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Nano-Surfactant Huff and Puff Optimization in Marginal X Field Using Commercial Simulator

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Abstract

Economic optimization of an oil and gas project is an obligation that has to be done to increase overall profit, whether the field is still economically feasible or the field has surpassed its economic limit. In this case, a marginal field was chosen for the study. In this marginal field EOR methods have been used to boost the production rate. However, a full scale EOR method might not be profitable due to the amount of resources that is required to do it. Alternatively, Huff and Puff method is an EOR technique that is reasonable in the scope of single well.

The Huff and Puff method is an EOR method where a single well serves as both a producer and an injector. The technique of Huff and Puff: (1) The well is injected with designed injection fluid, (2) the well is shut to let the fluid to "soak" in the reservoir for some time, and (3) the well is opened and reservoir fluids are allowed to be produced. The injection fluid (in this case, nano-surfactant) is hypothesized to reduce interfacial tension between the oil and rock, thus improving the oil recovery.

In this study, the application of Huff and Puff method using Nanoparticles (NPs) as the injected fluid, as a method of improving oil recovery is presented in a case study of a field in South Sumatra. The study resulted that said method yields an optimum Incremental Oil Production (IOP) in which the economic aspect gain more profit, and therefore it is considered feasible to be applied in the field.

Introduction

The economic optimization of the petroleum industry is one of the many challenges that petroleum engineers face. Maximizing the economic aspect of a project involves a multitude of areas, from increasing the recovery factor to expenditure efficiency. One of the methods to improve the recovery is by using surfactant, while still considering the cost of using said surfactant.

However, a full scale EOR project has many challenges. The main reason the problems exist in a full scale EOR is mainly due to the quantities of surfactant required, capital involved to develop surface facilities, and also a longer timeframe to develop lab testing and optimization. Surfactant quantities increase dramatically moving from small field tests to full scale EOR projects (Barnes, et al. 2018) A smaller, more feasible method is used in this study, a method that does not require high quantities of surfactant: Huff and Puff. The method only affects around a well and is considered as smaller project compared to full scale EOR.

nanoparticles (NPs) utilization as surfactant has been examined for past decades. Among the examinations, particularly Silica NPs were extensively utilized (Ahmed, et al. 2018). In this study, the utilization of Silica NPs is also used to improve the oil recovery, thus improving the economic aspect at the end of the production period.

Huff and Puff technique involves a well to be a producer as well as an injector in the same well. The technique is a cyclic process where three different periods are used in every cycle: (1) injection of surfactant (Huff); (2) soaking time (where the well is shut and the surfactant is allowed to reduce the interfacial tension, hence improving the production later on); and (3) the well is re-opened, thus allowing the fluids to be produced to the surface (Puff) (Wang, et al. 2006). Using NPs as surfactant, when the well is shut during the soaking period, the NPs reduce the interfacial tension between the oil and rock. Soaking period also translates to the well being allowed to recover its pressure, giving additional energy for the well to be produced. In the production period, after the surfactant has given its effect, the oil production should increase.

The advantages of Huff and Puff method is that it only needs a single but also provides a reduction in surface facilities cost (if compared to other injection methods), making it more feasible to be applied to marginal fields.

Data and Method

The objective of this study is to find the optimum Huff and Puff method economically and technically. In order to find the optimum method, several sensitivity analyses were conducted: Injection schedule, injection rate, injection sequence, and economic analysis. Ultimately, the best method (the one that yields maximum profit) is chosen.

Problem limitations set in this study:

- 3 Wells of the reservoir is selected
- Surfactant concentration is 0.1 %wt,
- The Injection period (Huff) is one day,
- The Soaking period is two days,
- Total production period is limited to one year (365 days),
- Only one cycle of Huff and Puff conducted within the one year of production, and
- The economic analysis only covers the cost of nanoparticles and brine treatment.

A limitation worth noting is that the concentration of which the nano-silica is diluted in brine is always 0.1 wt%. This is because this concentration, along with 0.05 wt% still remains stable, whereas 0.3 wt% was proved to be relatively unstable (Ahmed, et al. 2018).

- **Schedule Sensitivity**

During the experimental period of the study, the first step is to determine the best time to do huff and puff in a specific well. The way this is done is by defining the constraints in each well manually. Two methods were used in determining the best schedule for maximum profit. The first one is to choose the best injection time that yields maximum well increment, while the second one is to choose the best injection time that generates maximum field increment. At first, the well is simulated without any kind of treatment. The data obtained from said simulation is then used as the control data, mainly oil production rate (per well), field oil production and cumulative oil produced. From this control data, each well's maximum flow rate is known, and when the decrease in oil production happens is also known. The data is then tabulated, and each well is experimented one by one (to decrease the amount of uncertainty in the sensitivity testing) using the same injection rate. The injection schedule is based on the decrease in each well's oil production rate. The sensitivity of every well varies in terms of percentage consistency, due to the search for optimum injection time. The testing is further done until the results show a decrease in cumulative oil increase.

