Lecture 2:Measurement of Quantities

Contents

Key words: unit and dimension, fundamental units, power, pressure

Preamble

The material balance shows the weights and analysis of input and output materials and the calculated inputs and outputs of each of the important elements and compounds. This accounting serves as a check on plant data in that the various totals of inputs and output should be equal.

This lecture discusses the different ways of expression of measured quantities. It is felt that many a times the students have problems in unit and dimensions and to converting one unit to another.

Standard units of measurement

The adoption of standards has varied greatly as regards unit in different parts of the world. The following table lists some of the commonly used set of fundamental units from which all other units can be derived

Quantity	Absolute units				Engg. Units English
	FPS	CGS	MKS	SI	
Mass	Pound (lb)	gram (g)	kg	kg	Slug
Length	ft	cm	m	m	ft
Time	sec	sec	sec	s	sec
Amount of substance	Lb. mole	g.mole	kg mole	mole	Lb. mole
Temperature	^oF	^oC	^ok(ork)	k	^oF

FPS stands for feet, pound and second. It is british system

CGS stands for centimeter, gram and second

MKS stands for meter, kilogram and second

SI stands for international system of units. Extension of MKS system

Derived units and quantities

Physical quantities which can be derived from other physical quantities are called derived quantities.

Derived units: The units of physical quantities which can be expressed in terms of fundamental units, for example area, volume etc.

Lets us derive

(i) unit of force

Force =mass x acceleration.

In SI unit force $= \frac{\mathrm{kg}}{\mathrm{ms2}} = 1\mathrm{N}$ (Newton).

In CGS unit force = $\frac{\mathrm{g}}{\mathrm{Cms2}}$ =1 dyne

In MKS unit force is expensed in Newton(N)

In FPS systems force is $\frac{\mathrm{Lbft}}{\mathrm{s}}$ =1poundal

(ii) Energy =mu^2

we can substitute the units of m and u to derive unit of energy.

In SI system $\mathrm{E} = \mathrm{kg}\,\frac{\mathrm{m2}}{\mathrm{s2}} = 1\mathrm{Joule.}$

In CGS system $\mathrm{E} = \mathrm{g}\,\frac{\mathrm{Cm2}}{\mathrm{s2}} = 1\ \mathrm{erg.}$

1goule = 10^7 ergs.

In FPS system $\mathrm{E} = \mathrm{Lb}\ \mathrm{ft}^2/\mathrm{s}^2 =$ ft. poundal.

1British thermal unit (Btu) =778 ft. Lbf =1054.2 Joule = 252 cal

1kcal = 1000cal.=3.968 Btu

(iii) power (watts or W).

$1W = 1\frac{kg\ m^2}{s2}$ =1J/s.

1horse power =550 ft.lb_f /s = 746W

1KW =1000W =3414 Btu/hr.

1KW- hr =860 kcal =3414 Btu.

Composition of a mixture

It is expressed in terms of mole fraction or mass fraction. If mixture conatins n, moles of component 1, n_2 moles of component 2, n_3 moles of component of 3.; then mole fraction of i^{th} component is

$$x_i = \frac{ni}{\sum_i ni}$$

Similarly mass fraction of i^{th} component in the mixture is given by.

$$Y_i = \frac{m_i}{\sum_i m_i}$$

Derivation of unit of universal constant (R)

$$R = \frac{P_o\ V_o}{To} = \frac{1\ atms \times 22415\ cm^3}{gmole \times 273\ ok} = 82.10 \frac{cm^3.atm}{gmole\ ok}$$

In CGS unit

$$PO = 1.013125\ X10^6\ dynes\ cm^{-2}, To = 273k, Vo = 22451\ \frac{cm^3}{g.mole}$$

$$R = \frac{1.013125 \times 10^6 \times 22415}{273} = 8.319 \times 10^7 \frac{ergs}{g\ mole\ k}$$

Since $1J = 10^7$ ergs and $1cal. = 4.184J$

$\therefore\ R = 1.988\ cal/(g\ mole\ k)$.

In SI units.

$$PO = 1.013125\ X10^5\ pascals, To = 273k, and\ V_o = 0.022451\ \frac{m^3}{g.\ mole}$$

$$R = 8.314 \frac{J}{g.mole\ k}.$$

Similarly in M K S system $R = 8.314 \frac{J}{g.mole\ k}$.

Current =Ampere (A).   In solids current consists of electron flow. In electrolyte solutios.most of the current flow by motion of conic species for example cu^{+} or $Na+$

1coulomb is unit of charge: flow of 1A/s.

SI unit of electrical potential is volt. Volt is the potential in which the charge of 1 coulomb experiences a force of 1 Newtron.

SI unit of resistance is ohm. Ohm is defined as the resistance which permits flow of 1 A current under an imposed electrical potential difference of 1V.

Some basic equations of electrical flow are:

$V = R.I$

$P = I.V = I^2 R \quad P = \text{power}$

$t = \text{time}$

$W = t P = I^2 Rt$. W=energy measured in joules and power in watts

A Faraday is one mole of electrons.

1 faraday = 96500 coulomb. One faraday will discharge one gram equivalent of ions.

The liberation of one g equivalent of any metal consumes 96500 coulombs of electricity

How many gram moles of Al^{3+}ions could be discharged in one minute by $1.9 X10^4$ A current, if no loss of current occur.

In one minute a current of $1.9X10^4$ A will carry $1.9 X10^4 X 60$ coulombs of electricity.

Gram moles of Al deposited $= \frac{1.14\times10^6}{3\times96500} = 3.94$

Concentration of solids in slurry:

Many metallurgical processes have feed and/or product streams that consist of mixtures of solids and liquids. These mixtures are called slurries.

The relationship between wt % solid (%x) and specific gravity of solid phase (P_s) and that of slurry (P_m) when water is used as a medium can be obtained:

Volume of slurry = Volume of solid x Volume of water. Consider 1 kg slurry with %x as solids weight percent, then

$$\frac{1}{\rho_m} = \frac{\%x}{100\rho_s} + \frac{(100-\%x)}{100\rho_w}$$

$\rho_w =$ density of water

$\rho_s =$ density of solid

$\rho_m =$ density of mixture (solid + water)

(Wt percent solid)% x $= \frac{100\rho_s\,(\rho_m - 1000)}{\rho_m\,(\rho_s - 1000)}$ (1)

Volume % slurry $= \%\ x\ \frac{\rho_m}{\rho_s}$

Mass flow rate of dry solid in slurry (M)

$$= \frac{\text{volumetric flow rate} \times \text{slurry deunty} \times \%\ x}{100}$$

$M = \times \frac{F\,\rho_m\,\%x}{100}$ kg/hr (2)

F is volume flow rate in m3/hr.

By1 and 2

$M = \frac{F\,\rho_s\,(\rho_m - 1000)}{(\rho_s - 1000)}$ (3)

Conclusion

In this lecture the units and dimensions of physical quantities are derived from fundamental unit of mass, length, temperature and time. Suitable examples are given to illustrate the derivation of units.

Reference:

Schuhmann" Metallurgical engineering principles