Lecture 11: Material balance in mineral processing

Contents:

Key words: Material balance, ball mill, hydro cyclone, flotation.

Preamble

An important aspect of any mineral processing study is an analysis of how material is distributed whenever streams split and combine. This knowledge is necessary when a flow sheet is being designed and is also essential when making studies of operating plants.

In this lecture basics of material balance in mineral processing is discussed.

Material balance

It is based on the principle of conservation of matter. In general

Input – output=accumulation (1)

In a continuous system at steady state, there is no accumulation and hence

Input=output

In mineral processing operations, single input of feed (ore) produces a concentrate containing most of the valuable and the tailing containing gangue minerals. Thus

Tons of feed $(\mathrm{M_F})$ = Tons of concentrate $(\mathrm{M_C})$ + and tons of tailing $(\mathrm{M_T})$ (2)

$$\mathrm{M_F} = \mathrm{M_C} + \mathrm{M_T} \quad (3)$$

Let f is fraction of metal in feed, c and t are fraction of metal in concentrate and tailing respectively, then

$$\mathrm{f\,M_F} = \mathrm{cM_C} - \mathrm{t\,M_t} \quad (4)$$

By 3 and 4 we can obtain

$$\frac{\text{Mass of feed}}{\text{Mass of concentrate}} = \frac{\mathrm{M_F}}{\mathrm{M_C}} = \frac{\mathrm{c-t}}{\mathrm{f-t}} \quad (5)$$

Plant recovery (R) is $\frac{\mathrm{M_C \times c}}{\mathrm{M_F \times f}} \times 100$ (6)

By 5 and 6 we get

$$R = \frac{c\ (f-t)}{f\ (c-t)} \times 100 \qquad (7)$$

In lecture on measurements of quantities we derived the relationship between percent solids ($\%\ x$) and pulp densities, when water is used as a medium to make the pulp, (pulp and slurry are synonyms).

$$\%\ x = \frac{100\ \rho_s(\rho_m - 1000)}{\rho_m(\rho_s - 1000)} \qquad (8)$$

$\rho_s =$ density of solid and ρ_m is density of slurry

Mass flow rate of dry solids in pulp (slurry)

$$M = \frac{F\ \rho_s(\rho_m - 1000)}{(\rho_s - 1000)} \qquad (9)$$

$F =$ volumetric flow rate(m^3/hr) and $M =$ mass flow rate in kg/hr

$$M = \frac{F\ \rho_m \%x}{100}\ kg/hr \qquad (10)$$

Water balance (Dilution ratio)

Water is used in mineral processing

a. To transport solids in the circuit
b. To act as a medium for separation

Ball mills use $\sim 35\%$ water for milling and in the discharge water is further added for separation in solids by weight.

Most flotation operations are performed in between $25 - 40\%$ solids by weight.

Some gravity concentration devices operate most efficiently on slurry containing $55 - 70\%$ solids.

Roughly $20 m^3/min$ of water is required for a plant treating 10000 tons of ore.

Two product formula is of great use in assessing water balances. In two product formula; feed is divided in two products, namely concentrate and tailing.

Consider a hydrocyclone fed with a slurry containing $f_s\%$ solids by weight and producing two products:-

Under flow containing u$\%$ solids by wt. and an overflow containing v$\%$ solids by weight.

Consider weight of solids/unit of time in feed, underflow and overflow arc M_F^1, M_U, and M_V respectively, at equilibrium conditions of operation

$$M_F^1 = M_U + M_V \qquad (11)$$

Dilution ratio is defined as $= \frac{100-\%\ \text{solids}}{\%\ \text{solids}}$

Dilution ratio of feed $= \frac{100-f_s}{f_s} = f_s^1$

Dilution ratio of underflow $= \frac{100-u}{u} = u^1$ (12)

Dilution ratio of overflow $= \frac{100-v}{v} = v^1$

Water balance on the cyclone: weight of water entering the cyclone must equal the weight leaving in two products output

$$M_F^1 \times f_s^1 = M_U\, u^1 + M_v\, v^1 \quad (13)$$

By 11 and 13 we get

$$\frac{M_U}{M_F} = \frac{(f_s^1 - v^1)}{u^1 - v^1} \quad (14)$$

If % solids are unknown, two product balance can be performed by using pulp densities slurry densities.

A balance of slurry weights

$$\frac{M_F}{\%\ f_s} = \frac{M_U}{\%u} + \frac{M_v}{\%V} \quad (15)$$

By equation 8 in that $\%\ x = \%$ solids and 15 we get after simplification

$$\frac{M_F\, \rho_m}{\rho_m - 1000} = \frac{M_U\, \rho_u}{(\rho_u - 1000)} = \frac{M_v\, \rho_v}{(\rho_V - 1000)} \quad (16)$$

On simplifying further we get.

$$\frac{M_U}{M_F} = \frac{(\rho_v - \rho_f)(\rho_u - 1000)}{(\rho_v - \rho_u)(\rho_f - 1000)} = \frac{(\rho_f - \rho_v)}{(\rho_u - \rho_v)}\frac{(\rho_u - 1000)}{(\rho_f - 1000)} \quad (17)$$

In equation 17, ρ_u is density of slurry of underflow and ρ_v is density of slurry of overflow.

Illustration

Consider separation of feed into underflow and overflow by a hydro cyclone. Feed is 1000 tons/hr and the underflow is 70% of the feed. Determine the circulating load ratio.

In the hydro cyclone underflow is re circulated

Re circulating load ratio $= \frac{\text{Mass recycled}}{\text{fresh feed}}$

Material balance gives mass of underflow =700 tons and that of overflow is 300 tons. Every time 300 tons is the fresh feed.

Re circulating load ratio $= \frac{700}{300} = 2.33$.

If the feed stream slurry contains 35% solids by volume and 40% of the water is recycled, calculate concentration of solids in hydro cyclone products. Density of solid $= 3.215 \text{ tons/m}^3$.

Hydro cyclone products: underflow and overflow

Mass balance gives 700 tons underflow and 300 tons overflow

Volume of solid in feed = volume of solid in underflow+ volume of solid in overflow

$$\frac{1000}{3.215} = \frac{700}{3.215} + \frac{300}{3.215}$$

$$311\text{m}^3 = 217.7\text{m}^3 + 93.3\text{m}^3$$

Volume of water in feed $= 311 \times \frac{65}{35} = 578\text{m}^3$.

Volume of water in underflow $= 0.4 \times 578 = 231\text{m}^3$

Solids concentration in underflow $= \frac{217.7\times100}{217.7+231} = 48.5\%$

Volume of water in overflow $= 578 - 231 = 347\text{m}^3$.

Solids concentration in overflow $= \frac{93.3}{93.3+347} \times 100 = 21.2\%$

Conclusion

In this lecture material balance in mineral processing is discussed through some problems. The reader should also go through the references for the details.

References:

1. Kelly and Spotiswood: introduction to mineral processing
2. Gaudin: Elements of ore dressing.