Module 10: Filtration

Lecture 36: Pinciples of filtration, constant pressure and volume filtration

Principles of filtration (continued)

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Case 1: Constant Pressure-drop Filtration

$$v(t) = q(t)/_A = \frac{1}{A}\frac{dV}{dt}, \quad \text{where } V = \text{the volume of filtrate collected and } A = \text{filtering area}$$

dm =differential mass of the cake $= \rho_p\,(1-\epsilon)AdL$

Substituting,

$$dP = \frac{k_1 \mu\, v\,(s_p/v_p)^2\,(1-\epsilon)}{\rho_p\, A\, \epsilon^3}\,dm$$

Assuming, incompressible cake (Const ρ_p, μ, ϵ)

Δp_c (pressure–drop) through cake $= (p_a - p_1)$

$= \frac{k_1 \mu\, v\,(s_p/v_p)^2\,(1-\epsilon)}{\rho_p\, A\, \epsilon}\; m_c$, where, m_c = total mass of cake.

p_1 =upstream-pressure of filter–media

Define, $R = \text{hydraulic resistance} = \frac{\Delta p_c}{\mu_f V}$

$\alpha = \text{specific resistanc} = R/(m_c/A)$

$\boxed{\alpha = \left(\frac{\Delta p_c\, A}{\mu\, v\, m_c}\right) = \left(\frac{k_1\,(\Delta_p/v_p)^2\,(1-\epsilon)}{\epsilon^3\,\rho_p}\right)}$ = property of cake

$$\left.\begin{array}{c} \text{If constant } \Delta p - \text{filtration,} \\ v(t)\downarrow \;\; m_c \uparrow \\ \text{If constant } V - \text{filtration ,} \\ \Delta p_c \uparrow \;\; m_c \uparrow \\ \text{overall } \Delta p = \Delta p_c + \Delta p_m \end{array}\right\} \alpha \text{ remainst constant}$$

$\downarrow$ Pressure–drop through filter medium

$\boxed{\Delta p = \mu_f v\left(\frac{m_c \alpha}{A}\right)}$ hydraulic resistance of filter medium

Now ‘C' as the mass of the particles deposited in the filter per unit volume of the filtrate,

$$m_c(t) = V(t) \times C$$

It can be shown that

$$C = \frac{C_s}{\left[1-\left(\frac{m_f}{m_c}-1\right)\frac{C_s}{\rho_f}\right]}$$ where, $C_s = \text{slurry density} = \frac{\text{mass of solids}}{\text{volume of liquid fed to filter}}$

If turns out that $\frac{m_f}{m_c} = \text{property of cake } (= 2 \text{ for calcium carbonate slurry})$

Replacing m_c and v in the expression for Δp

$$\boxed{\frac{1}{q} = \frac{dt}{dV} = \frac{\mu_f}{A\Delta p}\left(\frac{\alpha CV}{A} + R_m\right)}$$

This is the working equation for cake filtration.

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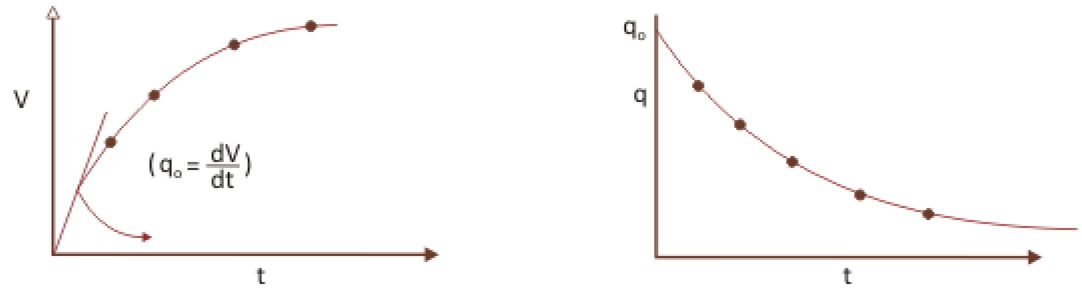
⇒ Case 1: constant–pressure filtration $(\Delta p = \Delta p_o)$



(Fig. 36a)

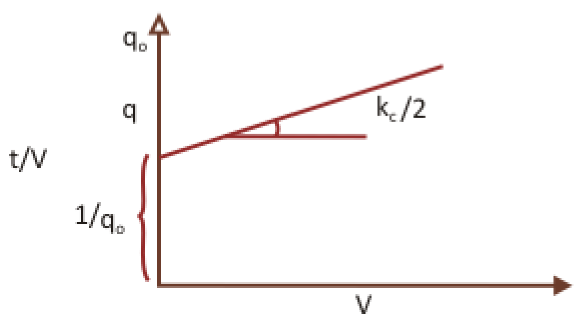
$t = 0, V = 0, \ \Delta p = \Delta p_o, q = q_o$

$$\frac{1}{q_o} = \left(\frac{dt}{dV}\right)_o = \frac{\mu_f R_m}{A\,\Delta p_o}$$

Therefore, $R_m = \dfrac{(\Delta p)_o A}{q_o\ \mu_f}$ (one can calculate R_m form the initial filtration-data when resistance due
to cake = 0)

One can also write,

$$\boxed{1/q = \frac{1}{q_o} + K_C\,V}, \text{where } K_C = \left(\frac{\mu_f\,\alpha\,C}{A^2\ \Delta p}\right)$$ = constant (known)



(Fig. 36b)

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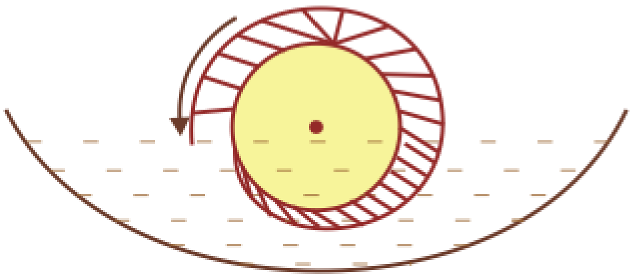
Or

$$\boxed{\frac{t}{V} = \frac{1}{q_o} + \frac{K_c}{2} V}$$ on integration

The above expression can be integrated to develop an expression for the amount of cake formed over time 't' or the production rate of cake for the rotary- drum filter:



(Fig. 36c)

$$\frac{\dot{m}_c}{A} = \left(\frac{2C\,\Delta p\, f\, \eta}{\alpha\, \mu}\right)^{1/2}$$

A = Total area of filtration

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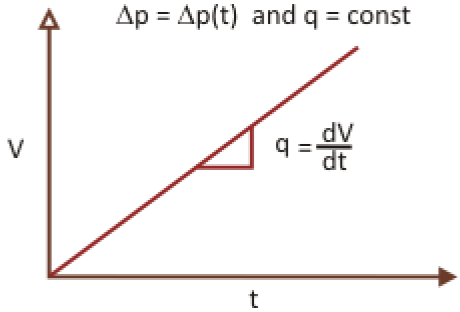
Case 2: Constant Rate Filtration



(Fig. 36d)

$$u = \frac{1}{A}\frac{dV}{dt} = \frac{V}{A\,t}$$

$$\Delta p = \mu v\left(\frac{m_c \alpha}{A} + R_m\right)$$

Or

$$\Delta p \simeq \frac{\mu_c V^2 \alpha}{t A^2}$$ (neglecting R_m)

$$\frac{\Delta p}{\alpha} = \frac{\mu C}{t}\left(\frac{V}{A}\right)^2 = \mu C t v^2$$ here, v is constant.

Δp varies linearly with time.

(Such operation is difficult to run, i.e, keeping volumetric flow rate constant)

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