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POLYMER INJECTION MODELING IN A SOLUTION GAS DRIVE-NATURALLY FRACTURED RESERVOIR

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ABSTRACT

Solution Gas Drive-Naturally Fractured Reservoir (NFR) has relatively high remaining oil reserves. This causes less optimum oil from the reservoir to be produced to the surface, so that it requires an enhanced oil recovery (EOR). EOR can be done by chemical injection, one of which is by polymer injection. Polymer injection emphasizes improving the swept efficiency. The most important parameter in this case is the mobility ratio. The injection process is very dependent on reservoir fluid characteristics, rock heterogeneity, and interactions between fluid and rock. Therefore, studies are needed to understand the mechanism of polymer injection that occurs in the reservoir.

Simulation modelling of polymer injection on solution gas drive naturally fractured carbonate reservoir will be done using a black-oil simulator. In the black oil simulator it can be observed changes in the parameters of the mobility ratio of water to oil. In this simulation will run water flooding case as comparison to polymer injection case.

The purpose of this study is to observe an increase in recovery factor with water flooding and polymer injection scenario on solution gas drive-NFR. The scenario that provides the greatest recovery factor can be considered in carrying out a strategy to increase oil recovery at EOR methods.

Keywords: *Polymer Injection, Naturally Fractured Reservoir, reservoir simulation*

INTRODUCTION

Reservoir with solution gas drive mechanism can have a good impact in water or chemical injection application. But, it is not with a large gas injection because it can overtake the fluid to be pushed. If the reservoir has a combination drive mechanism, it must be followed up, whether the link to the aquifer is very large or not. Chemical injection or water injection application will not have much effect. If the booster of gas injection has a large gas cap, it will not be able to significantly increase the oil recovery factor. This study has a purpose to increase the cumulative oil production by using polymer injection. NFR has special characteristic in production mechanism. It has dual porosity and dual permeability. It causes complexity in improving oil recovery. The purpose of this study is to observe an improved in oil recovery factor with water flooding and polymer injection scenario on solution gas drive-NFCR.

LITERATURE REVIEW

Naturally Fractured Reservoir

Naturally fractured reservoir has unique properties, namely having two flow media that occur in the production mechanism. The McNaughton & Garb method is a method commonly used to classify naturally fractured reservoirs. Reservoir classification using the McNaughton & Garb method is quite easy to determine based on core analysis and interpretation of well testing data.

Omega (ω) or commonly referred to as the storage capacity coefficient is the ratio of fluid stored in fractures to all fluid stored in the matrix, and lambda (λ) or commonly known as the inter-porosity coefficient is the ratio between permeability in the matrix and fracture permeability. Storage capacity coefficient and inter-porosity coefficient can be shown by the following equation:

$$\omega = \frac{\varphi_f C_f}{\varphi_f C_f + \varphi_m C_m} \qquad \text{..................(2-1)}$$

$$\lambda = a \, \frac{k_m}{k_f} \, r_w^2 \qquad \text{..................(2-2)}$$

The calculation results obtained based on **the equation (2-1)** can be concluded as follows:

When ω = 1: All storage in fracture (Type C)

When ω = 0.1: Storage in matrix equal to 9 x in fracture (Type A)

When ω = 0.01: Storage in matrix 90%; 10% in fracture (Type A)

When ω = 0.5: Storage in matrix = storage in fracture (Type B)

The calculation results obtained based on **equation (2-2)** will show the value of λ, the greater the value of λ means that the heterogeneity of the fracture-matrix system is getting smaller. Classification of type A, type B, and type C based on the McNaughton & Garb method describes the natural fracture reservoir as follows:

- Type A: Reservoir with high fluid storage capacity in the matrix and low in fractures.
- Type B: Reservoir in which matrix and fractured have nearly the same fluid storage capacity.
- Type C: Reservoir with high fluid storage capacity in fractured and low in the matrix.

Based on the Mc Naughton & Grab classification, reservoir type A will have a large matrix storage capacity, and the contribution of fracture porosity to total porosity is usually only about 10%. This type of reservoir often creates lost circulation problems during drilling operations. Also, this type of reservoir will have a small recovery factor, especially if the permeability of the matrix is tight. Reservoir with type B shows the fluid storage capacity in the matrix and fractures that are almost balanced. If this is supported by high matrix permeability, it will produce a reservoir with a high flow rate and recovery. Reservoir with type C will have almost all of its fluid stored in the fractures. This type of reservoir can provide a high flow rate at first, but in a short time, the flow rate can drop very drastically to a critical level or become uneconomical.

Polymer Injection

Polymer injection is an enhanced water injection. The addition of polymers to injection water is intended to improve the properties of water, hope that the oil recovery will be greater than before. Polymer injection can improve the oil recovery considerably compared to conventional water injection. However, the mechanism for drained the reservoir is complex and not fully known.

