Chemické inženýrství A/B

Filtrace

Filtration

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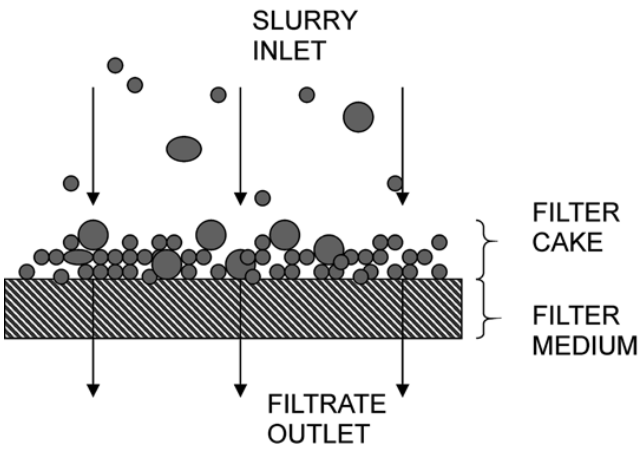
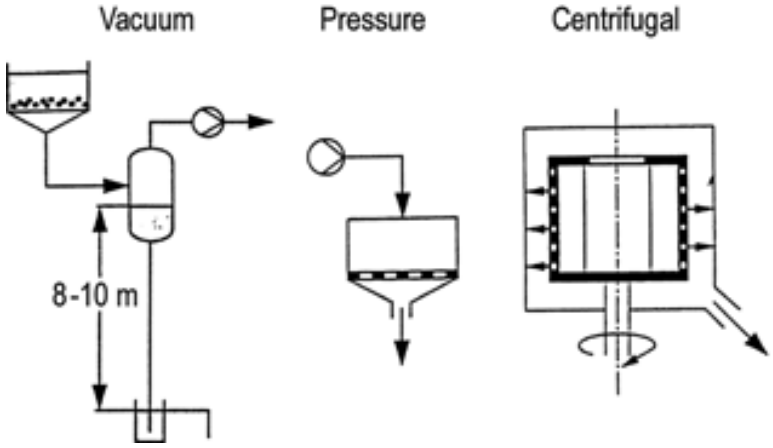
Evropský sociální fond
Praha & EU: Investujeme do vaší budoucnosti

