COMPOSITIONAL NUMERICAL EVALUATION OF MISCIBLE GAS INJECTION PERFORMANCE IN TIGHT OIL FORMATION

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INTRODUCTION

This study describes a compositional numerical simulation investigating the potential of applying miscible gas flooding in tight oil formation as an enhanced oil recovery method. Initially, a reservoir model built using Eclipse 300 software. Different sensitivity analyses have been conducted. Effect of well spacing between the producer and injector wells, primary depletion time, gas injection time, and formation permeability were the four main factors that have been studied to evaluate the feasibility of applying gas flooding in tight oil formation.

SIMULATION MODEL DESCRIPTION

In order to evaluate the Miscible Gas Flooding potential in tight formation, a compositional simulation model is used to mimic the process of miscible gas flooding in tight oil formation. A 2-D model has 50 x 50 x1 grid block specification. In x-direction, different length values were used to study the effect of distance between the producers well and injector well. The length of the model in y direction and depth z are kept constant at 500ft and 70ft, respectively. Local grid refinement option was used to model hydraulic fracture around the wells with, fracture width (w_f) of 1ft, permeability (k_f) of 100 md and fracture half length (L_f) of 250ft. The model used in this study represents homogenous reservoir formation. The study is conducted by using three models with a permeability values of 0.001md for Model_1and 0.01md for Model_2, 0.1 md for Model_3 as shown in Figure 1.

EVALUATING THE EFFECT OF WELL SPACING ON THE RECOVERY FACTOR

For each model, different spacing between the producer and injector wells, was studied as shown in Figure 2.

Primary Depletion Stage

For each model, the effect of primary depletion was studied. Two vertical wells have been used in each model; both of them were used as producers in the primary depletion stage. The reason was to lower the formation reservoir pressure which helps in gas injection stage. Each model needed different depletion time due to its formation permeability for example, Model_3, k = 0.1 md, needed less time than Model_1, k = 0.001 md. Furthermore, since the depletion area change with well spacing or distance between the producer and injector wells, more primary depletion time was needed if large distances between the wells are used. To overcome injectivity issues, such as formation pressure higher than injection pressure, one of the two producers was converted to gas injector well. All of the models were depleted before starting the injection stage as shown in Figure3.

EFFECT OF FORMATION PERMEABILITY, WELL SPACING, AND GAS INJECTION TIME ON GAS INJECTION STAGE

Model_1: Formation Permeability of 0.001 md at Different Well Spacing

This part investigate the impact of the well spacing (100ft, 150ft, 200ft, 250ft)on the recovery factor of the tight formation with permeability value of 0.001 md. After three years of production, the miscible Gas flooding process has been started by injecting gas for 12 years. The injection pressure was used in this study is 4000 psia. The performance of gas flooding at different spaces between the wells is investigated and the oil recovery factor was estimate at each well spacing used in the simulation study. As shown in **Figure 5**. As the distance between the wells increase, the recovery factor decrease until certain distance, where there will be slight difference in the recovery factor values at 200ft and 250 ft.

Model_1: Evaluating the Effect of Injection Time on Miscible Gas Flooding

Since the injection time is the crucial factor in displacing the fluid through the reservoir, it is necessary to study the gas flooding time impact on the oil recovery factor. Estimating the suitable injection time consider as the main goal of any economic analysis study, but here we will focus on the impact of the injection time on the recovery factor with different well spacing. In terms of Model_1, the relationship between injection time period (20 years) and the oil recovery factor is linear relationship. The recovery factor will increase significantly with long time of gas flooding process until gas breakthrough time takes place.

Model_2: Formation Permeability of 0.01 md at Different Well Spacing

In model_2 where the permeability is equal 0.01 md, the same scenario of depletion process and gas flooding have been conducted to estimate the recovery factor as function on well spacing. As a result, the optimum well spacing was observed at 100ft for 2, and 7 years of gas injection, whereas, at 12 years of injection the optimum well spacing was observed at 150ft, as shown in the **figure 7**. In a comparison between Model_1 and Model_2, Model_2 shows greater oil recovery factor at same well spacing comparing to Model_1. Hence, as the permeability of the formation increase as the oil recovery factor will be higher.