In porous media water tends to penetrate the oil, this will cause water to be produced quickly so that the pushing efficiency and oil recovery are low. Polymer injection can be applied in this reservoir. The polymer dissolved in injection water will thicken the water, reduce water mobility, and prevent water from penetrating the oil. Two things that need to be considered in polymer injection are reservoir heterogeneity and the ratio of reservoir fluid mobility.

RESEARCH METHODOLOGY

The methodologies in carrying out the simulation are as follows:

1. Modeling NFR by describing matrix and fracture porosity and permeability.
2. The pattern of injection well used in this study is inverted 5-spot with one injection well in the middle and four injection wells in each corner.
3. Perform polymer data processing of rocks
4. Make constraints on injection wells
5. Run scenario on water flooding and polymer injection
6. Make predictions with various scenarios and analyze them

FINDING AND DISCUSSION

Polymer Injection Modelling

This simulation used an inverted 5-spot pattern of injection well (Figure 2). This modelling is using dual porosity and dual permeability to represents NFR. The input parameters of the reservoir characteristics are presented in Table 1.

Table 1. Input Reservoir Parameters

Parameter	Matrix	Fracture
Cartesian Grid	23 x 23 x 10	23 x 23 x 10
Porosity, ϕ	0.2	0.1
Permeability, K (i, j, k)	(10, 10, 10)	(100, 100, 100)
Pressure, psi	3200 psi	3200 psi

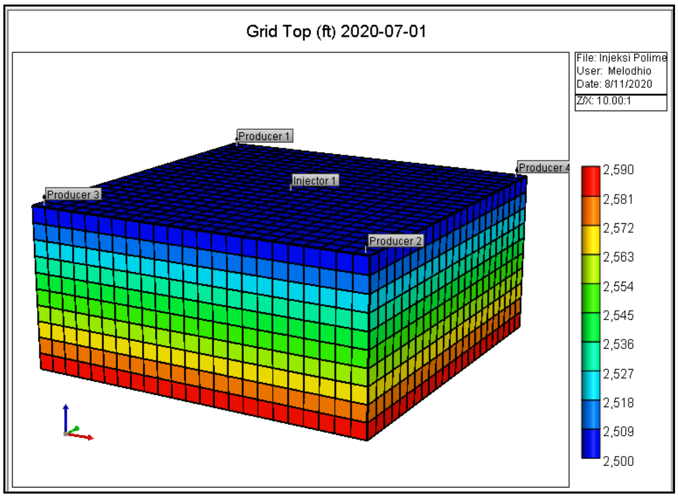

Figure 1. Reservoir Model

Input Pressure-Volume-Temperature (PVT) data is shown in Figure 2. The PVT data represents reservoir characteristics with dominant solution gas drive mechanism reservoir.

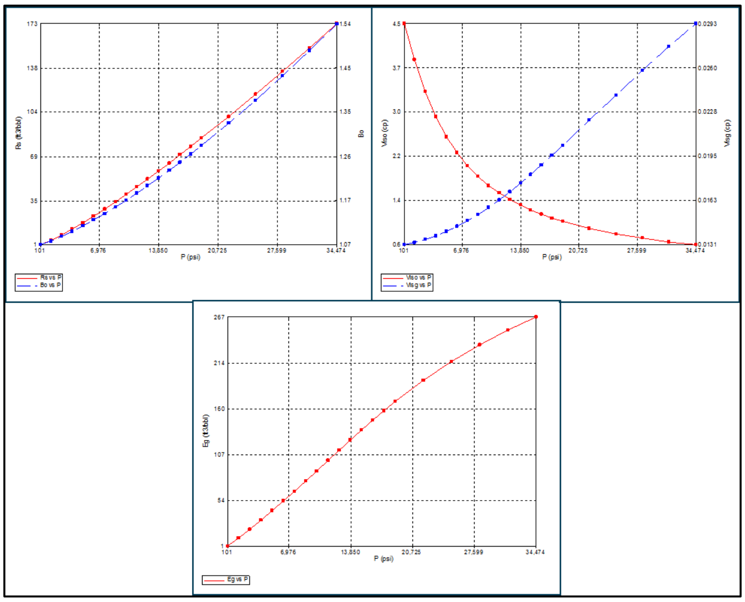

Figure 2. PVT data

Relative permeability is shown in Figure 3 that represents the NFR characteristic. The characteristic of NFR is oil wet, that shown in this figure the cross section of oil relative permeability and water relative permeability below 0.5.

