Lecture - 5

Size reduction:

- To produce a product of desired size or size range

* **Hardness:** Mohs scale in 1812 by Friedrich Mohs

Mohs hardness number	Examples
1-3 (soft material)	Waxes, gypsum, chalk, marble
4-6 (intermediate hardness)	Limestone, magnesite, Felspar
7-10 (Hard materials)	Quartz, diamond, sapphire

* Toughness

* Moisture content - higher than 3-4 wt% will lead to cake formation and will clog the machine. This will lead to reduction in crushing effectiveness

* Explosive nature

Three stages

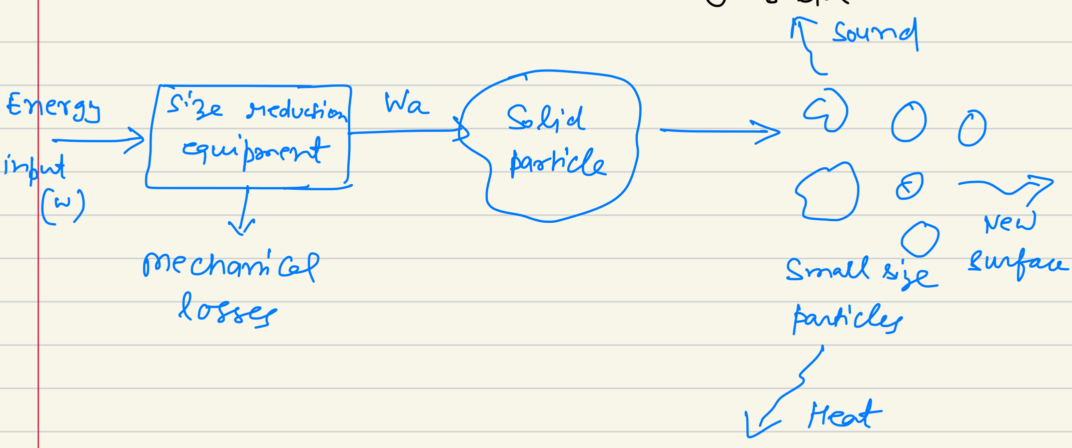
(1) Coarse size reduction: Feed size from 2 to 96 inch or more

(2) Intermediate size reduction: Feed size from 1–3 inch

(3) Fine size reduction: Feed size from 0.25 to 0.5 inch

Determination of power consumption:

$$\text{Crushing efficiency, } \eta_c = \frac{\text{Surface energy created by crushing}}{\text{Total energy absorbed by solid}}$$



W_a - Total energy absorbed by a unit mass of solid, J/kg

E_s - Surface energy per unit area, J/ m^2

A_{ssf}, A_{ssp} - Specific surfaces of feed/product, m^2/kg

$$\eta_c = \frac{(A_{ssp} - A_{ssf}) E_s}{W_a} \quad \text{---} \circledast$$

Mechanical efficiency, $\eta_m = \frac{W_a}{W}$

$$\eta_m = \frac{(A_{ssp} - A_{ssf}) E_s}{\eta_c \cdot W}$$

$$\Rightarrow \boxed{W = \frac{(A_{ssp} - A_{ssf}) E_s}{\eta_m \cdot \eta_c}}$$

Power required, $P = W \times \dot{m}$

$$\boxed{P = \frac{(A_{ssp} - A_{ssf}) E_s \, \dot{m}}{\eta_m \, \eta_c}}$$

$\dot{m}$ - flow rate of solids

Laws of Comminution :

* Emperical laws to relate size reduction with energy input to the machine
- Rittinger's law (1867)
- Kick's law (1885)
- Bond's law (1952)

Rittinger's law : The work required for size reduction is proportional to the new surface area created.

$$W_R = \frac{P}{\dot{m}} = K\, E_s \left(A_{ss_p} - A_{ss_f} \right)$$

$$K - \text{constant} = \frac{1}{\eta_c}$$

Volume surface mean dia, $\bar{D}_{vs} = \dfrac{6}{\phi_s A_{ss} \rho_p}$

$$W_R = 6\, K\, E_s \left(\frac{1}{\phi_p \bar{D}_{vs_p} \rho_{p_p}} - \frac{1}{\phi_f \bar{D}_{vs_f} \rho_{p_f}} \right)$$

For particles of constant sphericity & density,

$$W_R = \frac{6\, K\, E_s}{\phi\, \rho_p} \left(\frac{1}{\bar{D}_{vs_p}} - \frac{1}{\bar{D}_{vs_f}} \right) \quad (*)$$

$$W_R = K_R\left(\frac{1}{\bar{D}_{vsp}} - \frac{1}{\bar{D}_{vsf}}\right)$$

$$\boxed{K_R = \frac{6KE_s}{\phi \rho_p}}$$ → is known as Rittinger's constant

* inverse of Rittinger's constant is known as Rittinger's number.

* Rittinger's law mostly hold for fine grinding & feed size of less than 0.05 mm.

Kick's law: The work required for crushing a given mass of material is constant for a given reduction ratio irrespective of the initial size.

— Reduction ratio is the ratio of initial particle size to final particle size.

$$W_k = \frac{P}{\dot{m}} = K_k \ln\left(\frac{\bar{D}_{vsf}}{\bar{D}_{vsp}}\right)$$

K_k - Kick's constant

* more accurate for coarse crushing where surface area produced per unit mass is less.

* more applicable for feed size > 50 mm.

Bond's law: The work required to form particles of size D_{pp} from a very large particle size is proportional to the square root of the surface to volume ratio $\left(\frac{S_p}{V_p}\right)$ of the product.

$$W_B = \frac{P}{\dot{m}} = K\left(\sqrt{\frac{S_p}{V_p}}\right)_p \quad \text{---} \circledast$$

* Applicable to feed size b/w 0.05 & 50 mm.

$$\frac{S_p}{V_p} = \frac{6}{\phi D_p}$$

$$W_B = k\sqrt{\frac{6}{\phi D_{pp}}} = \underbrace{k\sqrt{\frac{6}{\phi}}} \times \frac{1}{\sqrt{D_{pp}}}$$

$k_b = k\sqrt{\frac{6}{\phi}}$ → Bond's constant

$$W_B = k_b \frac{1}{\sqrt{D_{pp}}}$$

More accurately,

$$\boxed{W_B = k_b \left(\frac{1}{\sqrt{D_{pp}}} - \frac{1}{\sqrt{D_{pf}}} \right)}$$

{ For very large feed size, $\frac{1}{\sqrt{D_{pf}}}$ become negligible }

Work index (W_i) – it is defined as the gross energy requirement in kWh per short ton of feed (kWh/ton feed) to reduce a very large particle size to such a size that 80% of product will pass through a 100 μm screen.

$k_b = W_i \sqrt{D_{pp}}$

Generalized law:

$$d(W) = d\left(\frac{P}{m'}\right) = -K \frac{d(\bar{D}v_s)}{(\bar{D}v_s)^n}$$

$n = 2$ Rittinger's law

$n = 1$ Kick's law

$n = 1.5$ Bond's law