Model_2: Evaluating the Effect of Injection Time on Miscible Gas Flooding

The simulation study in model_2 shows that the relationship between the recovery factor and the injection time was different comparing to the model_1. It can be seen in **figure 8**, that the optimum oil recover factor will be achieved in shorter period of time (10 years at 100ft well spacing), whereas, the optimum oil recovery factor at model_1 has not been reached yet.

MODEL_3: FORMATION PERMEABILITY OF 0.1 MD AT DIFFERENT WELL SPACING

As a result of high permeability in model_3 (K= 0.1 md), the investigation conducted under larger well spacing (100ft, 150ft, 200ft, 250ft, 372ft, 456ft,526ft, 645ft, and 745ft) to obtain better understanding of well spacing influence. In model_3, the recovery factor was increased significantly as a result of permeability which helped in improving the sweep efficiency of the oil through the reservoir. The optimum well spacing was observed at higher values comparing to the previews models. For instance, the optimum well spacing at 12 year of injection is 460ft, whereas at model_2, the optimum well spacing is 150ft at same injection time. Thus, higher permeability would lead to wider well spacing.

MODEL_3: EVALUATING THE EFFECT OF INJECTION TIME ON MISCIBLE GAS FLOODING

Model_3 has showed similar behavior in terms of injection time effect. However, the injection time to achieve optimum oil recovery factor was reduced significantly as a result of high permeability in model_3 which shown in **figure 6**. Therefore, gas injection time is considerably effected by well spacing and formation permeability. High permeability value will lead to shorter duration of gas flooding process, and oppositely lower permeability will lead to long period of gas flooding process. Moreover, the less well spacing leads to short period of injection time to achieve the favorable oil recovery factor.

STUDY CONCLUSION

The simulation results indicate that gas flooding project after primary production can effectively increase the recovery factor of the reservoir even under low permeability formation. According to the simulation results, major conclusions are presented as follows:

- The optimum well spacing is crucial factor to achieve high recovery factor and designing the gas flooding project.
- The recovery factor during the gas flooding process is significantly depending on the well spacing and permeability of the formation. In other words, at high permeability formation long well spacing can be conduct, and high oil recovery factor predicted.
- The gas injection time and breakthrough time are function on the formation permeability and well spacing. As the formation permeability is increased, the time that required achieving optimum recovery factor will reduced and breakthrough time will occur in short time. On the other hand, long distance between wells will lead to long injection time to reach the optimum oil recovery factor and breakthrough time.