2 Cake filtration

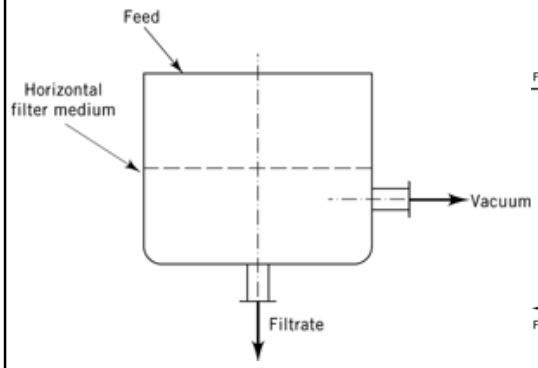


Filtration - by driving force

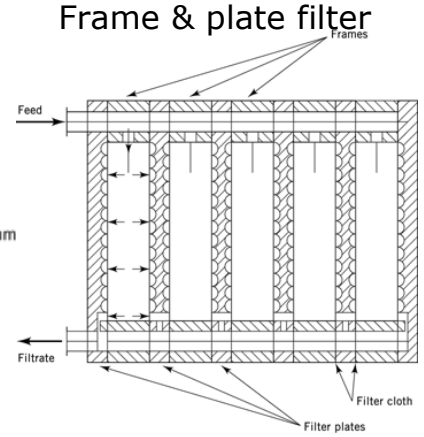


Filter types - batch

Nutsche filter

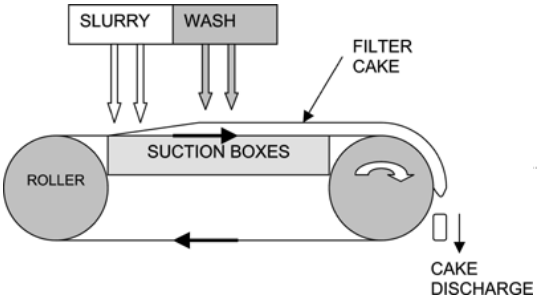


Frame & plate filter

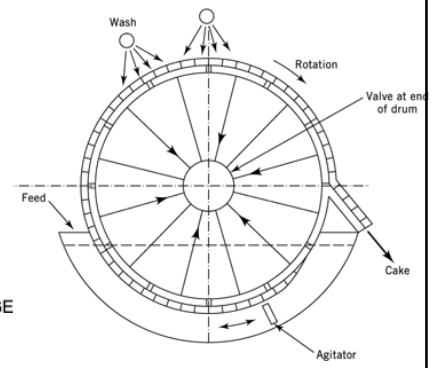


Filter types - continuous

Belt filter



Drum filter



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Cake filtration

$\Delta P_{total} = \Delta P_{filter} + \Delta P_{cake}$

Applying Darcy's law:

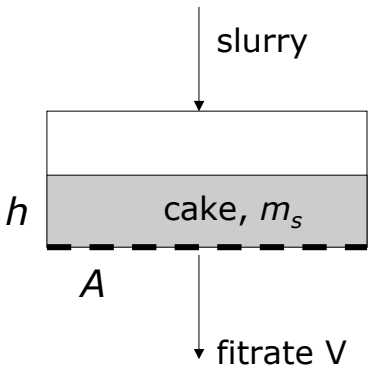
$\Delta P=(R_f+R_c)(\mu/A)dV/dt$

where

R_f filter resistance

and $R_c=h_c/\kappa_c$ cake resistance

(κ_c cake permeability)



$\alpha = AR_c / m_s$ … specific cake resistance

$x = m_s / V$ … dry cake mass per filtrate volume

General filtration equation:

$$dt/dV = \mu\alpha xV/A^2\Delta P + \mu R_f/A\Delta P$$

Solution for:

- constant pressure ΔP
- constant flowrate dV/dt

Constant pressure ($\Delta P = const.$)

by integrating the filtration equation:

$[\mu\alpha x / (2A^2\Delta P)]\ V^2 + [\mu R_f/(A\Delta P)]\ V - t = 0$

t/V vs. V is a straight line $\Rightarrow$ useful for data analysis

mass balance $\Rightarrow$ cake depth as function of filtrate V:

$$h_c = xV/[A\rho_s(1-\varepsilon)]$$

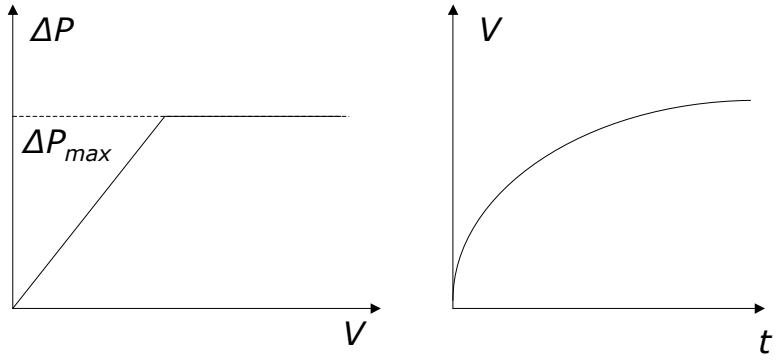
moisture ratio: ϕ = mass of wet cake / mass of dry cake

$$\phi = 1 + (\rho_L/\rho_S)\ \varepsilon/(1-\varepsilon)$$

Constant rate (dV/dt = *const.*)

from the general filtration equation:

$$\Delta P = (\mu \alpha x/A^2)(\mathrm{d}V/\mathrm{d}t)\, V + (\mu R_f/A)\, \mathrm{d}V/\mathrm{d}t$$



constant rate *constant pressure*

Compressible cake:

$R_c = h_c/\kappa_c = \alpha m_s/A \quad \Rightarrow \quad \alpha = [\kappa_c (1-\varepsilon)\, \rho_s]^{-1}$

Cake porosity ε is not constant in this case.

