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Investigation of the effect of equations of state on production well simulation results

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Abstract:

The effect of different equations of state on production well simulation results have been investigated. Concerning considerable application of PIPESIM software in production units in petroleum industry, the available equations of state in this software have been explored and compared in this article. A production well has been simulated using different equations of state and production rate, bottom hole pressure and well head pressure have been calculated and compared with actual data.

The simulation results show that 3 parameter Peng-Robinson equation of state in SISFlash PVT package has acceptable results which have the best match with actual data.

Keyword: Equation of state, Simulation, PIPESIM software, Production well

1.Introduction

An equation of State (EOS) ,equation that is analytically in the form of pressure (P), volume (V) and temperature (T) are linked together. One of the uses for pvt relations, set the volumetric behavior and fuzzy hydrocarbon reservoirs and Predict the performance of surface equipment in separation operations . The easiest and the most famous equation of stae the ideal gas equation, which is in the form P = RT/V _ V_m, (m) the volume of gas in cubic feet of gas on a mole. This equations PVT just to describe the volumetric behavior of hydrocarbon gases at very low pressure and is used to close the atmospheric. The limitations for the equation up there, which led researchers appoint to introduce a Wider application range equations for real gases pressure and temperature ranges that wider application.

2 . equations of state used in hydrocarbon mixtures

2.1The van der Waals equation

In 1873, Van derwal proposed the following equation to show the behavior of real gases:

$$\left(P + \frac{a}{V_m^2}\right)(V_m - b) = RT \tag{1}$$

The difference of this equation with the ideal gas equation is to add the term a / (V_m ^ 2) to the pressure and reduce the constant **b** of the molar volume. The term a / (V_m ^ 2) represents the tensile strength between the molecules.the actual pressure Imported into the walls of a container of a / (V_m ^ 2) is less than the pressure exerted by an ideal gas. The constant **b** is used to correct the molar volume due to the volume taken by molecules in real gases.

The constants **a** and **b** are the characteristics of each particular gas, and **R** is the constant of gas. The van der Waals equation has limited applications and can be used at low pressures.

Equations like the van der Waals equation are called "cubic" states of the equation. The van der Waals equation in the form of the third degree is as follows:

$$V_m^3 - \left(b + \frac{RT}{P}\right)V_m^2 + \left(\frac{a}{p}\right)V_m - \frac{ab}{p} = 0 \tag{2}$$

2.2 SRK state equation

In 1972, one of the most widely used state equations in hydrocarbon systems was presented as follows:

$$P = \frac{RT}{V_m - b} - \frac{a_T}{V_m(V_m + b)} \tag{3}$$

a_T is a temperature dependent parameter that is calculated as a_T = acα. In this equation, ac is a**T** at critical temperature. Also, α is a temperature-related and dimensionless term that is equal to one at a critical temperature. Equating zeroFirst and second derivatives of the pressure relative to molar volume at the critical point of the equilibrium, SRK equation of state is obtained as follows: :

$$a_c = 0.42747\frac{R^2T_c^2}{P_c}$$
$$b = 0.08664\frac{RT_c}{P_c} \tag{4}$$

The value of **α** is obtained from the following equation

$$\alpha^{0.5} = 1 + m(1 - T_r^{0.5})$$
$$m = 0.48 + 1.574\omega - 0.176\omega^2 \tag{5}$$

ω is the deviation of the pitzer center and is equal to:

$$\omega = -[\log(P_{vr}) + 1]_{T_r=0.7} \tag{6}$$

Pvr (vapor pressure) reduced pressure at a reduced temperature Tr = 0.7. Therefore, the Deviation factor from the center for any pure substance
There is a constant measurement. Whatever The material is heavier , the greater the amount of **ω**

2.3 Peng Robinson Equation(PR)

In 1976, Peng and Robinson carried out extensive research on how to estimate the effects of natural hydrocarbons by the SRK equation. Their research concluded that in order to improve the calculating the density and some other fluid properties in the near-distant critical regions, the SRK equation should be corrected. The two researchers presented the following equation:

$$P = \frac{RT}{V_m - b} - \frac{a_T}{V_m(V_m + b) + b(V_m - b)} \qquad (7)$$

The constants of the PR equation are obtained from the following relationships:

$$a_T = a_c \alpha$$
$$a_c = 0.45724 \frac{R^2 T_c^2}{P_c} \qquad (8)$$
$$b = 0.0778 \frac{RT_c}{P_c}$$

In the above equation, the parameter α, as in the SRK equation, is a function of temperature that is calculated from the following equation

$$\alpha^{0.5} = 1 + m(1 - T_r^{0.5}) \qquad (9)$$
$$m = 0.37 + 1.542\omega - 0.269\omega^2$$

These equations of state are presented for pure materials, and since in oil engineering we often encounter hydrocarbon mixtures, mixing rules must be calculated and corrected for mixtures for equations.

