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SIMULATION AND OPTIMIZATION OF STEAM FLOOD USING INJECTION INTERMITTENT

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Abstract
This research is about the simulation and optimization of a steam flood using intermittent injection with the purpose to simulate the steam flood method and design the scenario of steam flood intermittent to make steam flood more optimal in terms of gain lower steam oil ratio and higher oil recovery factor. The method used in this research is reservoir simulation with CMG-STARS software. The simulation results showed the difference in the value of steam oil ratio and the oil recovery factors between steam flood continuously (before optimization) with a steam flood after optimization with intermittent injection. The intermittent steam flood injection resulted in a lower steam oil ratio and a greater oil recovery factor than the continuous steam flood.

Introduction

The need for oil and gas will increase every day, while the level of oil and gas production will continue to decline. Due to the decrease in oil and gas production, this can lead to unmet energy needs of the people in society. Based on this situation, an effort is needed to increase the oil and gas production to meet the community's fuel energy needs. Actions can be made to find potential new oil and gas fields or evaluate the old field to increase production of the area.

Conventional technology in the field of drilling and exploitation of oil in the area is a simple technology. This technology is used by the petroleum industry and can only produce a maximum of 45% of the total petroleum reserves. Meanwhile, about 55% of petroleum left in rock pores cannot be a product made by conventional techniques, so it needs to be applied to the increase in refined petroleum oil or better known as Enhanced Oil Recovery (EOR). (Ko, Chon, Jang, & Jang, 2014)

Enhanced Oil Recovery (EOR) is a production technique applied to old oil and gas fields that have experienced significant production declines. EOR technology has been developed in old oil wells with large and profitable petroleum reserves when advanced oil drains (EOR) are carried out to overcome the decline in oil production. According to the Ministry of Energy and Mineral Resources (2016), about 13 thousand petroleum wells can be done with advanced draining or EOR. Draining the remnants of petroleum in the existing old oil wells is expected to increase national petroleum production and be more practical and economical than drilling new wells.

EOR technology is a method that in the process injects some materials such as gas, steam, or chemicals into underground reservoirs to encourage more oil. EOR technology is very strategically applied in Indonesia. And the EOR method that has long been used in Indonesia is the hot steam injection method.

In its operation, one of the disadvantages of the steam flood is the loss of heat from steam during distribution into the reservoir. It can happen due to the gravity override effect of injected hot steam. Hot steam tends to flow through the porous layer horizontally until eventually, the heat from the steam is trapped into impermeable rocks such as shale. This phenomenon makes the heat from the steam not enough to heat the oil as a whole so that as the steam moves away from the injection well, the heat will decrease, and the superheated steam phase turns into saturated steam and then becomes hot water.

There must be blocking or limiting between the permeable and impermeable layers to anticipate heat loss in the reservoir. The research was conducted by simulation method. The simulation was performed on a reservoir model representing a field with a heavy oil reservoir. Simulations are done with several scenarios. The determination of the scenario is based on the operation of steam injection, namely by distinguishing the interval of injection time or intermittent injection.

The simulation will be conducted on wells in this X-field using CMG-STARS reservoir software expected to be the best scenario for steam flood optimization.

Data and Method

- ***Reservoir Model***

The simulation is run using CMG-STARS simulator software. The reservoir model is designed multi-layered and has homogeneous fluid and rock data using heavy oil field data compiled from research journals as second or third parties. The reservoir model can be seen in Figure 1, which displays an image of the reservoir model with permeability properties. For initial condition data in the reservoir can be seen in Table 1. The area of draining is 5.5

acres, and the reservoir thickness is 80 ft. The distance between the producer and the injector is calculated so that it is obtained at 311 ft. And the highest peak of the reservoir or top of the reservoir is at a depth of 700 ft from the ground level.

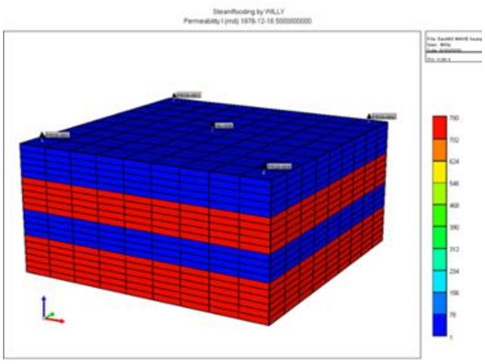

Figure 1. Reservoir model simulation: Permeability, model configuration, and wells location.

