ENP100 – Prosess og Produksjon

LØSNINGSFORSLAG, ØVING 2

Oppg 1. Eqn. (4.1), accelleration term neglected (constant velocity)

$$\Delta p = p_{wf} - p_{wh} = \left(\frac{g}{g_c}\right) \rho \Delta z + \frac{2 f_F \rho u^2 L}{g_c D}$$

$\frac{g}{g_c}$ = 1 in US field units $\left[\frac{lbf}{lbm}\right]$

Hydrostatic term:

$$\gamma_o = \frac{141.5}{°API + 131.5} = \frac{141.5}{16 + 131.5} = 0.959$$

$$\Rightarrow \rho_o = 0.959 \cdot \underbrace{62.4}_{\rho_{water}} \ lbm/ft^3 = 59.84 \ lbm/ft^3$$

$$\Delta p_H = 1 \frac{lbf}{lbm} \cdot 59.84 \frac{lbm}{ft^3} \cdot 1500 \ ft = \underline{89760 \frac{lbf}{ft^2}}$$

(Divide by 144 to get psi)

Friction term:

$$N_{Re} = \frac{1.48 \cdot 1000 \cdot 59.84}{2.259 \cdot 5} = \underline{7841}$$ → Turbulent

(~ quite low, but still above 2100...)

$$\bar{q}_o = 1000 \frac{bbl}{day} \cdot 5.6146 \frac{ft^3}{bbl} \cdot \frac{1}{86000 \ s/day} = 0.06498 \ ft^3/s$$

$$u = \frac{4 \bar{q}_o}{\pi D^2} = \frac{4 \cdot 0.06498 \ ft^3/s}{\pi \cdot \left(\frac{2.259 \ in}{12 \ in/ft}\right)^2} = \underline{2.33 \ ft/s}$$

Fanning friction factor:

$$f_F(N_{Re}, \varepsilon) = 0.00858 \quad \text{(By eqn. (4.5))}$$

$$f_F = \frac{f_M}{4} = \frac{0.0355}{4} = 0.00888 \quad \text{(By Moody diagram)}$$

$\underline{f_F = 0.009}$ Sufficiently accurate

~7800

$f_M \approx 0.0355$

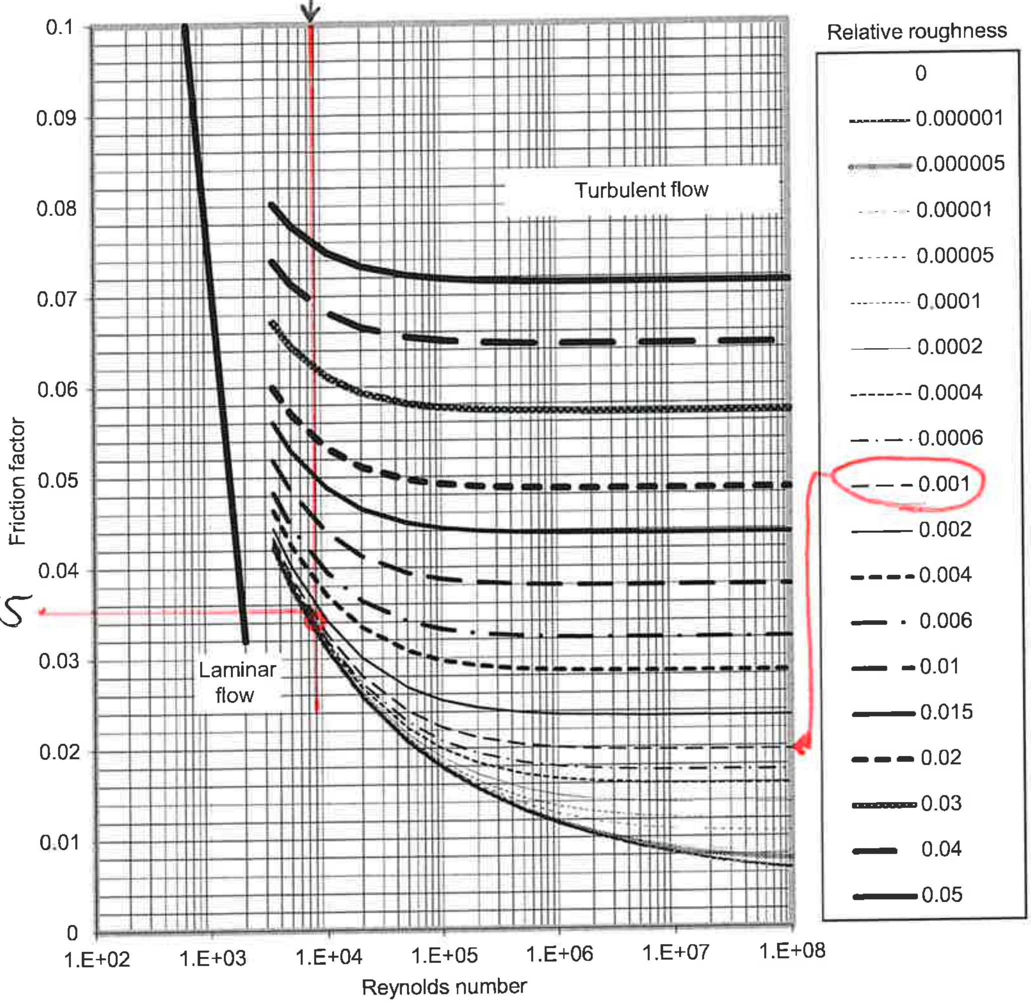
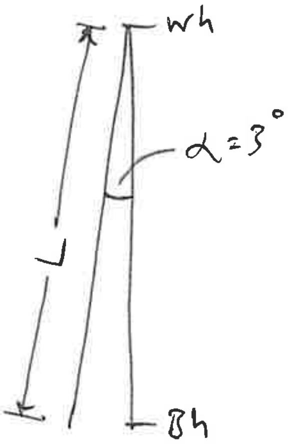