The formula that is used to calculate Incremental Oil Production is:

$$IOP_{\%} = \frac{Np - Np_0}{Np_0} \; x \; 100 \qquad \text{...(1)}$$

- **Injection Rate Sensitivity**

After the optimum schedule is determined, it is then used for the rest of the study. In injection rate sensitivity, the rate of surfactant injection is varied: 50, 250, and 500 barrels per day.

- **Sequence Sensitivity**

Sequence sensitivity variations are NP, brine-NP, and NP-brine-NP. Note that when varying the sequence for every experimental testing, the injection period is still one day. This means, for example, in NP-brine-NP sequence, the first nano injection period is 8 hours, another 8 hours for the brine, and the last 8 hours for NP. The soaking period is maintained at two days.

- **Economic Analysis**

The economic analysis of this study only considers the cost of brine treatment and NP price. Injection rate sensitivity and sequence sensitivity could not be concluded as to which is the "best" because the economic aspect of the methods was not yet done. As mentioned before, the analysis only covers the price of the NP and brine treatment cost. Fortunately, because the results show the increase of money at the end of production, it is easy to further study the price of, for example, surface facilities cost and the cost of converting a well into a huff and puff well.

$$Final\ Cash = Oil\ revenue - Brine\ Cost - surfactant\ Cost \qquad (2)$$

The assumptions used in this economic analysis:

- Brine density is 1020.7 Kg/m^3,

- Nanoparticle density is 2650 Kg/m^3
- The price of the nanoparticle is 237.98 USD/Kg
- Oil price is 70.77 USD/barrel
- Brine treatment cost is 0.095 USD/barrel

Result and Discussion

The data required for this study is gathered from a field model that has been recalibrated by history matching. By 2017, the model has around 3 MMSTB of remaining oil in place, with 25 wells operating. 20 of them being producer wells and the other 5 being injectors. Porosity ranges from 0.05 – 0.22, and permeability ranges from 130 – 330 md.

After sensitivity for individual wells, two best schedules were found. First schedule maximizes increment per well (table 1-3), and the other that maximizes field increment (table 4). Scheduling method is then to be determine based on those sensitivities. The best scheduling method is: well A in June 28th, well B in November 18th, and Well C in February 2nd. This optimum scheduling method does not require an economic analysis, thus can be easily concluded which is the best option because the amount of injected surfactant is the same for every case.

As for the injected rate sensitivity, the more fluid injected, the greater the oil production at the end of production time. This due to more surfactant injected means that more pore volume is affected by the surfactant allowing the interfacial tension of the rock reduce. Judging only by the incremental oil production, the injection rate that maximizes oil production is 500 barrels/day. In the injection sequence sensitivity, the results show that the incremental oil production is maximum when using the NP-brine-NP sequence. However, the injection rate and sequence sensitivity are yet to be concluded because there is a change in the amount of fluid injected, and that contributes to a difference in cost.

The economic analysis is straightforward, and doing this analysis will make the conclusion of which method maximizes profit. The results show that brine-NP injection sequence with 50 bbl/day injection rate is most profitable.

However, there is an anomaly in well B. The well experienced a decrease in oil production when treated with Huff and Puff. Interference effect may be a suspect towards this phenomenon. Rightfully so, when the Huff and Puff method is only applied in well A and C, with well B being opened all year without treatment, the cumulative oil production increased significantly.

Conclusions

The conclusions for this study:

- Optimum recovery is achieved if well B is not treated.
- The optimum schedule for each well is June 28th for well A, and February 2nd for well C.
- The optimum Injection rate for the Huff and Puff method is 50 barrels/day.
- The Optimum Sequence which generates maximum profit is brine-NP sequence.
- The maximum profit generated for 1 cycle, 1-year Huff and Puff is 5923 USD.

