reference ore. The value will be used to design a full-scale mill capable of processing 140 TPH of feed ore.

For more information on this topic, please reference: Gupta, Ashok, and Denis S. Yan. *Mineral processing design and operations: an introduction*. Elsevier, 2016.

Helpful Equations

Reference Ore Comparison

$$W_{iU}\left[\frac{1}{\sqrt{P_U}}-\frac{1}{\sqrt{F_U}}\right]=W_{iREF}\left[\frac{1}{\sqrt{P_{REF}}}-\frac{1}{\sqrt{F_{REF}}}\right]$$

Nomenclature

W_{iU} = Bond Work Index of the unknown ore,
W_{iREF} = Bond Work Index of the reference ore,
F_U, P_U = F_{80} and P_{80} of the unknown ore,
F_{REF},P_{REF} = F_{80} and P_{80} of the reference ore

Mill Capacity

$$Q=\frac{C_B D^{3.5}(L/D)(\rho_b)F_1(J)F_2(\phi_c)}{W_i\left(\frac{10}{\sqrt{P}}-\frac{10}{\sqrt{F}}\right)}$$

Nomenclature

Q mill circuit capacity in TPH,
J fraction filling of the mill volume with balls,
ϕ_c fraction of critical speed,
ρ_b true density of grinding media in metric tons per m^3,
D mill diameter in meters,
L mill length in meters.

$$F_1(J)=J-0.937J^2$$

$$F_2(\phi_c)=\phi_c-0.1\phi_c/2^{9-10\phi_c}$$

C_B = 6.13 for D < 3.81 m

C_B = 8.01 for D > 3.81 m

Procedure

1. Don all appropriate safety and personal protective equipment

2. A reference ore with a known Bond Work Index and feed size distribution will be provided to you. Obtain exactly 1,000 grams of this material as fresh feed to the grinding mill.

   Please note: the reference ore has a **Work Index of 8.1 kW-hr/ton and an F_{80} of 1,554 microns.**

3. Load the Bond mill with the standard charge of grinding balls and the 1,000 grams of the reference ore.

4. Close the mill lid tightly and rotate the mill for 200 revolutions.

5. Empty the mill and separate the grinding balls from the mill product.

6. Determine the size distribution of the ground product by dry sieving for 10 minutes with the sieve stack provided by the instructor. Record the values on the data sheet.

7. Plot the size distribution data using the graph paper provided on the data sheet. From this plot, determine the P_{80} of the reference ore by interpolating between the two closest points.

8. While the Ro-Tap is running, repeat Steps 2 – 7 for the chalcopyrite ore from Morenci. Recall that the F_{80} of this material can be determined from the data collected in Lab #3.

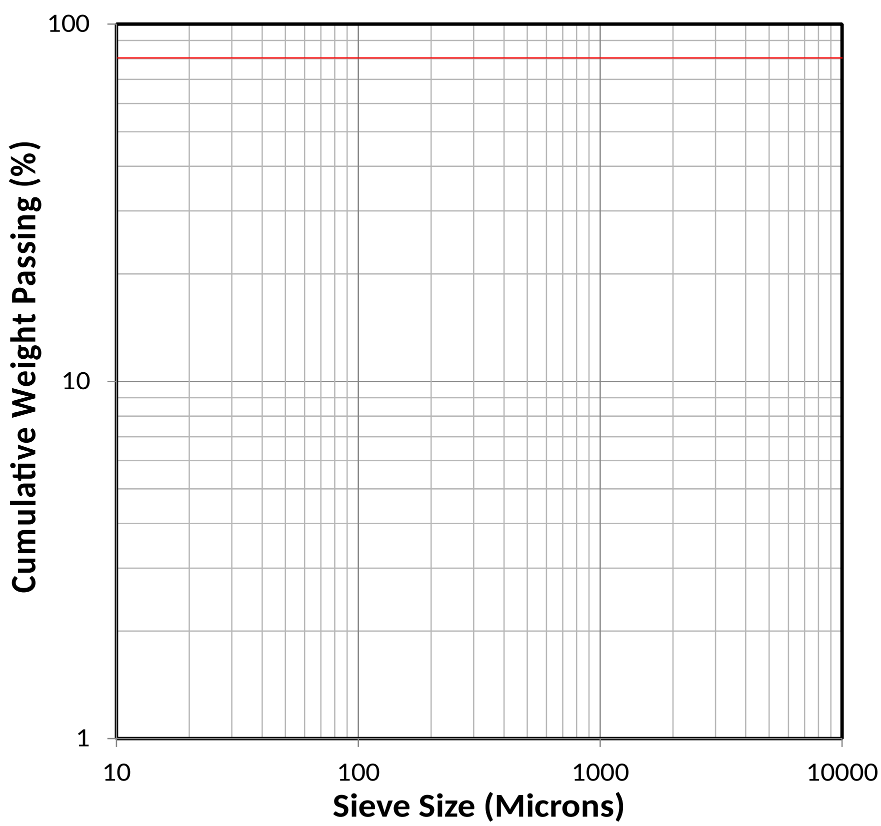
9. You should now know the F_{80} and P_{80} for both the reference ore and the Morenci ore as well as the Bond Work Index of the reference ore. Use these values to determine the Bond Work Index of the Morenci ore and answer the following discussion questions.

