COMMINUTION:

Comminution is the whole operation of crushing and grinding in order to reduce the crude ore to the fineness necessary for mechanical separation or metallurgical treatment.

The main purposes of comminution:

a) Liberation of specific mineral(s).
b) Convenience in transport.
c) Production of graded sizes and shapes.
d) Exposure of contained values to chemical attack (mainly for leaching, i.e. Hydrometallurgy).
e) Production of granular material suitable for treatment by gravity or other physical concentration methods.
f) Production of feed (-35 or -48 Tyler mesh)(-417 or -295 microns) for flotation.

CRUSHING:

Crushing is accomplished by compression of the ore against rigid surfaces or by impact against surfaces in a rigidly constrained motion path.

Crushing is the first mechanical stage in the process of comminution.

Stages of crushing:

Primary crushing → Run-of-mine ore (ROM) reduced to 10-20 cm (4"-8"), ( " = inch = 2.54 cm)

Secondary crushing → From 10-20 cm to about 1-2 cm (1/2"-3/8"),

Tertiary crushing → From about 1-2 cm to about 0.5 cm or less (<1/4").

Types of Crushers:

<table>
<thead>
<tr>
<th>Primary</th>
<th>Secondary</th>
<th>Tertiary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jaw Crusher</td>
<td>Gyratory Crusher</td>
<td>Roll Crusher</td>
</tr>
<tr>
<td>Gyratory Crusher</td>
<td>Jaw Crusher</td>
<td>Hammer Mill</td>
</tr>
<tr>
<td></td>
<td>Cone Crusher</td>
<td>Short Head Cone Crusher</td>
</tr>
<tr>
<td></td>
<td>Roll Crusher</td>
<td>Disc Mill</td>
</tr>
</tbody>
</table>
Gyratory, jaw and cone crushers are most often used for crushing of hard, abrasive and tough metallic ores.

Jaw Crushers: There are three general types of jaw crusher. (See Figure 1)

![Figure 1. Crusher types and the crusher dimensions to be used in the experiment](image)

Reduction Ratio (Theoretical) = \[ \frac{Gape}{Set} \]

Reduction Ratio (Calculated) = \[ \frac{Max. \text{ Feed Size}}{Max. \text{ Product Size}} \]

Reduction ratio generally varies between 3 to 6 or 7.

Theoretical Capacity of Jaw Crusher = \( (0.6 \times W \times S) \) tons/hour, (W: Width", S: Set")
**Set:** The horizontal distance between the fixed jaw and the pivot. The size of the crushed product is determined by the set of the crusher.

**Gape:** The distance between the fixed jaw and the tip of the swing jaw at the widest opening.

**Throw:** Maximum distance of movement of the swing jaw.

**Angle of nip:** The largest angle made by the two jaws that will allow the pieces of rock to be nipped and crushed.

**Factors** influencing the energy consumed by crushers:

1) Size of feed,
2) Size of product,
3) Capacity of machine,
4) Properties of rock or ore,
5) Percentage of idling time (the time when the crusher is not in use) etc.

**Roll Crusher:**

Not widely used; also being replaced by cone crusher(s).

Crushing is conducted by two horizontal cylinders rotating towards each other (See Figure 2).

**Advantages of Roll Crushers:**

a) Sticky, wet, clayey, frozen materials can be crushed more easily.
b) Less fines are produced.
c) Good for preparing feed to gravimetric concentration.

**Disadvantages of Roll Crushers:**

a) Reduction ratio is smaller than the other crushers.
b) Very large rolls are required to crush small piece of ores, i.e. Capital investment is high.
Theoretical Capacity of Roll crusher = (0.0034 * N * D * W * S * ρ) tons/hr

N = Number of revolutions of the rolls, RPM.
D = Diameter of the roll, inches = 8"
W = Width of a roll, inches = 5"
ρ = Density of the crushed ore, gram/cm³

GRINDING:

Grinding is the last stage in the process of comminution. In this stage the particles are reduced in size by a combination of impact and abrasion forces, either dry or in suspension in water.

Grinding is a random process and is subjected to the laws of probability.

Grinding steps:

i. Primary (Coarse) grinding (generally a rod mill is used)(Feed size as large as 50 mm, product size as fine as 300 microns)(1000 microns = 1 mm)
ii. Secondary (Fine) grinding (generally a ball mill is used)(Feed size as large as 0.5 mm, product size less than 100 microns or finer)
iii. Ultra-fine, super-fine grinding.

Objectives of Grinding:

1) To obtain proper liberation of ore particles (i.e. proper mesh of grind),
2) To increase the specific surface area of the valuable minerals for hydrometallurgical treatment.
Grinding should be proper. If the grinding is less than proper (undergrinding), the ground product will be too coarse, therefore not ready for mineral processing. If the grinding is more than necessary (overgrinding), mineral processing may be again more difficult; also energy is wasted and filtration of fine material may create problems.