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List of Figures

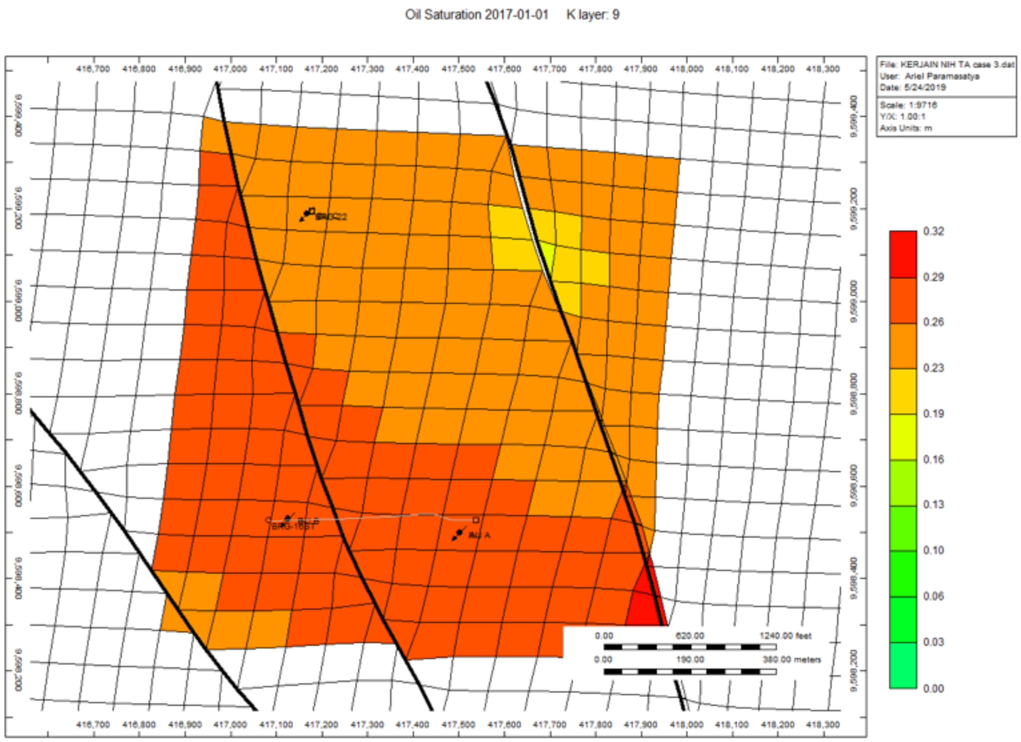

Figure 1. Model Reservoir of X Field

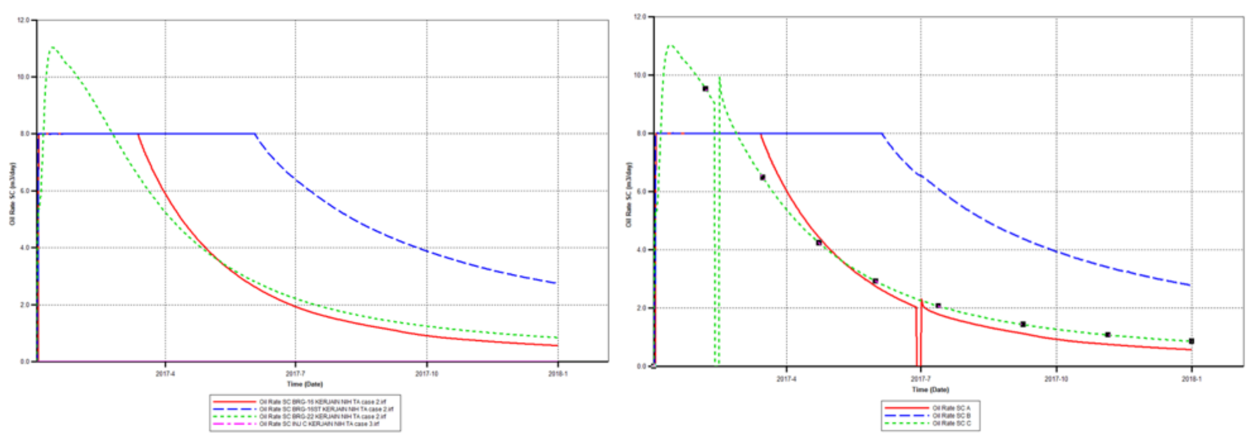

Figure 2. Well Production Profile (Before and after Huff and Puff Treatment

Table 1. Schedule Sensitivity for Well A

Inj Rate, bbl/d	Date	Case	Field oil cum, bbl	Well Oil Cum, bbl	Field increase, bbl	Field increase, %	Well Increase, bbl	Well Increase, %
0	-	Base	29311.32	7493.14	-	-	-	-
500	10/21/2017	10%	29307.30	7479.87	-4.03	-0.01	-13.27	-0.18
500	8/27/2017	15%	29315.22	7521.19	3.90	0.01	28.05	0.37
500	7/22/2017	20%	29322.83	7473.52	11.51	0.04	-19.62	-0.26
500	6/28/2017	25%	29333.02	7470.25	21.70	0.07	-22.90	-0.31
500	4/30/2017	50%	29331.57	7444.09	20.25	0.07	-49.06	-0.65
500	4/1/2017	75%	29315.47	7419.69	4.15	0.01	-73.47	-0.98

