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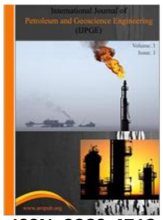

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Economical Evaluation of Injection Frequency in Surfactant and Water Flooding Using Genetic Algorithm

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Abstract

Keywords:

Surfactant,
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Reservoir,
Injection,
Simulation.

Waterflood operation is the most widely used secondary recovery method. Large reservoirs containing thousands of wells are operated under waterflood conditions to increase the ultimate recovery. Due to lack of resources and appropriate tools, waterflood optimization is often done on trial and error bases.. waterflooding is an effective process, surfactant flooding is used to recover oil from reservoirs by wettability alteration and interfacial tension reduction. Surfactants have been identified which can lower the IFT between oil and aqueous phase. The reduction of IFT leads to mobilization of the oil by buoyancy forces. In all the enhanced oil recovery processes, flow of displacing and displaced fluid in a petroleum reservoir is affected by the wettability of the reservoir rock.
Economical effectiveness is a main challenge in feasibility of any EOR method. In this study, we investigate the economical efficiency of both surfactant and water flooding by algorithm genetic optimization. One of the important optimization variables is well placement. Determining of the location of new wells is a complicated problem which depends on reservoir and fluid properties. Various methods have been suggested for this problem. Among these, direct optimization, although accurate, is impossible due to the number of simulation required.
Optimal placement of up to three surfactant injection wells was studied at two fields. One of the Iranian conventional field and a hypothetic fractured field. Injection rate and injection time was also optimized. The net present value of the surfactant and water flooding projects was used as the objective function. Profits and costs during the time period of the project were taken into consideration.

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1. Introduction

Enhanced oil recovery (EOR) is oil recovery by injecting materials that are not present in a petroleum reservoir. One of the important methods in EOR is chemical flooding such as surfactant flooding. Injection of surfactant increases the oil recovery [1]. Chemical flooding in the petroleum industry has a larger scale of oil recovery efficiency than water flooding. On the other hand, it is far more technical, costly and risky.

The well location is one of the most important aspects in production definition. Reservoir performance is highly dependent on well locations [2]. The use of an optimization algorithm to find a good position for the wells can be very useful to the process but it can also lead to an exhaustive search, demanding a great number of simulations to test many possibilities, most of the them disposable [3].

The optimization algorithm used in this work is the genetic algorithm. The main characteristic of GA is the ability to work in a solution space with non-smooth and non-linear topology where the traditional methods generally fail. A reservoir simulator has been used in the present study. Genetic algorithm depends on the principle of artificial intelligence similar to Darwin's theory of natural selection. The genetic algorithm is coupled with the simulator in order to re-evaluate the optimized wells at each iteration.

2. Simulation Study

The objective of this study is time of injection result and economical evaluation water and surfactant flooding at two reservoirs. The genetic algorithm is the selected optimization method for this study. We coupled reservoir simulation software with genetic algorithm for optimization. While the cost of the drilling is so high and drilling process is time-consuming, in this study, the strategy was to use the available wells without drilling any new well for injection to eliminate the cost of drilling new wells. Therefore, it was assumed that up to three production wells of each reservoir can be changed to injection wells. Therefore by an appropriate optimization process, we are able to choose the best wells that are candidates for the surfactant flooding and water flooding. Also the injection rate of wells and the injection time should be optimized in order to maximize the production income. The schematic of the conventional and fractured reservoir is presented in Fig. 1 and Fig. 2 respectively.

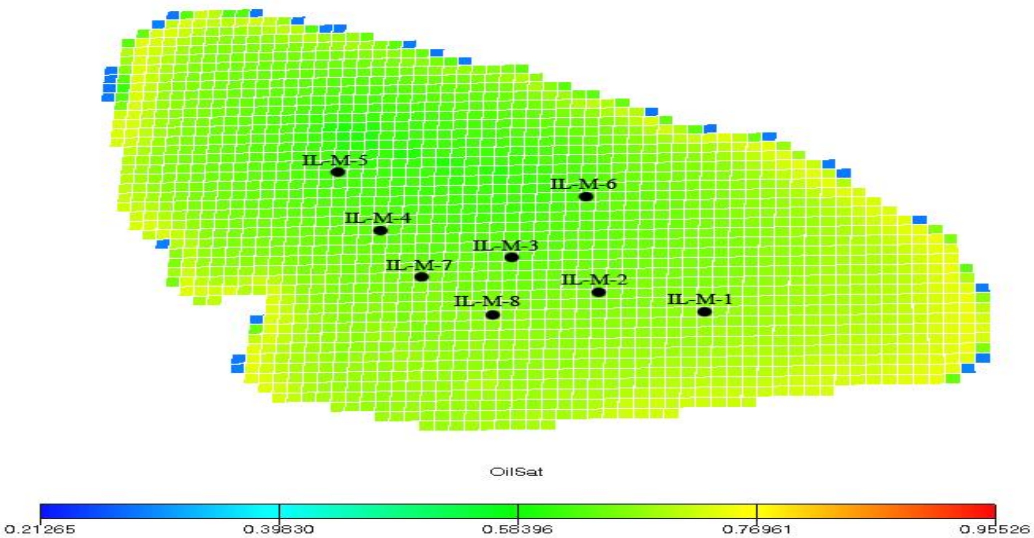

Fig. 1: The schematic of the conventional oil reservoir.

