Lecture 9 Energy balance and metal extraction

Contents:

Keywords: Metal Extraction, energy balance, material balance

Preamble

The material and heat balance for an operating process is an essential and routine plant record, in much the same way as income and expenditure record is a part of operating a business.

The material balance shows the weights and analysis of input and output materials and the calculated inputs and outputs of each of the important metal elements and compounds.

This accounting also serves as a check on plant data in that the various totals of inputs and outputs should be equal.

The material balance is the starting point for other calculations like energy requirements and cost calculations. From the energy calculations, one can design the energy flow path and identify energy losses to optimize energy consumption.

Basics of Materials Balance

Law of conservation of Mass

Mass of isolated systems remains constants irrespective of the changes occurring within the system. Consider an open system of constant volume & mass

Mass is transferred in to and out of the system; mass will accumulate if transfer rates are unequal .Material balance at unsteady state is

$$\begin{bmatrix} Rate\ of\ Mass \\ in \end{bmatrix} = \begin{bmatrix} Rate\ of\ Mass \\ out \end{bmatrix} + \begin{bmatrix} Rate\ of\ \ accumlation \\ of\ mass \end{bmatrix} \quad (1)$$

$$\frac{\mathrm{dm}}{\mathrm{dt}} = \dot{\mathrm{m}}_{\mathrm{in}-}\dot{\mathrm{m}}_{\mathrm{out}} \qquad (2)$$

Material balance equation is written for each component involved in the process;

$$\frac{dm_1}{dt} = (\dot{m}_{in})_1 - (\dot{m}_{out})_1$$

$$\frac{dm_2}{dt} = (\dot{m}_{in})_2 - (\dot{m}_{out})_2$$

$$\frac{dm_3}{dt} = (\dot{m}_{in})_3 - (\dot{m}_{out})_3$$

$$\frac{dm_i}{dt} = (\dot{m}_{in})_i - (\dot{m}_{out})_i \qquad (3)$$

For a systems with multiple input and output streams, the material balance equation for I^{th} component

$$\frac{dm_i}{dt} = \sum(\dot{m}_{in})_i - \sum(\dot{m}_{out})_i \qquad (4)$$

For steady state

$$\sum(\dot{m}_{in})_i - \sum(\dot{m}_{out})_i \qquad (5)$$

For chemically reacting systems in addition to the law of conservation of mass, following two laws must also hold:

1. Law of definite proportions:

   A given chemical compound always contains the same constitute elements in the same weight proportions. True for stoichiometric compounds.

2. Law of multiple proportions:
   If two elements can form more than one compound, then the respective weights of one element that combines with a given weight of the other are in the ratio small whole numbers.

Basics of Energy balance

Energy balance at steady state is

Heat input=Heat output

All sources of heat input should be considered for example

- Heat of reaction at 298 K
- Heat of fusion and evaporation
- Sensible heat in reactants

Many a time specific heat capacity is required to calculate sensible heat. Also heat of formation of compound would be required .In the reference section some sources are given to obtain the thermo chemical data.

Similarly all different sources of heat output must also be considered .To mention few:

- Sensible heat in solid products
- Sensible heat in gases exiting the reactor
- Sensible heat in liquid products
- Heat losses

In all heat calculations a convenient reference temperature 298K is selected.

Metal Extraction Principles

As discussed in lecture 1,pyrometallurgical extraction of metals from natural oxide reserves involve the following steps:

- Removal of oxygen from the valuable mineral.
- Separation of metal from the gangue minerals.

For sulphide ore an additional step to convert sulphide into oxide is required. Several unit processes are employed to extract metal from ore by pyrometallurgical route. These are: roasting, matte smelting, reduction smelting, converting and refining. Different unit processes are combined to extract metal for example.

Production of metal	**Combination of unit processes**
Copper	Roasting +matte smelting +converting +refining
	Flash smelting +converting +refining.
Zinc & lead	Roasting +reduction smelting + refining
Nickel	Roasting +matte smelting + reduction smelting +refining.
Pig iron	Reduction smelting
Steel	Reduction smelting +refining.

Hydrometallurgical extraction is suitable for lean ores .here leaching followed by separation of metal from solution are the principal unit processes. Some examples of Hydrometallurgical extraction are

Copper:	Roasting +leaching +cementation+ electro wining
Zinc:	Roasting +leaching +cementation+ electrolysis

Aluminum: Leaching + electrolysis

Magnesium: Leaching + electrolysis

Titanium: Reduction smelting +leaching +chlorination +reduction by Mg.

Conclusion:

This lecture discusses basics of materials and energy balance .Metal extraction unit process and their combination are given to produce a metal .The readers must bear is mind that unit processes are described briefly .For details please see the references.

References:

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