Journal Of Oil, Gas and Petrochemical Technology 6(1): 39-50, Summer 2019

RESEARCH PAPER

On the Reduction of Optimization Time in Simulation of Oil Reservoirs

Kaveh Mohammadi, Forough Ameli*

School of Chemical Engineering, petroleum and gas, Iran University of Science and Technology, 16846 Tehran, Iran

ARTICLE INFO

Article History:
Received 16 April 2019
Revised 30 May 2019
Accepted 14 June 2019

Keywords:
Discretization
Optimization
Reservoir Simulation
Fast-SAGD

ABSTRACT

Thermal recovery techniques including Fast-SAGD process increases the production efficiency of heavy oil reservoirs. Effective parameters in this study included injection and production rates, height of the injection, production, and offset wells, production and injection cycles, and pressure of the offset wells. In this study, optimization studies were performed. The objective function was defined as the cumulative steam injection to the produced oil to recovery factor. As optimization studies is a time- consuming process, discretized form of effective parameters were applied in this study. Three methods of discretization were selected including linear, square, and logarithmic techniques and their results were compared. In this approach, discretization was based on the results of sensitivity analysis without the exact recognition of the reservoir parameters. Applying this technique, the optimization speed increased three times while the accuracy of the results remained constant. The difference between the optimization results in the continuous and discrete states was less than 3%. Moreover, simulation results of the fast-SAGD process with two cycles were presented in terms of RF, CSOR, temperature and pressure distributions, and the produced oil from SAGD and injected steam to the offset well.

How to cite this article
Mohammadi K, Ameli F. On the Reduction of Optimization Time in Simulation of Oil Reservoirs. Journal of Oil, Gas and Petrochemical Technology, 2019; 6(1): 39-50. DOI: 10.22034/JOGPT

1. INTRODUCTION

Three main classes for EOR techniques include thermal techniques [1, 2], chemical processes [3, 4], and injection methods [5]. For the heavy oil samples, thermal methods are more applicable. The basis for all these thermal techniques is the injection of hot fluids which leads to the viscosity reduction. A number of more practical techniques for the thermal recovery include Cyclic Steam Stimulation (CSS), Steam Assisted Gravity Drainage (SAGD), in-Situ Combustion (ISC), and Continuous Steam Injection (CSI). In SAGD method, two horizontal wells are drilled in parallel. The upper well is applied for the steam injection and the lower well is utilized for the oil production. This would be possible as heat is transferred from the upper well to the lower one where the viscosity of the heavy oil would reduce and result in the increase of oil production while flowing to the production well [6]. Unheated areas of this method would reduce the process efficiency. The extension of the steam chamber in vertical direction would lead to the development of the steam chamber in sideway while attaining an impermeable layer, which results in increasing the effect of gravity force [7-10]. In CSS method, using a horizontal offset well, the steam chamber is propagated with lateral growth and efficiency of the process would increase [11-14]. In this hybrid-SAGD technique, considering different number of cycles for the injection of the steam, start-up time, soaking and production periods would be possible. This technique is

---

* *Corresponding Author Email: Ameli@iust.ac.ir*

called Fast-SAGD method [15-19]. This process was simulated by Shin and Polikar [20]. Results revealed that the operating costs increased. More oil was produced in Fast-SAGD process and the cumulative steam to oil ratio (CSOR) was reduced in comparison to SAGD method [21]. An optimization study of fast-SAGD process was also performed by Shin and Polikar [19]. Steam injection pressure, rate of steam injection, and location of offset well were optimized. The oil production rate increased 35% and CSOR value reduced, leading to 24% enhancement in the energy efficiency. The optimum pressure of the edge well was obtained by Jeong et al. [15] using artificial neural network technique. A field scale study was done by Rios et al. [22]. The beginning of the CSS process and its impact on NPV was determined using the sensitivity analysis. Kamari et al. [23] also performed a comparative study on Fast-SAGD and SAGD methods in a fractured reservoir. To completely study the sensitivity analysis, the interaction parameter should be considered. For the complicated problems in petroleum engineering, this might be a time-consuming process.

In this study, discrete form of variables was applied to decrease the optimization run time. Decreasing the search space leads to obtaining the optimum point in a shorter time. One possible problem would be decreasing the accuracy of the results in comparison to the optimum point of the continuous space. To overcome this obstacle, a systematic approach was applied. To maintain the accuracy of the results, sensitivity analysis was performed. The influence of each variable for the optimization was examined on the objective function using the Minitab software. The optimization variables were then transferred from the continuous to the discrete space. The process was simulated using CMG STARS and optimized by the genetic algorithm.

2. Research Method

This study was based on Kamari et al. [23] model and consists of 30×5×10 grid blocks in x,y, and z directions with reservoir size of 150, 1000, and 50 ft, respectively. An offset well and two pairs of injection and production wells were also located in the reservoir. The black oil simulator was applied in CMG STARS. Three pseudo- components were selected for the oil sample characterization namely, CO2–C1, C2–C6, and C7+ with mole fractions of 0.1124, 0.1854, and 0.7022, respectively. The schematic of the model with loci of the SAGD wells is depicted in Figure 1. The characteristics of the Fast-SAGD process are represented in Table 1. The temperature and quality of the injected steam were 600 F and 0.9, respectively. The fluid and rock characteristics are represented in Table 2.