Data Records & Calculations

Reference Ore

		Individual Weights (gm)				Cum. Weights (%)	
Sieve (Mesh)	Sieve Opening, X (mm)	Sieve Tare	Sieve + Sample	Sample, Wt	Percent in Class	Retained	Passed, Y
						100.00	0.00
			Totals:				

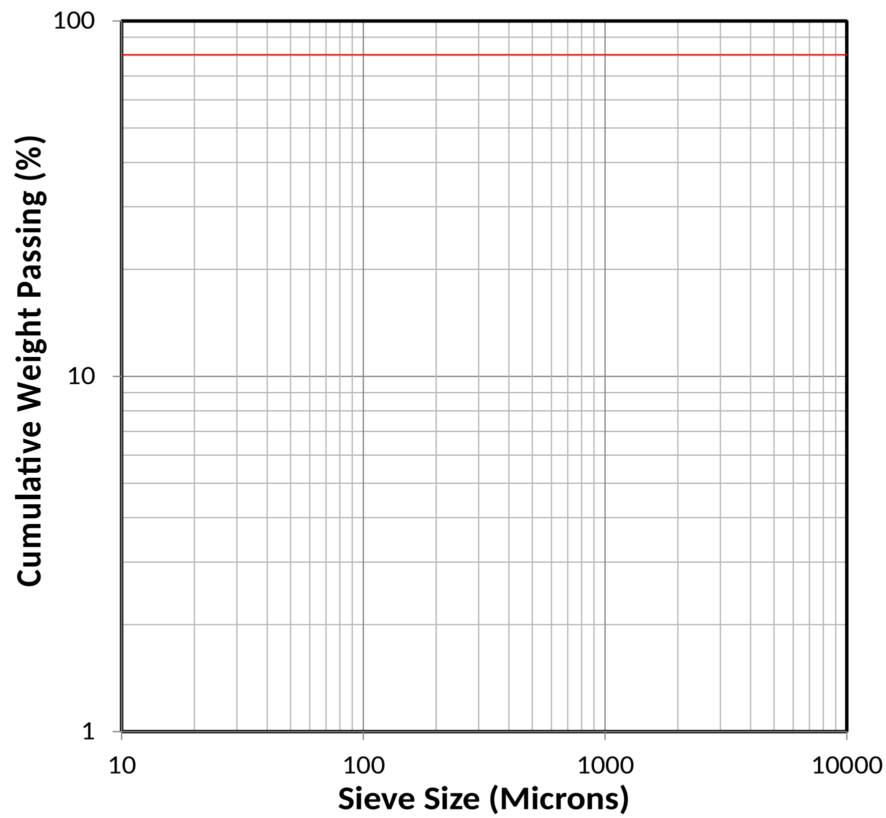
Head Weight = ___________



F_{80} = ______________ P_{80} = ______________

<u>Morenci Ore</u>

		Individual Weights (gm)			Percent in Class	Cum. Weights (%)	
Sieve (Mesh)	Sieve Opening, X (mm)	Sieve Tare	Sieve + Sample	Sample, Wt		Retained	Passed, Y
						100.00	0.00
Head Weight = ___________			**Totals:**				



F_{80} = _______________ P_{80} = _______________

Discussion Questions

1. Use the work index equation to estimate the Bond Work Index for the Morenci ore. How does this value compare to values for similar materials reported in the literature (i.e., Silica = 13.5 kW-hr/ton)?

2. Using the scale-up parameters given below, estimate the size of the mill required to handle 140 TPH of this particular ore.

Mill length-to-diameter ratio:	1.70
Fractional filling of mill volume with balls:	0.45
Fraction of critical speed:	0.75
True density of steel media:	7.83 t/m^3
80% passing size of feed	2000 microns
80% passing size of product	220 microns

3. If this same mill described in question #2 is also used to grind the reference ore, what will the 80% passing size of the product be if all other parameters are held constant?

Conclusions

1. What was the objective of this laboratory exercise?

2. What were your major findings?

3. What important fundamental concepts did you learn from the exercise?