Module 10: Filtration

Lecture 37: Examples

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Examples on filtration

Example 1: A rotary drum filter with 30% submergence is used to filter a concentrated aqueous slurry of calcium carbonate containing $15\ \text{lb}$ of solids per cubic foot of water. The pressure–drop is $20''\ \text{Hg}$. If the filter cake contains 50% mixture (wet basis), calculate the filter area required to filter 10 gal/min of slurry. The filter cycle time is 5 min. The specific cake resistance depends on the pressure–drop as:

$$\alpha\ (\text{ft/lb}) = \alpha_o\ (\Delta p)^{0.26}, \text{where}\ \alpha_o = 2.90 \times 10^{10}$$

Viscosity of the filtrate $= 6.72 \times 10^{-4}\ \text{lb/ft} - \text{s}$. Density of $\text{calcium carbonate} = 168.8\ \text{lb/ft}^3$.Neglect filter medium resistance.

Answer:

Re–call the expression for the production rate of cake.

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

Here, m_c =production rate of cake

$$= c\frac{V}{t}$$

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where $c = \dfrac{C_s}{1 - \left[\dfrac{m_f}{m_c} - 1\right]\dfrac{C_s}{\rho}}$; $C_s =$ concentration of slurry

$\dfrac{m_f}{m_c} = 2$ (assumed for $CaCO_3$)

$f =$ Submergence–fraction $= 0.3$

$n \equiv$ Speed of the drum $= \dfrac{1}{\underbrace{5 \times 60}_{\text{Cycle-time}}}\ s^{-1}$

$\alpha = 2.90 \times 10^{10}\ (\Delta p)^{0.26}$

$\mu = 6.72 \times 10^{1-4}\ \text{lb/ft} - \text{s}$

$\rho = 62.3$ (density of filtrate) lb/ft^3

$\Delta p = 20''H_g = 1414\ \text{lbf/ft}^2$

$C_s =$ Slurry–density $= 15/\left(1 + \frac{15}{168.8}\right) \simeq 15\ {}^{\text{lb}}/_{\text{ft}^3}$

$$C = \frac{15}{1 - (2-1)\,15/62.3} = 19.2\ \text{lb/ft}^3$$

$$\dot{m}_c = 19.2 \times \frac{10}{60 \times 7.48} \times \left(\frac{1}{1 + \dfrac{15}{168.8}}\right) = 0.3\ \text{lb/s}$$

On substitution,

$$\frac{0.3}{A_t} = \left(\frac{2 \times 19.2 \times 1414 \times 32 \times 0.3}{6.72 \times 10^{-4} \times 2.90 \times 10^{10}\ (1414)0.26 \times 300}\right)$$

$A_t \simeq 82\ \text{ft}^2$

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Example 2: A calcium–carbonate slurry is to be filtered in a press having a total area of $16 m^2$ and operated at a constant pressure drop of 2 atm. The frames are $36\ mm$ thick. Assume that the filter medium resistance is 1.55×10^{10} per ft. Calculate filtration time and the volume of filtrate obtained in one cycle. Cake density $= 73\ lb/ft^3$. The specific cake resistance,

$$\alpha(ft/lb) = 2.90 \times 10^{10} \left(\Delta p \text{ in } lb/ft^2\right)^{0.26}$$

Concentration of slurry $= 14.7\ lb/ft^3$

Answer:

$$C = \frac{C_s}{1 - \left[\frac{m_f}{m_c} - 1\right]\frac{C_s}{\rho}} = \frac{14.7}{1 - [2-1]\frac{14.7}{62.3}} = 19.24\ lb/ft^3$$

$$A = \text{filtration area} = 8\ m^2 = 86\ ft^2$$

$$\Delta p = 2\ atm \times 14.696 = 29.39\ lbf/in^2$$

$L_c =$ Thickness of the cake $= 36 \times 10^{-3} \times 3.28 = 0.118\ ft$

$m_c =$ total mass of the cake formed in one cycle

$= A \times L_C \times \rho_C$ (cake density)

$= 86 \times 0.118 \times 73$

$= 742\ lb$

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Note:

$m_c = V \times C$

$V =$ Volume of the filter $= \frac{742}{19.24} = 38.6\ ft^3$ in one cycle

$\alpha = 2.90 \times 10^{10}\ (\Delta p\ )^{0.36}$

$R_m = 1.55 \times 10^{10}\ ft^{-1}$

Re-call the expression for constant pressure–drop filtration

$$\boxed{\frac{t}{V} = \frac{k_c}{2} V + \frac{1}{q_o}}$$

where $q_o = \frac{(\Delta p\ o)A}{\mu R_m} = \frac{86 \times 29.39 \times 144 \times 32}{6.6 \times 10^{-4} \times 1.55 \times 10^{10}} = 1.145\ ft^3/s$

$$K_c = \frac{\mu\ c\ \alpha}{A^2\ \Delta P g_c} = \frac{6.6 \times 10^{-4} \times 19.24 \times 2.90 \times 10^{10} (29.39 \times 0.26144)}{86^2 \times (29.39 \times 144) \times 32} = 0.9$$

Therefore,

$$t = \left(\frac{k_c}{2} V^2 + \frac{1}{q_o}\right) = 12\ min\ (appprox)$$

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Example 3:

The following relation between specific resistance and pressure drop has been determined:

$$\alpha = 8.8 \times 10^{10}[1 + 3.36 \times 10^{-4}(\Delta p \text{ in } lb/ft^2)^{0.86}]$$

This relation is valid over a pressure range of $0 - 1000\ lbf/sq.in$. A slurry of this material yielding $3\ lb$ of cake solid per cubic filtrate is to be filtered at a constant pressure drop of 70 $lbf/sq.in$ and $70°F$. The resistance of filter $-medium\ Rm = 1.2 \times 10^{10}$ per ft. Determine square feet of the filter surface area required to give 1400 gal of filtrate in a 1-hr-filtration? $\mu_{filtarte} = 6.6 \times 10^{-4}\ lb/ft - s$

Answer:

$$\Delta p = 70 \times 144 = 10080\ lbf/ft^2$$

$$\alpha = 8.8 \times 10^{10}\ [1 + 3.36\ \times 10^{-4} \times (10080)^{0.86}]$$

$$= 1.70 \times 10^{11}\ ft/lb$$

$$C = 3\ lb/ft^3, R_m = 1.2 \times 10^{10}\ ft^{-1}$$

$$V = \frac{1400}{7.48} = 187.2\ ft^3$$

Re-call the expression:

$$q_o = \frac{(\Delta p)g_c}{\mu R_m} = \frac{A \times 10080 \times 32}{6.6 \times 10^{-4} \times 1.2 \times 10^{10}} = \frac{A}{24.42}$$

$$K_c = \frac{\mu c \alpha}{A^2 \Delta P g_c} = \frac{6.6 \times 10^{-4} \times 3 \times 1.7 \times 10^{11}}{A^2 \times 10080 \times 32} = 1038\ A^2$$

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

Substitute,

$$\Rightarrow 3600 = \frac{10\ 38A^2}{2} \times 187.2^2 + \frac{24.42}{A} \times 187.2$$

Or

$$A^2 - 1.2698A - 5051.7 = 0$$

$$A = 7107\ ft^2$$

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