ØVING 2 – 2022

Oppgave 1: Singe-phase flow

Single-phase oil is produced from a reservior at 1500 ft depth, against a wellhead pressure of 500 psi a.

Calculate the bottom-hole pressure

The following data are given:

Oil production rate:	q_o	$= 1000$	stb/day
Oil specific gravity:	G	$= 16$	°API
Oil viscosity:	μ_o	$= 5$	cP
Tubing inner diameter:	D_i	$= 2.259$	in
Tubing wall relative roughness:	ε	$= 0.001$	
Well inclination:	α	$= 3°$	(From vertical)

Oppgave 2: Multi-phase flow

For multiphase wells the following flow ratios are defined:

$$\begin{aligned}
\text{GLR} &= \frac{\dot{Q}_g}{\dot{q}_o + \dot{q}_w} && \text{(Gas-liquid ratio)} \\
\text{GOR} &= \frac{\dot{Q}_g}{\dot{q}_o} && \text{(Gas-oil ratio)} \\
\text{WC} &= \frac{\dot{q}_w}{\dot{q}_o + \dot{q}_w} && \text{(Water cut)} \\
\text{WOR} &= \frac{\dot{q}_w}{\dot{q}_o} && \text{(Water-oil ratio)}
\end{aligned}$$

GLR and WC are often stated as measured data, while the correllations require GOR and WOR as input.

a) Show that

$$\begin{aligned}
\text{WOR} &= \frac{\text{WC}}{1 - \text{WC}} \\
\text{GOR} &= \frac{\text{GLR}}{1 - \text{WC}}
\end{aligned}$$

The following data for a three-phase well are taken from Problem 4.2 in the text book [1]:

Wellhead pressure:	p_{wh}	$= 300$	psi a
Wellhead temperature:	T_{wh}	$= 100$	°F
Tubing inner diameter:	D	$= 1.66$	in
Well depth:	Δh	$= 8000$	ft
Bottom-hole temperature:	T_{wh}	$= 170$	°F
Liquid production rate:	$\dot{q}_L$	$= 2000$	stb/day
Water cut:	WC	$= 30$	%
Producing GLR:	GLR	$= 800$	scf/stb
Oil gravity:	G_o	$= 40$	°API
Water-specific gravity:	γ_w	$= 1.05$	
Formation volume factor of water:	B_w	$= 1.0$	
Gas-specific gravity:	γ_g	$= 0.70$	

b) Use an Excel sheet to calculate the mixture densities used in Poettmann-Carpenter's model [2] at both ends of the well (wellhead and bottom-hole). For the bottom-hole, use an estimated pressure of 2500 psi a.

Note that:

- Air density, ρ_{air} in equation (4.40) is to be taken at standard conditions, i.e. it is a constant of $0.0765\ \mathrm{lb}_m/\mathrm{ft}^3$.
- Gas compressibility factor z, in equation (4.41) can be calculated in a variety of ways; for this exercise use $z_{wh} = 0.95$ for wellhead, and $z_{bh} = 0.80$ for bottom-hole.

c) Find the bottom-hole pressure from Poettman-Carpenter's model, equation (4.36), for example using the Goal-Seek function in Excel (or a simply manual trial-and-error procedure). The result can be checked against the spreadsheet `Poettmann-Carpenter-BHP.xsl`.

Hint: Δp in equation (4.36) is the pressure difference between bottom-hole and wellhead when Δh is the total well depth; solve for p_{wh} (which is given);

$$p_{wh} = p_{wf} - \left(\bar{\rho} + \frac{\bar{k}}{\bar{\rho}}\right)\frac{\Delta h}{144}$$

then use Goal Seek or trial-and-error to set p_{wh} to 300 psi by adjusting the estimate for p_{wf}.

Note especially:

- The friction factor f_{2F} calculated from equation (4.44) should be multiplied by 4 before used with equation (4.37). This makes it in fact the *Darcy* friction factor, not the Fanning friction factor.

Referanser

[1] Guo, B., Liu, X., Tan, X.: *Petroleum Production Engineering*, 2nd Ed., Gulf Professional Publishing, 2017, ISBN 978-0-12-809374-0

[2] Poettmann, F.G., Carpenter, P.G.: *The Multiphase Flow of Gas, Oil, and Water Through Vertical Flow Strings with Application to the Design of Gas-lift Installations* API, Drilling and Production practice, 1952