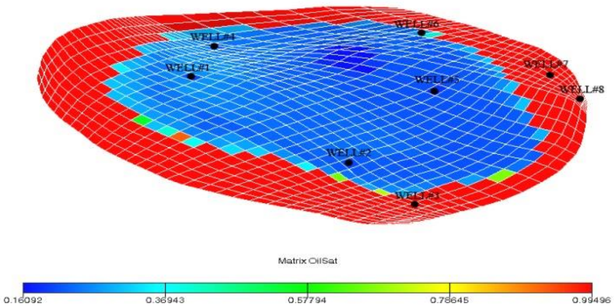

Fig. 2: The schematic of the fractured oil reservoir.

As it can be seen in the figures, there are eight production wells at each of them. The Iranian conventional oil reservoir is located at ILAM formation. The name of the wells is based on the formation name. The fractured reservoir is a hypothetic one.

The parameters that are selected as optimization variables are given in table 1.

Table 1: The range and number of bits of optimization variables in genetic chromosome.

Parameters	Ranges
Well number	1-8
Injection rate	100-400
Injection time	1000-3000

3. The Fitness Function

In any optimization problem, there is an objective function which should be maximized or minimized. Genetic algorithm requires a fitness function ($F(x)$) to be defined and tries to Maximized this function. A fitness function is a particularly objective function that quantifies the optimality of a solution (chromosome) in a genetic algorithm so that the particular chromosome maybe ranked against all other chromosomes[5]. The net present value is defined as the fitness function. The net present value is defined as the revenue from produced oil, after subtracting the cost of disposing produced water and the cost of injection water. During the optimization, objective function is defined as the Maximizing of Net Present Value[6].

$$Net\ cash\ flow(t) = Revenue\ (t) - \ Opex(t)$$

$$Revenue\ (t) = Oil\ production\ (t) \times Oil\ price\ (t)$$

$$OPEX(t) = (Water\ production\ (t) \times Water\ handling\ cost$$

$$+Water\ injection\ (t) \times WAter\ injection\ cost$$

$+ surf\ production(t) \times surf\ handling\ cost)$

$CAPEX = Water\ injection\ installment\ cost + surfactant\ price$

$NPV = Net\ cash\ flow - CAPEX$

For this study, NPV parameters were assigned as listed in table 2 [7].

Table 2: Economic parameters used to calculate the NPV.

Economic parameters	Value
Oil price, $/bbl	126
Water production cost, $/bbl	32
Water injection cost, $/bbl	6
Surfactant price, $/lb	1.5
Operating cost of surfactant, $/bbl	0.25
Water injection installment cost, $	10000000

4. Optimization Results

In order to use genetic algorithm for optimization, setting up a number of parameters is required. The GA input parameters presented in table 3.

Table 3: GA input parameters.

Input parameters	value
Population size per generation	50
Maximum number of generations	100
Crossover rate	0.8
Mutation probability	0.1
Crossover type	Single point

The optimization of the six cases lasted approximately 1 day for each of them in a conventional PC to find the best values for surfactant flooding and water flooding process. The best values for conventional reservoir presented at Table 4 to Table 9. The NPV maximization versus generation plots are also shown at fig 3 to fig 5.

Table 4: Optimal parameters for 1 injection well for the conventional reservoir by surfactant flooding.

Optimization variable	Best value
Well number	2
Injection time	3000days
Injection rate	400bbl/day
Best NPV	1.7819*1010$

Table 5: Optimal parameters for 1 injection well for the conventional reservoir by water flooding.

Optimization variable	Best value
Well number	2
Injection time	3000days
Injection rate	400bbl/day
Best NPV	1.7528*1010$

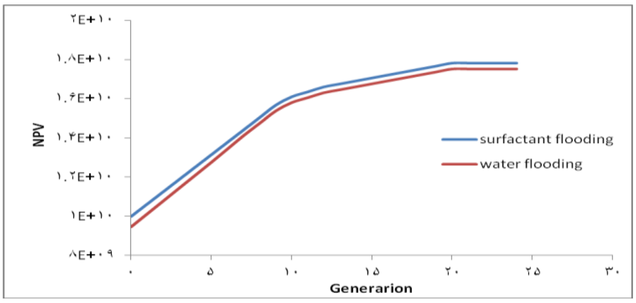

Fig. 3: The NPV vs. generation plot for 1 injection well for the conventional reservoir.

