Lecture 10: Mineral Beneficiation

Contents:

Keywords: mineral beneficiation, Milling, gravity concentration flotation

Preamble

Mineral beneficiation is the first step in extraction of metal from natural resources. With the depletion of high grade metal ores it is important to increase the metal grade of an ore by physical methods; which are termed mineral beneficiation .The objectives of mineral beneficiation are

- To increase the metal grade of ore
- To reduce the amount of gangue minerals so that lower volume of slag forms in pyromettallurgical extraction of metals .Slag contains mostly gangue minerals.
- To decrease the thermal energy required to separate liquid metal from gangue minerals.
- To decrease the aqueous solution requirement in hydrometturgical extraction of metals.

In this lecture, mineral beneficiation science and technology are briefly reviewed so that readers can apply materials balance principles. Details about the mineral beneficiation can be studied in the reference given in this lecture.

What constitutes mineral beneficiation?

Ore is an aggregate of minerals and contains valuable and gangue minerals .The mineral beneficiation involves separations of gangue minerals from ore and is done in the following two stages:

1. Liberation of valuable mineral by size reduction technologies. In most ores the valuable minerals is distributed in the matrix of ore.
2. Concentration technologies to separate the gangue minerals and to achieve increase in the content of the valuable mineral to increase the metal grade.

Sizes reduction technologies

Size reduction or communication is an important step and may be used

- ✓ To produce particles of required sizes and shapes
- ✓ To liberate valuable mineral so that it can be concentrated.
- ✓ To increase the surface area available for chemical reaction.

It is often said that the efficiency of energy utilization during fragmentation of solid particles is only about 1% with respect to the new surface created . Energy consumption represents major cost in the mineral processing operation.

Crushing and grinding are size reduction methods. Crushing is applied to subsequent size reduction down to about 25mm. In grinding finer size is produced. Grinding or milling is an important size reduction method. In grinding force is applied by a medium which could either balls or rods .Both dry and wet grinding is done Wet grinding has the following characteristics.

- I t requires less power
- It does not need dust central equipment.
- Wet grinding uses more steel grinding media to mill the material/per ton of product, as a result there occurs increase in erosion of the lining material.
- Water is required for wet grinding.

Material balance is important to determine

- Amount of water in a milling circuit
- % solid in slurry (slurry is a mixture of solid in water)

Both information are needed to determine the pump capacity to transport slurry.

In wet milling water /solid ratio is important to control the viscosity of slurry .Too dilute slurry will lead to excessive wear of the medium .Too high a solid concentration results in cushioning of the medium. Percent solid in slurry can be determined by

$$\% \text{ Solid in slurry } = \frac{100\, \rho_s\, (\rho_{m-100})}{\rho_{m(\rho_{s-1000})}} \qquad\qquad 1)$$

ρ_s, ρ_m is density of solid and slurry respectively. For example   if ρ_s is 3000 kg/m^3 and $\rho_m = 1500$ Kg/m^3 then slurry contains 33.3% solid according to equation 1.

Wet milling gives the following advantages:

- Less power requirement
- Required pollution as compared with dry milling.

After wet milling the milled product is classified by a hydro cyclone in to undersize (also termed underflow) and oversize (overflow) .The overflow is taken to the plant for concentration operation, for example flotation .The undersize is recirculated after milling in a ball mill for further separation .

The interested reader may see the references for more details.

Concentration technologies: Basics

The objectives of concentration technologies is to separate the valuable mineral from the gangue minerals .In all concentration methods feed is divided in three streams, namely concentrate, middling and tailings.Middlings are recycled within the plant and as such the plant output is two products, namely concentrate and tailings. Tailings are disposed whereas concentrate is sent to metal extraction.

Plants Recovery and grade:

Recovery of the mineral in the concentrate and metal grade of the concentrate are important .Recovery is defined as

$$\text{Recovery} = 100 \times \frac{\text{Amount of valuable mineral in concentrate}}{\text{amount of feed}}$$

Grade of the concentrate can be defined either mineral grade or metal grade. Since concentrate is employed for metal extraction, metal grade is important (Note that concentrate contains mineral but not metal).

$$\text{Metal grade} = \frac{\text{Amount of metal in concentrate}}{\text{amount of concentrate}} \times 100$$

Metal grade means grade of valuable metal of the mineral in the concentrate. For example in the concentrate of chalcopyrite the grade of Cu is important. Similarly in the concentrate of galena, the grade of Pb is important. It must be clearly understood that ore does not contain metal. Metal grade is used to give an idea about the removal of gangue minerals and removal of oxygen or sulphur. For example mineral grade of pure Fe_2O_3 is unity but metal grade (or iron grade) of pure mineral Fe_2O_3 is 70% which means 30% oxygen has to be removed to get iron.