3. PIPESIM software:

PIPESIM software is one of the most widely used approach for production engineers to evaluate and check production performance of wells and efforts to optimize production. Various multiphase equations, different models of well completion, the use of black oil and hybrid models, and the facility of simulations of artificialgas (gaslift, downholepumps, ...) has turned this software into one of the most powerful computational tools in petroleum engineering. Given the importance of using this software in oprations units in oil industry, In this study this software is used.

Simulation in PIPESIM software is done in two general sections, which are briefly mentioned below.

3.1 Fluid flow in wells and pipelines

In this section of the software, simulated by Using different relationships multiphaseflows within production and injections wells, and pipelines , and performed Sensitivity analysis on various parameters. Performance evaluation of all equipment needed for the transfer of hydrocarbon fluids and performing heat transfer calculations can be performed. By drawing different charts, we can examine the effect of important parameters on the model.

3.2 Simulation of networks

In this part of the software, theproduction wells network, gathering systems or pipelines network needed to distribute hydrocarbon fluids can be studied. The characteristic of this part of the software is the ability to solve fluid flow equations in looped pipelines and the high number of branch with high precision. simultaneously

4. Equations of state in PIPESIM software

Equations of state are widely used in various calculations in petroleum engineering. Most physical and thermodynamic(PVT) properties of various materials and mixtures are calculated using the equation of state. The PIPESIM software has two PVT packages for calculations:

1- SIS Flash
2- Multiflash

Each of the above thermodynamic packets has a set equations of state. In the SIS flash package, four equations of the following state are usable:

- 2Parameter Peng-Robinson
- 3 Parameter Peng-Robinson
- Standard 2 Parameter PR
- Standard 3 Parameter PR

In the Multiflash package, the following equations can be used:

- Standard Peng-Robinson
- Standard SRK
- Peng-Robinson
- SRK
- BWRS

The BWRS equation has 11 parameters and is most commonly used for gases of light hydrocarbons. This equation can accurately and correctly compute the thermal and volumetric properties.

5. production wells simulation

By simulating a production well with PIPESIM software, the effect of different equation of state on the calculated results was investigated. Table 1 shows reservoir characterisation and flow data for production wells . In tables (2) and (3), respectively, the profile of the tubing pipe and reservoir fluid composition have shown.

Table 1: characterisation of production wells

Reservoir pressure	4196psia
Reservoir temperature	207F
Liquid Productivity Index	39bbl/(d.psi)
Production Rate	155 (bbl/d)
Choke size	32/64 in
Well Head Pressure	190 psia
Well Head Temperature	120 F
Separator pressure	120 psia

TABLE 2: TUBING DIAMETER

Tubing ID (in)	MD (ft)
8.681	8776.2
6.184	967.5

According to Fig. 1, the necessary equipment for simulating the reservoir fluid flow in production wells are :

1.Vertical Completion: Which is used to simulate fluid flow from reservoir to wellbore and definition of IPR model

2.Tubing: used to define the dimensions and characteristics of the tubing pipe of the well according to Fig. 2 and to simulate the flow of fluid within it .

.3.Choke: is used to simulate the wellhead valve-defined well for pressure control and flow rate.

4.A separator: used to simulate the separation of water from oil in a two-phase separator.

.5.The equipment: used in the software to simulate the pressure drop generated on the fluid in the separator.

Table (3): Combined production of wells

Components	Mole Percent	MW	S.G.
N_2	0.08		
CO_2	0.15		
C1	37.37		
C2	7.19		
i-C4	5.62		
n-C4	3.12		
i-C5	1.2		
i-C5	1.27		
C6	4.97		
C7	3.78		
C8	2.46		
C9	2.45		
C10	2.86		
C11	2.19		
C12+	24.17	473	0.97

By choosing the compositional composition of the fluid model, according to table (3), the reservoir fluid composition was defined and different equations were used to calculate the fluid composition. Each time performing computations by performing Nodal Analysis operations by drawing the IPR and TPR charts and determining the intersection of these two charts, the production rate of well (Q), bottom hole pressure (Pwf) and wellhead pressure (Pwh)