Table 2. Schedule Sensitivity for Well B

Inj Rate, bbl/d	Date	Case	Field oil cum, bbl	Well Oil Cum, bbl	Field increase, bbl	Field increase, %	Well Increase, bbl	Well Increase, %
0	-	Base	29311.32	13657.61	-	-	-	-
500	12/26/2017	35%	29269.06	13615.35	-42.27	-0.14	-42.27	-0.31
500	11/18/2017	40%	29291.19	13636.48	-20.13	-0.07	-21.13	-0.15
500	9/26/2017	50%	29285.16	13627.99	-26.17	-0.09	-29.63	-0.22
500	7/12/2017	75%	29249.31	13585.97	-62.02	-0.21	-71.64	-0.52
500	6/16/2017	90%	29237.86	13568.55	-73.47	-0.25	-89.07	-0.65

Table 3. Schedule Sensitivity for Well C

Inj Rate, bbl/d	Date	Case	Field oil cum, bbl	Well Oil Cum, bbl	Field increase, bbl	Field increase, %	Well Increase, bbl	Well Increase, %
0	-	Base	29311.32	8160.50	-	-	-	-
500	8/12/2017	15%	29327.80	8150.44	16.48	0.06	-10.06	-0.12
500	7/2/2017	20%	29340.69	8144.34	29.37	0.10	-16.17	-0.20
500	6/5/2017	25%	29351.82	8137.48	40.51	0.14	-23.02	-0.28
500	3/29/2017	50%	29378.62	8114.78	67.30	0.23	-45.73	-0.56
500	2/21/2017	75%	29405.47	8105.72	94.16	0.32	-54.79	-0.67
500	2/11/2017	85%	29423.14	8113.02	111.84	0.38	-47.49	-0.58
500	2/1/2017	90%	29416.16	8104.78	104.85	0.36	-55.73	-0.68

Table 4. Field Schedule Optimization

Inj Rate, bbl/d	Well	Date	Case	Field increase, bbl	Field increase, %
500	A	8/27/2017	Best Well Increment Date	-0.629	-0.0021
	B	11/18/2017			
	C	8/12/2017			
500	A	6/28/2017	Best Field Increment Date	112.9684	0.3854
	B	11/18/2017			
	C	2/11/2017			

Table 5. Economic Analysis

Inj Rate, bbl/d	Sequence	Total NP injected, bbl	Total Injected Brine, bbl	Field oil cum, bbl	Field increase, bbl	NP Cost, USD	Brine Cost, USD	Cash at final, USD	Cash Increment, USD
0	-	0.00	0.00	29311.32	-	-	-	2074362.17	-
50	NP	150.00	0.00	29397.92	86.60	5796.88	0.00	2074694.24	332.07
50	Brine-NP	75.00	75.00	29396.67	85.35	2898.44	7.13	2077496.54	3134.37
50	NP-Brine-NP	100.00	50.00	29396.67	85.35	3864.58	4.75	2076532.77	2170.60
250	NP	750.00	0.00	29408.68	97.36	28984.38	0.00	2052267.85	-22094.32
250	Brine-NP	375.00	375.00	29404.28	92.96	14492.19	35.63	2066412.85	-7949.32
250	NP-Brine-NP	500.00	250.00	29408.11	96.79	19322.92	23.75	2061865.50	-12496.67
500	NP	1500.00	0.00	29424.28	112.96	57968.77	0.00	2024387.30	-49974.87
500	Brine-NP	750.00	750.00	29426.29	114.97	28984.38	71.25	2053442.86	-20919.31
500	NP-Brine-NP	1000.00	500.00	29426.35	115.03	38645.84	47.50	2043809.60	-30552.57

Table 6. Optimized Huff and Puff Method

Inj Rate, bbl/d	Sequence	Total NP injected, bbl	Total Injected Brine, bbl	Field oil cum, bbl	Field increase, bbl	NP Cost, USD	Brine Cost, USD	Cash at final, USD	Cash Increment, USD
50	Brine-NP	75.00	50.00	29436.04	124.72	2898.44	4.75	2080285.20	5923.03