Correlations for average cake porosity:

$\alpha' = \alpha_0 (1-n)\, (\Delta P)^n$ n…compressibility coefficient

calcite: n=0.2

kaolin: n=0.6

Dry cake mass per filtrate volume also isn't constant.

from mass balance: $x = [(1-w_F)/w_F\rho_L - \varepsilon/(1-\varepsilon)\rho_s]^{-1}$

Filtration cycle

- filtration ...τ_F
- cake washing ...τ_W
- cake deliquering (drainage) ...τ_D
- cake removal ...τ_R
- filter cleaning ...τ_C

Objective:maximize total throughput

single cycle ($\tau_F + \tau_W + \tau_D + \tau_R + \tau_C$)

$\Rightarrow$ batch scheduling

Cake washing

-wash volume

-$V_w = \varepsilon h A = (m_s/\rho_s)\ \varepsilon/(1-\varepsilon)$

Drainage

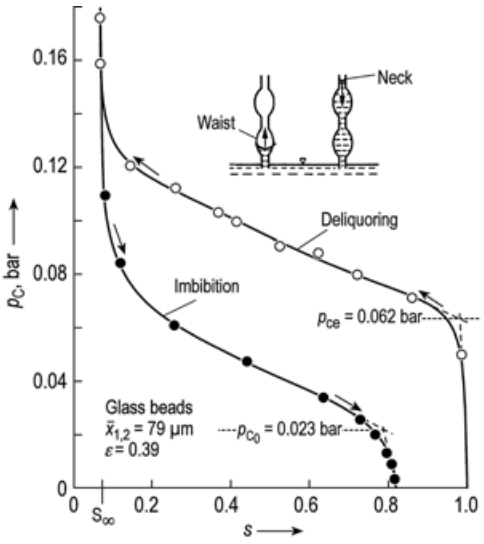
-Capillary pressure

$P_{cap} = 2\ \sigma \cos\theta / r_{pore}$

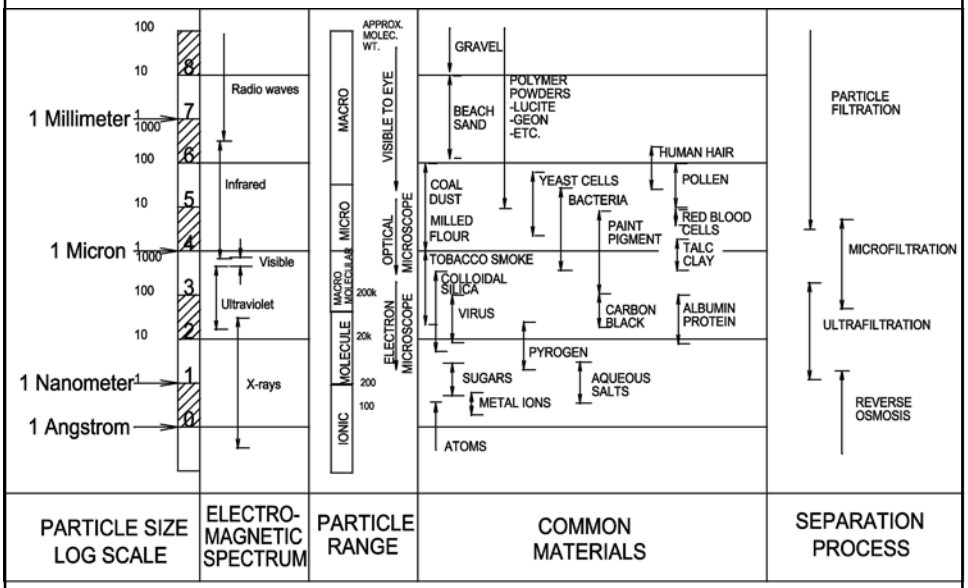
-Bond number

$Bo = \rho g d_{pore}^2/\sigma$

(gravity/surface tension)



Filtration process applicability



Centrifugation

Similar analysis as filtration, but…

Force on volume element of mass m: $F=ma$

a…acceleration $a=r\omega^2$

ω…angular velocity [rad s^{-1}]

Modern ultracentrifuges: up to 600,000 g

up to 70,000 rpm

pressure drop:

$\Delta P = \rho_L \omega^2 (r_0^2 - r_L^2)/2$