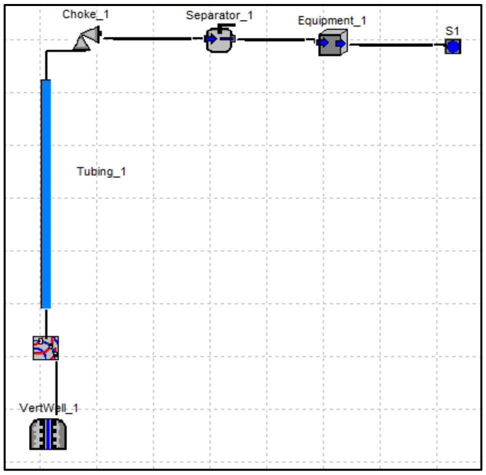

Figure (1): Production wells simulation in PIPESIM

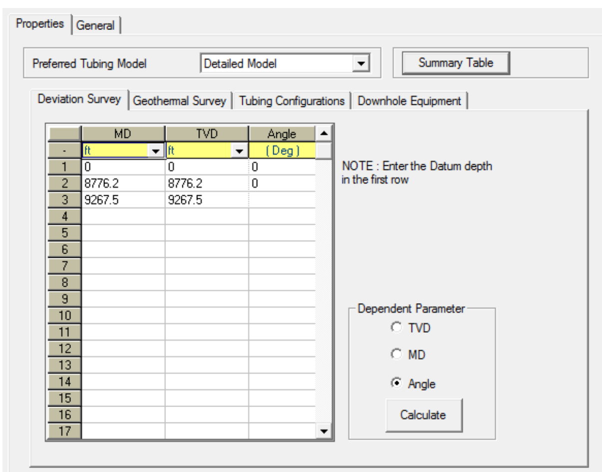

Figure (2): tubing pipe parameters

6. Discussion of results

The purpose of the simulation of production wells is to study the effect of different equations of state on the calculation results and to determine the production rate and bottom hole pressure of the well. Considering the information of a actual data from prodction well, the effect of choosing the three degree equations of state in PIPESIM software was investigated.

In a general comparison equations of state in the SISFLAH thermodynamic(PVT) package, than to the Multiflash, shows the more production rate for more than just the pressure drop in the wellhead, which seems to be due to the complex formulation and the more parameters that exist in SISFlash mode. Math calculations and operations have increased the accuracy of the resulting equation.

In computing using the SISFlash thermodynamic(PVT) package, the Peng Robinson equation of state has two and three parametric . The difference between these two equations is in the Volume Shift Correction Factor, which is considered in the three-parameter equations of state.three Parameter equations are more accuracy in estimate the properties of fluid(liquid),saturation, compressibility, and fluid density.

In calculations using the SISFlash thermodynamic(PVT) package, as shown in Table (4), the results obtained with three-parameter equations of state have higher accuracy and more consistent than the two-parameter mode equations with experimental data.

In equations of state in the form of a standard, the production rate of well is more calculated, which can be attributed to the effect of the center deviation factor (ω). In correlations of the Equation 3 of Parameter(PR), this correction coefficient is applied and is effective in the calculation results, but in the relations of the equation of state 3 of Parameter PR Standard, this correction coefficient is not considered, because of the production rate is more achived.

In the Multiflash thermodynamic(PVT) package, there are two equations of state the most widely used state of in petroleum engineering, namely Peng Robinson and SRK. In computing with the Multiflash thermodynamic package, the Standard PR and Standard SRK modes have stimate more production and less bottom hole pressure than PR and SRK equation .

Table 4: Results of the calculations with equations of state

Multiflash	Q(bbl/d)	P_{wf} (psia)	P_{wh} (psia)
PR	209	4195	128
SRK	195	4192	108
Standard PR	319	4193	284
Standard SRK	555	4186	585
SIS Flash	Q(bbl/d)	P_{wf} (psia)	P_{wh} (psia)
2param PR	1014	4171	961
3 param PR	176	4191	213
2 param PR standard	1046	4173	970
3 param PR standard	194	4195	243

7. Conclusion

From the comparison of the results of simulation of wells and available experimental data, it can be concluded that the results of the simulation with the 3Parameter(PR) equation of state in the SISDF PVT package are most consistent with the production well data and the error rate in calculating the flow rate of production well About 12 percent. According to the above mentioned, it can be concluded that the correct choice equation of state has a significant effect on the result of calculation and the forcaste rate of production. It should always be considered that the best equation of state should be used according to the type of reservoir fliud and flow conditions.

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