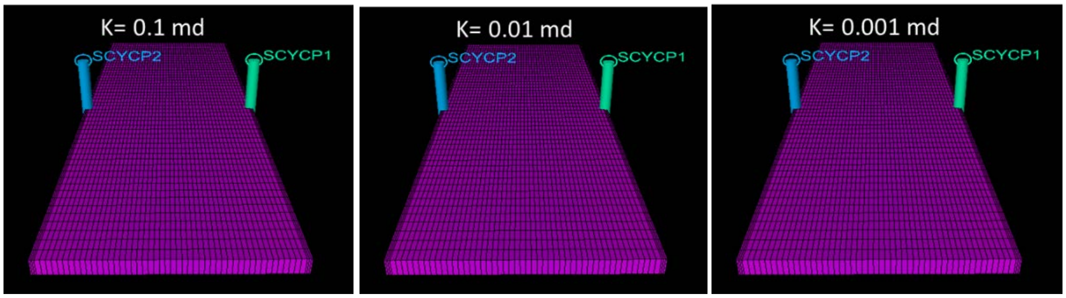

Figure 1. Three Models with Different Formation Permeability

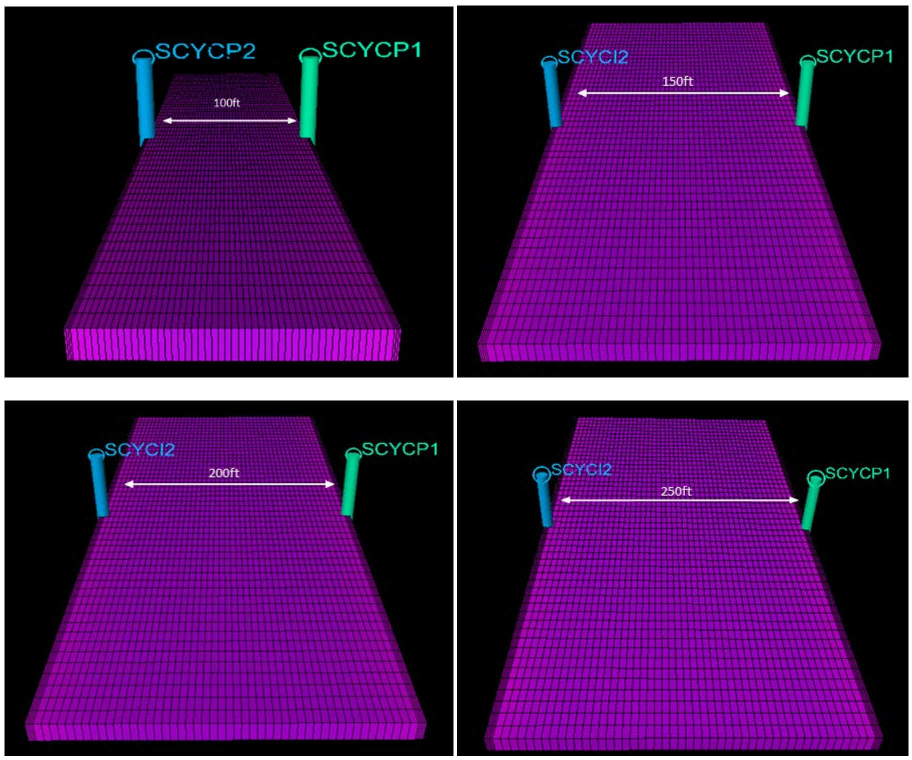

Figure 2. Reservoir Model for Different Well Spacing

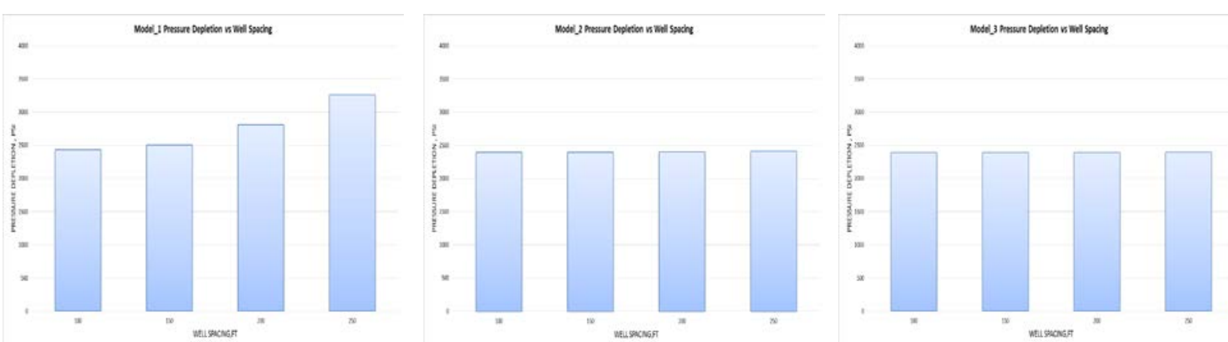

Figure 3. Pressure Depletion for Different Well Spacing

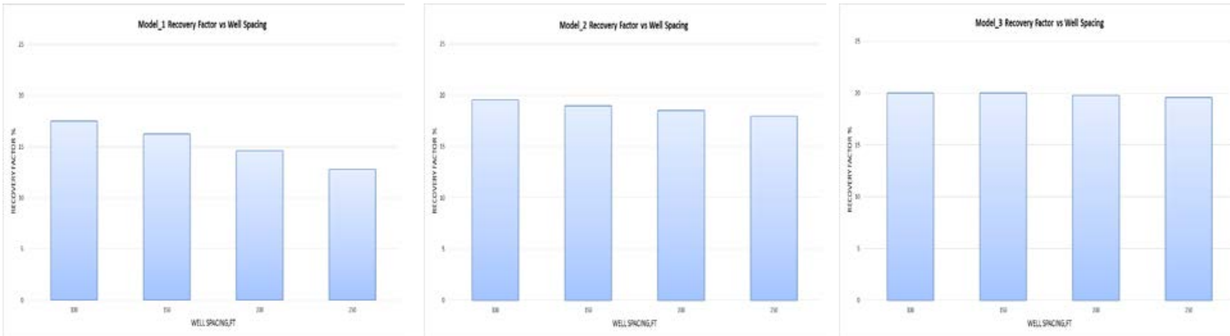

Figure 4. Recovery Factor for Different Well Spacing

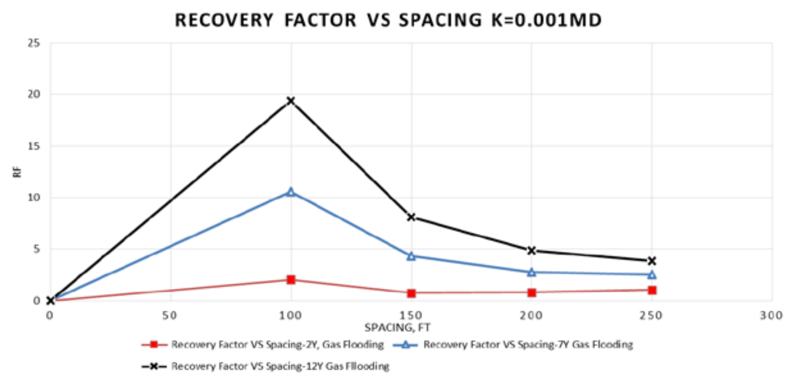

Figure 5. Recovery Factor vs. spacing at 0.001 md permeability