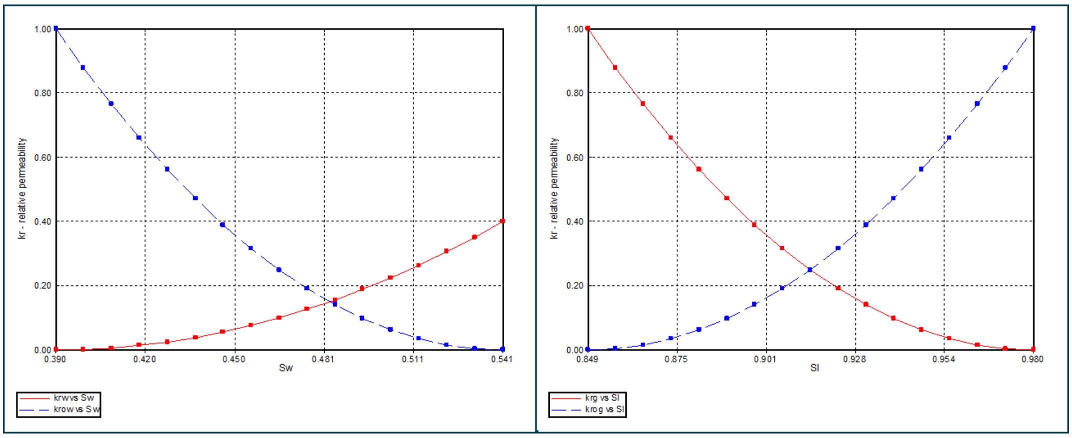

Figure 3. Relative Permeability

Properties input for polymer is shown in Table 2 below. The following table shows the change in polymer relative concentration with viscosity ratio.

Table 2. Polymer Data

Relative Concentration	Viscosity Ratio
0	1
0.1	3
0.2	5
0.3	7
0.4	9
0.5	11
0.6	13
0.7	15

The well constrains is using 100 BOPD in oil rate and 1250 BFPD in injection rate. The initialization process gets Original Oil in Place (OOIP) of this model 12.129 MMSTB. In the base case this model will run up to 30 years as a primary recovery. The production rate and cumulative production of oil, gas and water can be seen in figure 4.

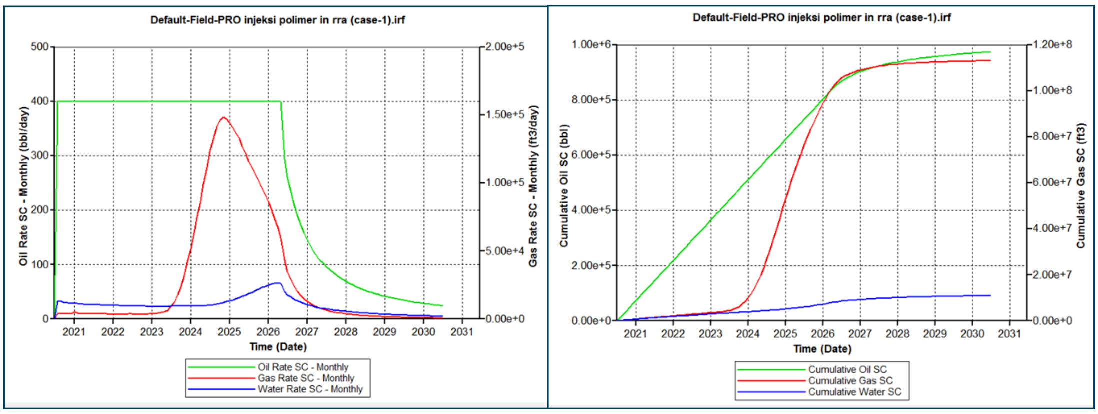

Figure 4. Production Rate and Cumulative Production

From the figure 4 the characteristic of solution gas drive-NFR shows by the high of gas production and the small of oil recovery amount 8%. The gas cumulative reaches the maximum production when reservoir pressure below bubble point pressure. The next step is to run water flooding and polymer injection to improving oil recovery.

Water Flooding Scenario

Water flooding scenario is run with continuous injection rate 1250 BWPD. This scenario is not much good because the characteristic of water itself. When water reached the fracture permeability that high it will flow ahead than oil. The mobility ratio oil to water is too high so that oil not in good flow. Water flooding aims to maintain reservoir pressure so not decrease rapidly. When the reservoir pressure is maintained it will cause stabilize in oil production and can be prevented the overproduction of gas. This scenario not enough optimum because the recovery still under the target. Figure 5 shows that cumulative oil production about 1.84 MMSTB or recovery factor 15.21%.

Polymer Injection Scenario

Polymer Injection scenario is run with continuous injection rate 1250 BFPD. Polymer injection aims to enhance the water injection. Screening criteria for the reservoir is needed before applied polymer injection. This scenario is better than water flooding because the characteristic of polymer compatible with this reservoir. When polymer reached the fracture permeability that high it will flow along with the oil. The mobility ratio oil is same as to polymer slug so that oil in good flow. This condition can reduce the mobility ratio, thereby increasing swept efficiency. When swept efficiency is improved the oil recovery will increase. Figure 6 shows that cumulative oil production about 2.28 MMSTB or recovery factor 18.81%.