Control of product size in grinding exercised by:

i. The type of medium used (balls, rods, etc.)
ii. The speed of rotation of the mill.
iii. Nature of the feed.
iv. Type of the grinding circuit.

Basic types of grinding mills:

1) Rod mills (uses steel rods as grinding medium),
2) Ball mills (uses steel balls as grinding medium),
3) Pebble mills (uses pebbles as grinding medium),
4) Autogeneous mills (uses ore itself as grinding medium),
5) Tube mills (mills whose lengths are much more greater than diameter),
6) Disc mills [pulverizer], (grinding is done by means of discs).

**SAMPLING:**

Sampling is the art of securing a small weight of sample as a representative fraction of relatively large lot. To be representative, a sample must contain an adequate number of particles, and the sample must have been selected in a fair way.

There are many ways of taking samples either manually or by a machine. In this laboratory exercise, two methods will be used. These are coning and quartering, and riffle sampling. These will be discussed in detail in the procedures section.

**SCREENING:**

Screening is one of the methods of particle size analyzing. Function of the size analysis is to obtain data quantitatively about the size and size distribution.

**MESH** (≠): Number of openings per linear inch or number of wires per linear inch. As mesh number increases, the particle fineness increases, and also screen aperture decreases.

There are many screen standards; each standard uses different wire thicknesses. Screening is done by simply putting different mesh number screens on top of each other, and simply shaking
them. After the screen-test, the obtained results can be presented either by tabulation of results or by drawing graphics or both together.

An example to the tabulation can be seen in Table 1. By using this table some different graphics can be drawn:

1) Direct charting of the sizing analysis or frequency curve (histogram), (See Figure 3). Rapid way of visualizing the relative frequency of occurrence.
2) Direct charting of the size analyzing, logarithmic scale (semi-log plot), (See Figure 4).
3) Cumulative charting of sizing analysis (direct type), (See Figure 5).
4) Cumulative charting of the sizing analysis, logarithmic scale (semi-log plot), (See Figure 6).
5) Gates - Gaudin - Schuhmann plot (log-log plot). This plot is preferred for mineral processing applications. Gives more information than others. Reading and extrapolation are easier (See Figure 7).

Table 1. Presentation of screen analysis data in table form

<table>
<thead>
<tr>
<th>Tyler mesh Size (mm)</th>
<th>Actual Wt. %</th>
<th>Cumulative Wt. % Oversize</th>
<th>Cumulative Wt. % Undersize</th>
<th>Actual Wt. %</th>
<th>Cumulative Wt. % Oversize</th>
<th>Cumulative Wt. % Undersize</th>
<th>log size (μ)</th>
<th>log cumulative wt% undersize Roll Crusher</th>
<th>Pulverizer</th>
</tr>
</thead>
<tbody>
<tr>
<td>- 13.33</td>
<td>0.74</td>
<td>0.74</td>
<td>99.26</td>
<td>- 9.423</td>
<td>2.60</td>
<td>3.34</td>
<td>96.66</td>
<td>3.974</td>
<td>1.985</td>
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<tr>
<td>- 6.680</td>
<td>11.41</td>
<td>14.75</td>
<td>85.25</td>
<td>- 4.699</td>
<td>32.12</td>
<td>46.87</td>
<td>53.13</td>
<td>3.825</td>
<td>1.931</td>
</tr>
<tr>
<td>3 4.699</td>
<td>32.12</td>
<td>46.87</td>
<td>53.13</td>
<td>6 3.327</td>
<td>18.34</td>
<td>65.21</td>
<td>34.79</td>
<td>3.522</td>
<td>1.541</td>
</tr>
<tr>
<td>4 3.327</td>
<td>18.34</td>
<td>65.21</td>
<td>34.79</td>
<td>8 2.362</td>
<td>11.05</td>
<td>76.26</td>
<td>23.74</td>
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<td>1.375</td>
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<td>16.61</td>
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<tr>
<td>14 1.168</td>
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<td>91.55</td>
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<tr>
<td>20 0.833</td>
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<td>91.55</td>
<td>8.45</td>
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<td>35 0.417</td>
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</tr>
<tr>
<td>48 0.295</td>
<td>1.33</td>
<td>96.89</td>
<td>3.11</td>
<td>65 0.208</td>
<td>0.94</td>
<td>97.83</td>
<td>2.17</td>
<td>2.318</td>
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<tr>
<td>65 0.208</td>
<td>0.94</td>
<td>97.83</td>
<td>2.17</td>
<td>100 0.147</td>
<td>0.70</td>
<td>98.53</td>
<td>1.47</td>
<td>2.167</td>
<td>0.167</td>
</tr>
<tr>
<td>100 0.147</td>
<td>0.70</td>
<td>98.53</td>
<td>1.47</td>
<td>150 0.104</td>
<td>0.52</td>
<td>99.05</td>
<td>0.95</td>
<td>2.017</td>
<td>-0.022</td>
</tr>
<tr>
<td>150 0.104</td>
<td>0.52</td>
<td>99.05</td>
<td>0.95</td>
<td>200 0.074</td>
<td>0.33</td>
<td>99.38</td>
<td>0.62</td>
<td>1.869</td>
<td>-0.208</td>
</tr>
<tr>
<td>200 0.074</td>
<td>0.33</td>
<td>99.38</td>
<td>0.62</td>
<td>-200 - 0.62</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>-200 - 0.62</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Σ 100.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figures 3 to 7. Graphical presentations of screen analysis data.
OBJECTIVES OF EXPERIMENT:

To become familiar with crushing, grinding, sampling and screening techniques.

Apparatus:

Jaw crusher, Roll crusher, Disc mill or Pulverizer, Riffle sampler, Tyler standard screens, Vibratory screen shaker, Balance, Microscope.

Sample:

Any ore that is available.

Procedure:

1. Crush a given amount of sample through the jaw crusher. Determine the maximum particle size before and after crushing. Note the dimensions of the machine, its operational setting, speed and horse power (HP) rating of the motor.
2. Take a sample which is about 2 kilograms from the jaw crusher product by coning and quartering sampling method.
   a) Form the product from the jaw crusher into a cone so that all particles have an equal chance to roll in any direction from the central point.
   b) Flatten the top of the cone, then spread out a circle and walk around the pile gradually widening the circle with a shovel until all the material is spread out to form a disc of uniform thickness, approximately 0.1 times of its diameter.
   c) Mark the flat pile into quadrants and remove diagonally opposite quadrants to form one half the weight of the original.
   d) Repeat the procedure until the desired weight of sample is obtained.
3. Pass prepared sample through roll crusher. Record the diameter and width of the rolls, its operational setting, speed and HP rating of the motor.
4. Pass the roll crusher product through a sample splitter and save ½ for further grinding tests. A sample splitter, commonly known as Jones Riffle, divides a sample in half but by repeated passes the sample can be reduced into quarters, eights, etc.
5. Pass the reserved half of the roll crusher product through laboratory pulverizer (disc grinder). Riffle out about 200 grams sample for screen analysis.
   Note: Do not attempt to arrive at exactly the amount specified for the test.
6. Weigh out sample of pulverizer product for screen analysis. Assemble a set of screens, 48-65-100-150-200 mesh complete with a bottom pan and a cover, and screen the pulverizer sample for 15 minutes on a mechanical shaker. Remove the cover and dump the material retained on the coarsest sieve onto a clean sheet of paper. Invert the sieve and place it over the paper, using a soft brass brush or a nylon bristle brush gently brush the underside of the sieve with a circular motion. The sieve can then be raised from the pan and the side of the
frame can gently be tapped by the handle-of the brush to clean the remaining material on the sieve.

DO NOT FORCE ANY PARTICLES THROUGH. Transfer the material into the weighing pan of the balance, weigh to the nearest 0.1 grams and record immediately. After weighing save the material retained on each screen on a labeled sheet of paper for microscope analysis.

7. Sprinkle few particles on a watch glass and study each size fraction under the microscope. By counting and careful examination of the particles, the degree of liberation, mineralogical and approximate chemical composition of the size fractions can be determined.

**HOMEWORK**

a) Draw up eight columns, the first labeled "mesh". List down in this column the respective Tyler mesh numbers. In the second column list down the corresponding screen openings in mm. In the third, fourth and the fifth columns list the wt.% cumulative wt.% oversize and cumulative wt.% undersize of the roll crusher product (using Table 7, page 55 in A. M. Gaudin, Ref.1). Use sixth, seventh and eighth columns for the pulverizer product in the same order. (Refer to Table 1)

b) Using the data tabulated in section (a), do the following plots for the roll crusher

   i. Direct charting as a histogram.(Fig 3)

   ii. Cumulative charting, logarithmic scale (semi-logarithmic plot). Determine the median size for each sample. (Fig 5 & 6)

   iii. Gates-Gaudin-Schuhmann plot (log-log plot). Determine 80% passing size for each sample. (Fig 7)

c) Calculate the theoretical and experimental reduction ratios of the jaw crusher and approximate capacities of the crushers used.
REFERENCES