Recovery of a mineral in the concentrate can be 100% if all the feed is diverted in to concentrate. But metal grade will be very low. The maximum metal grade of the concentrate can be that of corresponding pure mineral, for example Cu grade in pure Cu Fe S_2 is 34.1%, lead grade in pure Pbs is 86.6%, Zn grade in pure ZnS is 67%. Consider 1000 kg feed of chalcopyrite which produces 1000 kg concentrate. The concentrate contains 500 kg CuFes$_2$200 kg , Fe$_2$O$_3$, 200 kg SiO$_2$ and 10 kg Al$_2$O$_3$ .The analysis of feed is same as that of concentrate.

Now the recovery $CuFeS_2$ in concentrate is 100%. But Cu grade in the concentrate $= \frac{500 \times 0.347}{1000} \times 100 = 17\%$

Separation efficiency

The feed of any concentration method is the milled product. The milled product is a mixture of particles of different Sizes, shapes and with different proportion of valuable mineral and gangue minerals .We have to separate particles containing valuable minerals for the maximum recovery. At the sametime metal grade should also be maximum of the concentrate.

In the following the valuable mineral in the concentrate is defined as metallic value of the valuable mineral.

Thus a concentrate is composed of metal in the valuable mineral +gangue . Let m is the metal grade of pure mineral and c is the metal grade of the concentrate.

Gangue in concentrate $= (m - c)$

Gangue in feed $= (m - f)$

f is the metal grade of the feed .If m_F is mass of feed and m_C is mass of concentrate

Recovery of gangue in concentrate $\left(R_g\right) = \frac{M_c(m-c)}{M_F(m-t)} \times 100$

Recovery of gangue in concentrate $(R_M) = \frac{M_c \times C}{M_F \times f} \times 100$

(SE) Separation efficiency $\left(R_M - R_g\right)100 = 100 \frac{M_c}{M_f}\left[\frac{m(c-f)}{f(m-t)}\right]$

Illustration of separation efficiency

Consider concentration of SnO_2 mineral in cassetrite ore. It is possible to produce concentrate of the following grade and recovery

Concentrate	Tin Grade	Recovery
1	63%	62%
2	42%	72%
3	21%	78%

Tin grade in feed is 1% and tin grade of pure mineral is 78.76% calculate separation efficiency (SE)

$SE = 100 \frac{M_C}{M_F}\left[\frac{m(c-f)}{f(m-f)}\right]$

$$\frac{M_C}{M_F} = \frac{f\,R_M}{C \times 100}$$

$$SE = \frac{f\,R_M}{C}\left[\frac{m(c-f)}{f(m-f)}\right]$$

Concentrate	Separation efficiency
1	61.8%
2	71.18%
3	75.24%

Note separation efficiency in concentrate 3 is high but tin grade is very low as compared to concentrate 1. But tin grade of concentrate is very high.

Concentrate methods:

The most important processes are

1) Gravity concentration
2) Flotation
3) Magnetic and electrostatic separation

Gravity separation separates the minerals according to their different densities. It is used for the concentration of very heavy or very light minerals within a wide range of grain sizes.

In heavy media separation the density of pulp is intermediate between that of valuable mineral and gangue minerals. In that case light minerals float on top and the heavy minerals sink to the bottom of the pulp independent of particle size.

Other methods of gravity concentration utilize a combination of gravitational, inertial, frictional and viscous effects. Commonly used methods are jigging, washing tables, spirals etc.

Separation by flotation is based on the ability or lack of ability of different surfaces to be wetted by water. Hydrophobic minerals will cling to the air bubbles and rise with them, whereas the hydrophilic minerals will sink. Reagents like frothers, collectors, activators, depressors and conditioners are added to make the separation. Floatation has found its greatest application in the concentration of the sulphide minerals.

Electro statics and magnetic separation is based on differences in electrical conductivity of the mineral and magnetic properties the minerals respectively.

Conclusions

In this lecture basic of minerals processing is discussed in brief with the objective to perform materials balance is processing of minerals .Details of the technologies are given in brief and the readers can see the references.

References

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