The effect of water injection or polymer injection to solution gas drive is not significant. Table 3 shows that cumulative gas production from water flooding scenario not much different from polymer injection scenario.

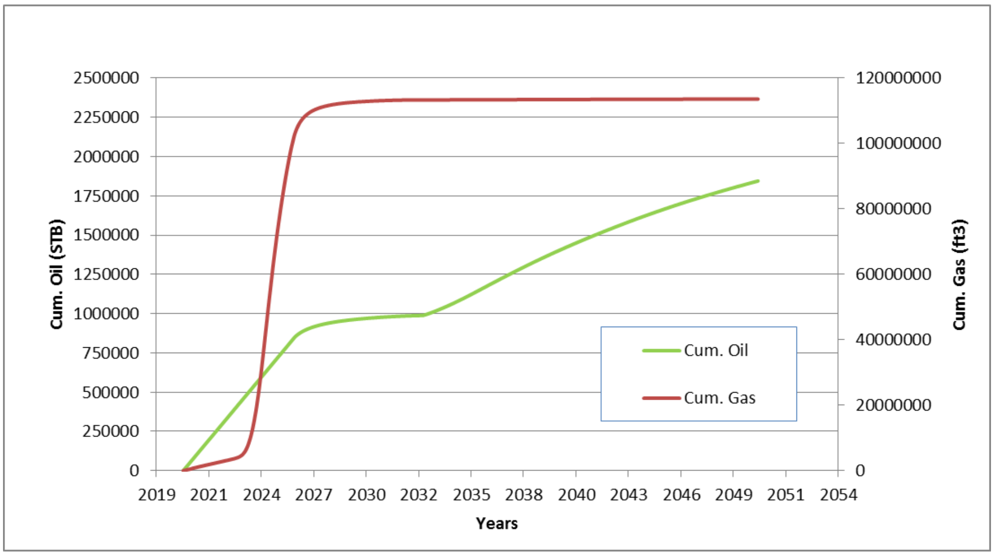

Figure 5. Water Flooding Scenario

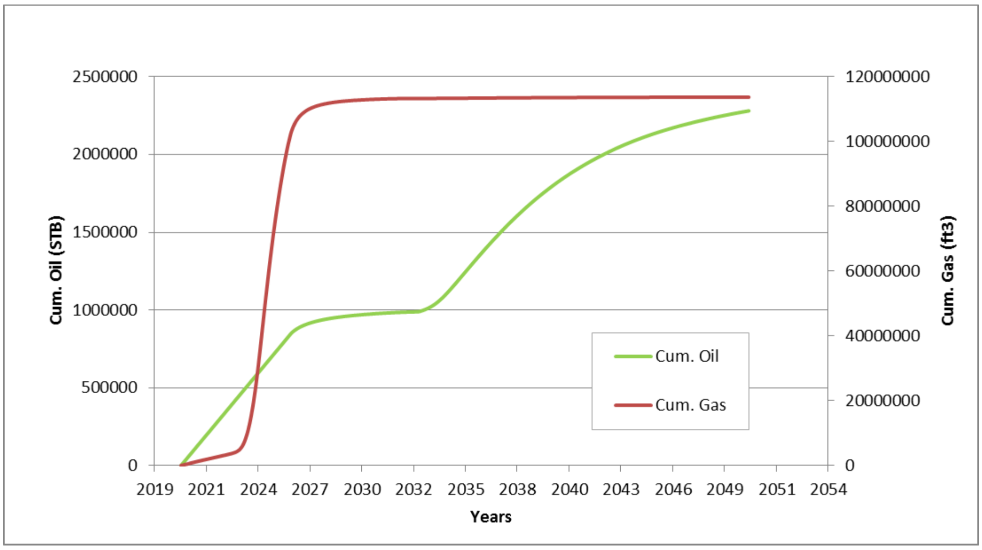

Figure 6. Polymer Injection Scenario

Table 3. Cumulative Production Results

Scenario	Rate Injection	Concentration	Oil Cumulative	Gas Cumulative
	bbl/d	lb/bbl	MMSTB	MMSCF
Water Flooding	1250	-	1.84	113.60
Polymer Injection	1250	0.15	2.28	113.74

CONCLUSION

Based on the simulation results, it is concluded as follows:

1. Recovery factor in solution gas drive-NFR is too low about 8%.
2. Water flooding or polymer injection is not to significant effect in solution gas drive-NFR.
3. Comparing water flooding and polymer injection is more effective polymer injection to give high oil recovery with adding in recovery factor up to 10%.

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