Table 1. Initial Reservoir Properties

INITIAL RESERVOIR PROPERTIES		
Properties	**Values**	**Units**
Oil Gravity	**13**	**API**
Top of Formation	**1700**	**ft**
Initial Pressure	**200**	**psi**
Initial Temperature	**140**	**oF**
In-Situ Oil Viscosity at 140 °F	**399**	**cp**
Thickness	**80**	**ft**

This reservoir model assumes no aquifer zone or gas zone either above the oil zone or below the oil zone. The gas phase is not present in the reservoir system because the reservoir pressure is above the bubble point pressure. The thickness of the layer or grid layer on this model is 4 ft and consists of 20 layers. Refer to the 20 layers contained in the reservoir model; there are 11 layers of sand and 9 layers of shale. It is divided into 2 types of zones, namely, pay zone or sand zones and shale zones. Different property values are made to distinguish the shale layer from sand, especially in the components of heat capacity, heat conductivity, porosity, and permeability. Each layer of sand has a uniform porosity of 30%. For sand layer permeability, it has a value that varies between 780-2220 mD, while shale layers have a uniform porosity and permeability value of each layer, which is 3% and 0.05 mD.

For pay zone itself is divided into 2, namely, pay zone 1 and pay zone 2. At the same time, the shale zone is also divided into shale zone 1 and shale zone 2. For more details, the comparison of sand and shale zone components can be seen in Table 2.

Table 2. Rock Properties and Components of Sand and Shale

ROCK & FLUID PROPERTIES		
Property	**SAND**	**SHALE**
Porosity, %	**30**	**5**
Permeability, mD	**780-2220**	**0.5**
Heat Capacity, Btu/(ft3*F)	**35**	**27**
Thermal Conductivity, Btu/(ft*day*F)	**35**	**14**
Oil Saturation	**70%**	**0%**
Layer	**6-10 and 15-20**	**1-5 and 11-14**

- **Grid Model**

The grid-type used in this reservoir modelling is the Cartesian type with a 5-spot inverted injection pattern shown in Figure 2.2. The dimensions of this model's grid are 9 x 9 x 20 consisting of a total of 1620 blocks. Each layer is 4 ft thick. The grid model used is symmetrical square with the reason:

- Compared to IMEX simulators, STARS requires a bigger CPU memory capacity and more storage time process. Thus, due to storage limitations and to save CPU processing time, smaller grid blocks are used.
- The simulation result of 1 square element will be applied to other square elements with the same rock and fluid properties. That way, the steam generator will still work.

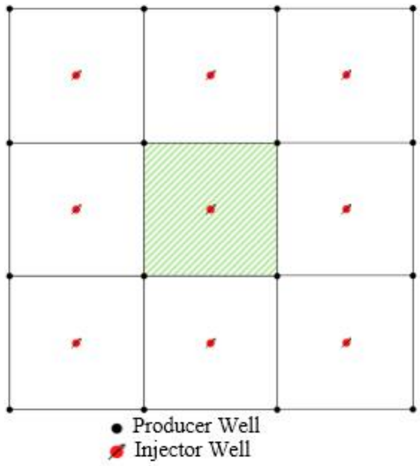

Figure 2. Inverted 5-spot Pattern Scheme

- **Operating Condition**

For the operating condition in this steam flood simulation, the steam temperature is made into 550 oF. It is the highest temperature that can be owned reservoir with reservoir composition in steam or hot water (Hochstein & Sudarman, 1993) and will be a fixed temperature for designed scenarios. At the same time, 70% of steam quality was used in this study. Then for the injected/perforated layer is the same as the bottom layer of the sand zone, namely layer 10 and layer 20.

All 4 production wells have the same pressure constraints and injection rate of 17 psi and MAX 1000 bbl/day. The pressure and injection rate are kept constant at 1500 psi and 300 bbl/day. The economic limit is assumed to be 10 bbl/day per 4 wells or 2.5 bbl/day for the economic limit per well.

Since one of the tasks is to make Steam Flood more optimal in gain lower steam oil ratio and higher oil recovery factor, oil Recovery Factor (Oil RF) and cumulative Steam Oil Ratio (Cum SOR) would be the factors for comparison. In term of getting the best optimization simulation, the various intermittent steam injection from 1 week to 4 weeks was evaluated for different scenarios as proposed in the following:

- Scenario 1 (Intermittent 1 Week). The intermittent scenario was done by injecting steam with periodic time intervals 1 week to reduce excessive use of steam while still producing good sweep effectiveness. Technically, the steam injector was set ON for 1 week, then set off for 1 week, and so on.
- Scenario 2 (Intermittent 2 Weeks).
- Scenario 3 (Intermittent 3 Weeks).
- Scenario 4 (Intermittent 4 Weeks).
- Scenario 5 (Intermittent 4 Weeks).