FIGURE 4.2

Darcy—Wiesbach friction factor diagram.

After Moody, 1944.



$$\cos\alpha = \frac{\text{Depth}}{L} \rightarrow L = \frac{1500}{\cos 3^\circ} = \underline{1502 \text{ ft}}$$

(Almost vertical, so why bother...)

$$\Delta P_F = \frac{2 f_F \rho u^2 L}{g_c \cdot D}$$

$$= \frac{2 \cdot 0.009 \cdot 59.84 \frac{lbm}{ft^3} \cdot \left(2.33 \frac{ft}{s}\right)^2 \cdot 1502\ ft}{32.17 \frac{lbm\ ft}{lbf\ s^2} \cdot \left(\frac{2.259\ in}{12\ in/ft}\right)} = \underline{1450 \frac{lbf}{ft^2}}$$

Check of Units:

$$\boxed{\frac{\cancel{lbm}\ \cancel{ft^2}\ \cancel{ft}\ lbf\ \cancel{s^2}\ \cancel{in}}{\cancel{ft^3}\ \cancel{s^2}\ \cancel{lbm}\ \cancel{ft}\ \cancel{in}\ ft} = \frac{lbf}{ft^2}}$$

Bottom hole pressure in psi:

$$P_{bh} - P_{wh} = \Delta P_H + \Delta P_F$$

$$\Rightarrow P_{Bh} = 500\ psi + \frac{89760}{144} + \frac{1450}{144} = \underline{\underline{1133\ psi\ a}}$$

Oppg. 2

a)

$$\frac{WC}{1-WC} = \frac{\frac{\dot{q}_w}{\dot{q}_o + \dot{q}_w} \times (\dot{q}_o + \dot{q}_w)}{1 - \frac{\dot{q}_w}{\dot{q}_o + \dot{q}_w} \times (\dot{q}_o + \dot{q}_w)}$$

$$= \frac{\dot{q}_w}{(\dot{q}_o + \dot{q}_w) - \dot{q}_w} = \frac{\dot{q}_w}{\dot{q}_o} = \underline{WOR} \qquad \underline{QED}$$

$$\frac{\frac{\dot{Q}_g}{\dot{q}_o + \dot{q}_w}}{1 - \frac{\dot{q}_w}{\dot{q}_o + \dot{q}_w}} = \frac{\dot{Q}_g}{(\dot{q}_o + \dot{q}_w) - \dot{q}_w} = \frac{\dot{Q}_g}{\dot{q}_o} = \underline{GOR} \qquad \underline{QED}$$

b) Mixture density is a function of p and T; see eqn. (4.41) (R_s is also function of p)

Since p is unknown for the bottom-hole conditions, an estimate is needed.

* place this estimate in a cell in Excel, then refer to this when calculating all the pressure dependent quantities.

c) * Later, adjust this estimate until equation (4.36) solved for p_{wh} gives 300 psi

See Excel sheet for details