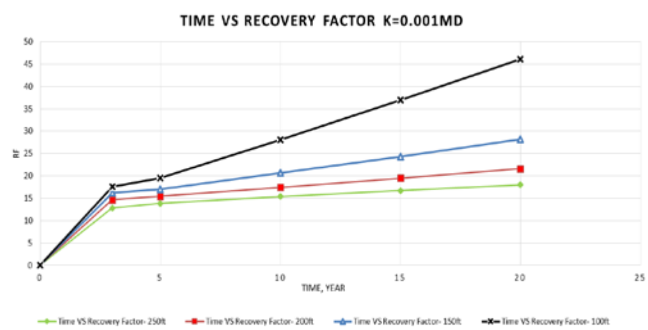

Figure 6. Time vs. Recovery Factor at K=0.001 md

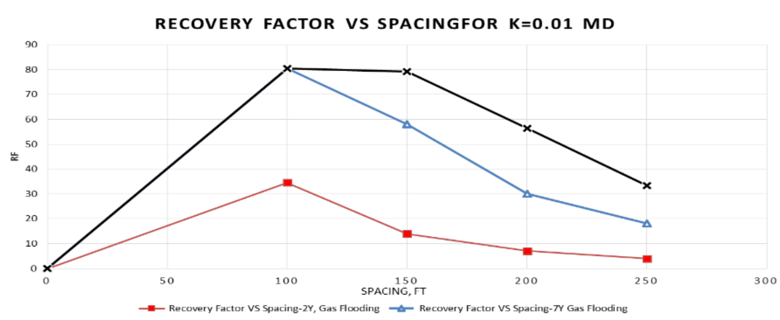

Figure 7. Recovery Factor vs. spacing at 0.01 md permeability

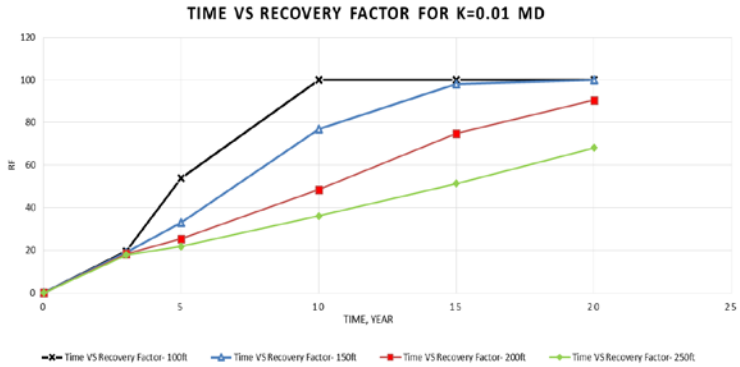

Figure 8.Recovery Factor vs. spacing at 0. 01 md permeability

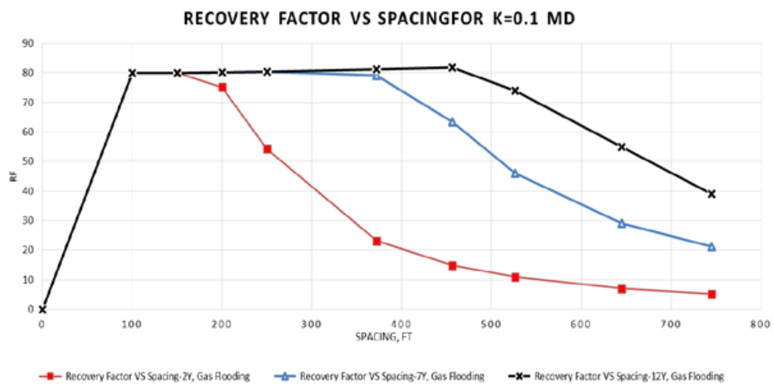

Figure 9.Recovery Factor vs. spacing at 0. 1 md permeability

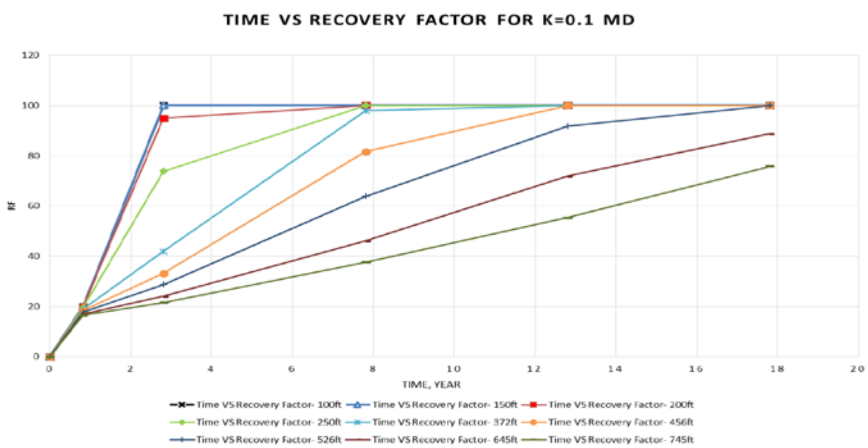

Figure 10.Recovery Factor vs. Well Spacing at 0.1 md Permeability

The basic reservoir properties data for all of the three models are shown in below, **Table 1**.

Table 1. Parameters for Simulation Model

Parameter	Value
Initial Reservoir Pressure	7300
Reservoir Temperature	240
Depth	10,000
Thickness	70
Bottom Hole Pressure	2400
Injection Pressure	4000
Injection Gas Composition	C1, C2.
API	42
Porosity	7 %

Table 2. Composition for Crude Oil Used in Simulation Model

C1	0.50
C3	0.03
C6	0.07
C10	0.20
C15	0.15
C20	0.05

Table 3. Composition of Gas used in the Injection Stage

C1	0.80
C2	0.20