Table 6: Optimal parameters for 2 injection wells for the conventional reservoir by surfactant flooding.

Optimization variable	Best value
Well number	2
Well number	4
Injection time	3000days
Injection rate	400bbl/day
Best NPV	1.7221*1010$

Table 7: Optimal parameters for 2 injection wells for the conventional reservoir by water flooding.

Optimization variable	Best value
Well number	2
Well number	4
Injection time	3000days
Injection rate	400bbl/day
Best NPV	1.6928*1010$

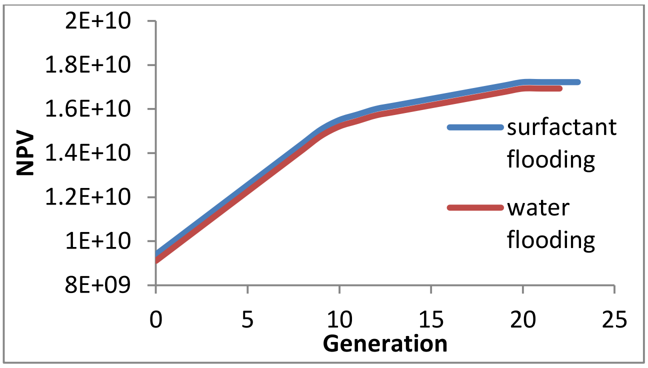

Fig. 4: The NPV vs. generation plot for 2 injection wells for the conventional reservoir.

Table 8: Optimal parameters for 3 injection wells for the conventional reservoir by surfactant flooding.

Optimization variable	Best value
Well number	2
Well number	3
Well number	4
Injection time	3000days
Injection rate	400bbl/day
Best NPV	1.6066*1010$

Table 9: Optimal parameters for 3 injection wells for the conventional reservoir by water flooding.

Optimization variable	Best value
Well number	2
Well number	3
Well number	4
Injection time	3000days
Injection rate	400bbl/day
Best NPV	1.5792*1010$

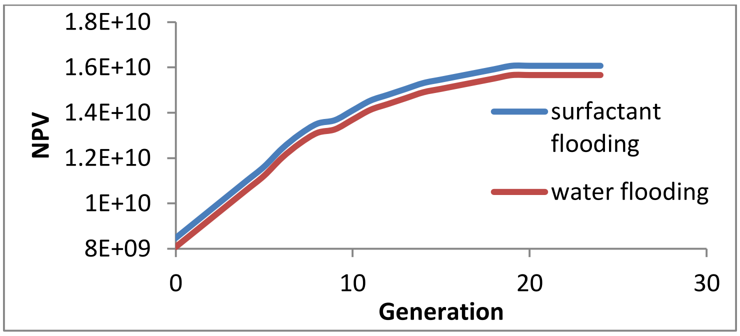

Fig. 5: The NPV vs. generation plot for 3 injection wells for the conventional reservoir.

In each case, the total time of simulation is 10000 days and it can be seen that surfactant flooding is an efficient method respect to the water flooding for all cases. At all of the cases, by increasing the injection time and injection rate, the NPV increases. So we can say that the more injection time the more economic efficiency. One another point is that the best wells are the middle ones. By looking at the reservoir schematic, we will understand that the best candidate wells for surfactant injection and water flooding processes are the wells located at the middle of the reservoir since in this case we can recover more oil and most part of the reservoir is drained.

The best values for fractured reservoir obtained by optimization are presented in Table 10 to Table 15. The NPV versus generation plots of these cases are also shown in Fig 6 to Fig 8.

Table 10: Optimal parameters for 1 injection well for the fractured reservoir by surfactant flooding.

Optimization variable	Best value
Well number	2
Injection time	3000days
Injection rate	400bbl/day
Best NPV	1.3966*109$

Table 11: Optimal parameters for 1 injection well for the fractured reservoir by water flooding.