Result and Discussion

- Base Case

Table 3. Simulation Result of Base Case

BASE CASE SIMULATION RESULTS	
Oil Recovery Factor	69.72%
Cumulative Steam Oil Ratio, bbl/bbl	4.49
Production Age, years	15

As shown in Table 3 above, after the base case simulation was run for 15 years or 5474 days, the oil recovery factor result was quite good at 69.72%. Thus, although it has a high oil recovery factor, the total amount of steam used is still relatively high. It needs to inject the water of 1338.1 Mbbl to obtain the cumulative oil production of 297.25 Mbbl. Therefore, the cumulative steam oil ratio is 4.49 bbl water/bbl oil. So, to produce 1 barrel of oil, it is necessary to inject steam of 4.49 barrels. In this situation, it is required to optimize the steam flood to use a lower cumulative steam oil ratio but still get a high recovery factor.

- ***Optimization Scenario***

The optimization goal is to get a smaller steam oil ratio (SOR) than the base case. Several scenarios are performed to obtain a smaller steam oil ratio by maintaining the operation condition of steam injectors and producers. The scenario is done by injecting steam with intermittent time intervals to reduce excessive use of steam while still producing good sweep effectiveness.

This scenario is applied by assuming that the reservoir still stores enough heat if the steam injection is turned off for some time. What distinguishes one scenario from another is its intermittent time interval.

The interval time is divided into 1 week, 2 weeks, 3 weeks, and 4 weeks. To compare the oil production effectiveness of each scenario with the base case, the production rate limit set on the last day is 10 bbl/day, just like the base case.

This steam flood optimization scenario was applied on the 2800th day of simulation or 7.6th year after the simulation. It was applied at that time because, at that time, instantaneous SOR began to show a very high increase until the SOR ratio touched 30 bbl water/bbl oil.

- ***Comparison Results of Base Case with Optimization Scenario***

From the base case and all optimization scenarios simulation results, the economic limit is set at 10 bbl/day. Therefore, there will be a difference in production age between the base case and optimization scenarios. From the simulation of steam flood optimization, all of them produced a lower cumulative SOR than the base case, with the production length /life being 2.1 - 2.2 years longer than the base case. The comparison result is shown in the following Table 4.

Table 4 Comparison Results of Base Case with Optimization Scenario

Scenario	Oil RF (%)	Cumulative SOR	Production Age	Cumulative Steam Injected (MMbbl)
Base Case	69.72	4.49	15	1.33
1	71.32	3.62	17.8	1.09
2	71.11	3.57	17.8	1.08
3	70.9	3.57	17.5	1.08
4	70.92	3.56	17.6	1.07
5	**71.7**	**3.43**	**17.1**	**1.05**

From 5 optimization scenarios, scenario 5 produces the highest oil recovery factor and the lowest cumulative SOR. Scenario 5 is also the fastest scenario to reach the economic limit when compared to other optimization scenarios. This result means that scenario 5 is the most efficient and effective scenario to apply. The following figure is shown the comparison of heat loss to overburden scenario 5 with base case.

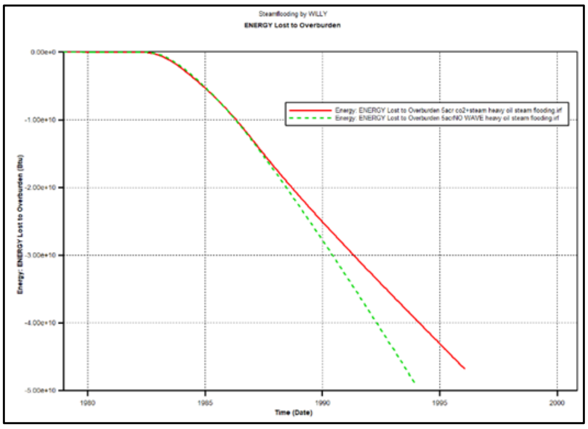

Figure 3 Comparison of Heat Loss to Overburden of Scenario 5 with the Base Case.

Conclusions

After simulating the scenario of steam flooding intermittent steam 1-4 weeks, then obtained several conclusions, including:

1. Intermittent steam flood model simulation is divided into 5 scenarios. That is an intermittent scenario of 1 week, 2 weeks, 3 weeks, 4 weeks.
2. Optimization scenario of intermittent steam flooding can produce a higher oil recovery factor than steam flooding continuously.
3. Scenario 5 with steam flood intermittent is the best optimization scenario. It can produce the lowest cumulative SOR of 3.43 bbl water/bbl oil and produce the highest oil recovery factor of 71.7%.

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