Optimization variable	Best value
Well number	2
Injection time	3000days
Injection rate	400bbl/day
Best NPV	1.3928*109$

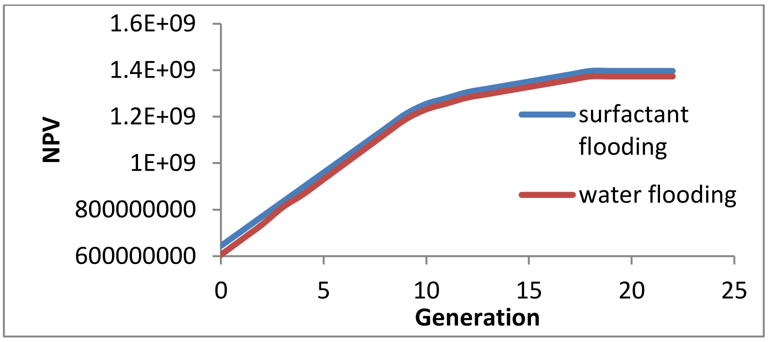

Fig. 6: The NPV vs. generation plot for 1 injection well for the fractured reservoir.

Table 12: Optimal parameters for 2 injection wells for the fractured reservoir by surfactant flooding.

Optimization variable	Best value
Well number	1
Well number	2
Injection time	3000days
Injection rate	400bbl/day
Best NPV	1.4617*109$

Table 13: Optimal parameters for 2 injection wells for the fractured reservoir by water flooding.

Optimization variable	Best value
Well number	1
Well number	2
Injection time	3000days
Injection rate	400bbl/day
Best NPV	1.4543*109$

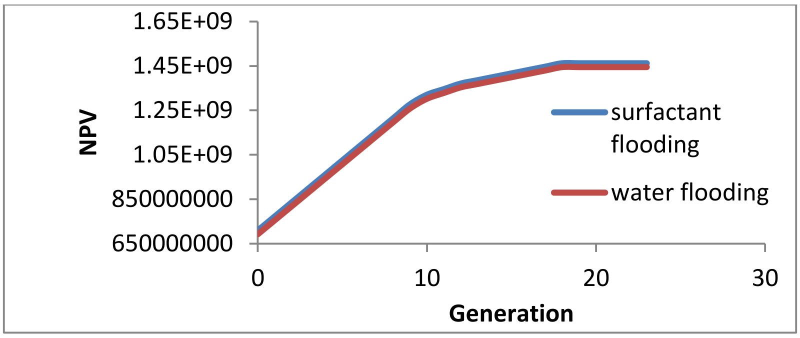

Fig. 7: The NPV vs. generation plot for 2 injection wells for the fractured reservoir.

Table 14: Optimal parameters for 3 injection wells for the fractured reservoir by surfactant flooding.

Optimization variable	Best value
Well number	1
Well number	2
Well number	4
Injection time	3000days
Injection rate	400bbl/day
Best NPV	1.5608*109$

Table 15: Optimal parameters for 3 injection wells for the fractured reservoir by water flooding.

Optimization variable	Best value
Well number	1
Well number	2
Well number	4
Injection time	3000days
Injection rate	400bbl/day
Best NPV	1.5516*109$

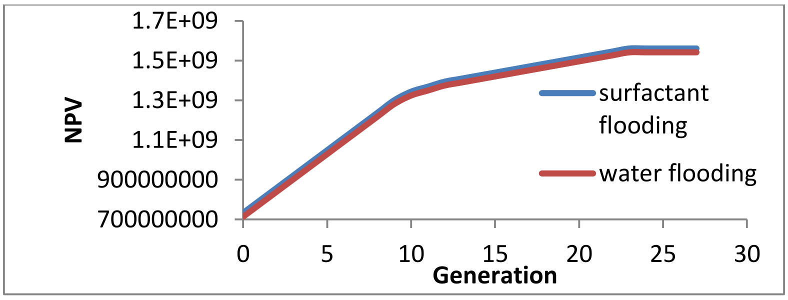

Fig. 8: The NPV vs. generation plot for 3 injection wells for the fractured reservoir.

In each case, the total time of simulation is1000 days and it can be seen that surfactant flooding is an efficient method respect to the water flooding for all cases. At all of the cases, by increasing the injection time and injection rate, the NPV increases. So we can say that the more injection time the more economic efficiency. In this case, the best candidate wells are located at the side of the Reservoir because when we choose the middle wells for injection, because of the fractures, the water cut increases and also the NPV decreases. So it can be concluded that for the surfactant flooding and water flooding projects, the location of injection wells are dependent to the reservoir characteristic and we should consider numerous variables.

5. Conclusion

In this study, we knew that the surfactant flooding process is an efficient one and is dependent to numerous variables. The variables that are under our control are location of the injection wells, injection rate and injection time. Also it was shown that the surfactant flooding is dependent to the type of reservoir and reservoir characteristics. From the optimization results it can be concluded that for the conventional reservoirs, the best wells are located at the middle of the reservoir and increasing the injection rate and injection time also increase the net present value. For the fractured reservoirs, the best wells are located at the side of the reservoir and increasing the injection rate and injection time also increase the net present value. So before the chemical flooding like surfactant flooding, we must be familiar to type and characteristic of the reservoir.

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