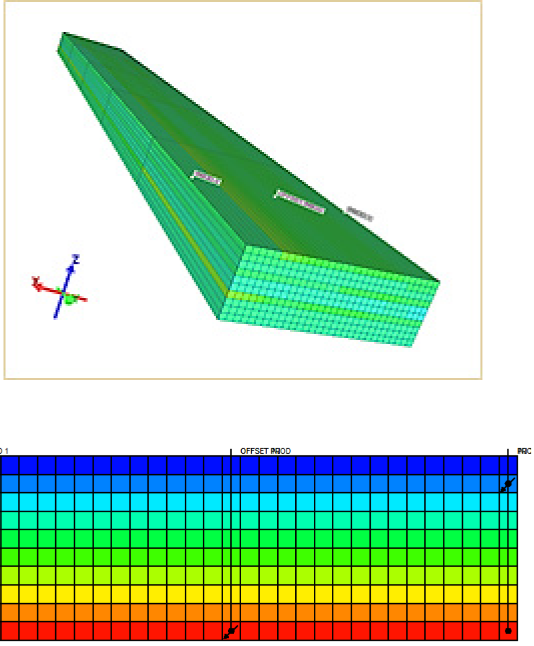

Figure 1. Schematic of the model and loci of SAGD wells

Table 1. Characteristics of Fast-SAGD process in one-cycle mode [1]

Variable	Value
SAGD production well height	4 ft.
SAGD injection well height	44 ft.
SAGD production well BHP	1100 psi
Max SAGD injection well rate	1000 bbl/day
Max SAGD injection well pressure	1320 psi
Offset well height	4 ft.
Offset production well BHP	1100 psi
Soak Time	25 day
Injection onset time	0 month
Injection period	6 month
Offset well injection pressure	1950 psi
Offset well injection rate	1000 bbl/day

Table 2. Reservoir Rock, Fluid Properties [1]

Parameter	Value
Fracture Permeability	2000 md
Fracture porosity	0.006%
Rock Matrix Porosity	0.195%
Matrix Horizontal Permeability	50 md
Matrix Vertical Permeability	50 md
Matrix Oil Saturation	85%
Fracture Oil Saturation	95%
Reservoir Pressure	1200 psi
Reservoir temperature	140 F
Residual Oil Saturation	40%
Residual Water Saturation	15%
Viscosity	4000 cp
Formation Thermal Conductivity	24 Btu/day.ft.F
Oil Thermal Conductivity	2 Btu/day.ft.F
Matrix Heat Capacity	30 Btu/ft^3.F

2.1 Optimization

Genetic algorithm was applied as one of the most practical approaches for optimizing the oil industry problems. Optimization variables included pressure, injection and production rate of offset well, heights of offset and SAGD wells, and injection and production times of the offset well. The objective function of this study was:

Objective function= CSOR/RF

where CSOR represents the ratio of cumulative steam injection to the produced oil and RF stands for the recovery factor. Decreasing the value of the objective function leads to increasing the value of oil production and decreasing the steam production rate. The primary random population for the genetic algorithm was 20 members. The crossover fraction was 0.8. For the stopping criteria, the repetition of the population members was not changed in 20 consecutive generations. The process was terminated while the best results were not obtained in 20 successive generations, in a change range of 1e-6.

2.2 Discretization

Converting the continuous interval of a variable into several intervals and selecting a point representative of that interval is called discretization. The number of the nodes is called steps, and the consecutive distance of each two points is called step length. The discretization leads to increasing the optimization speed. The continuous space for variables x and y is represented as a square. For the discretized form, this space is converted to a number of specified points. The optimum solution may be placed in points other than those are specified in the discretized form. In this case, the actual optimal point would tend to the closest defined point. This would lead to errors in the solution which could be reduced by increasing the discretization steps to an optimum value in terms of the accuracy of the results and run time. For large values of the discretization steps, there is a little difference in the results of continuous and discrete modes and the discretization would not lead to the increased values of speed in the optimization process. As a result, the effect of optimization variables should be defined on the objective function using the empirical and analytical techniques. Empirical techniques are applicable for reservoirs with well-defined characteristics to forecast the reservoir behavior for any variations. For the reservoirs without the fully defined characteristics, analytical approaches are applied to study the model sensitivity to various parameters.

2.2.1 Sensitivity Analysis

In this section, sensitivity analysis of the input parameters is studied for the model outputs. Minitab software was applied for this purpose. A two-level factorial technique was also applied for defining the number of runs and the analysis of variance for the mathematical analysis of the results.

2.2.2 Defining the number of steps for the discretization

In the next step, a logical connection was established between the sensitivity value for each parameter and the number of steps. For this purpose, three various functions were defined namely, square, logarithmic and linear. These functions are represented as follows [24]:

$$
\begin{aligned}
y_i &= \exp(ax_i + b) \\
y_i &= \sqrt{ax_i + b} \\
y_i &= ax_i + b
\end{aligned}
\qquad \textbf{(1)}
$$

These functions are used to define the step number for other parameters using the variables with minimum and maximum effects. In this study, the number of steps allocated to the variables with the least and the most error values were defined as 3 and 20, respectively, using trial and error. Figure 2 represents the number of steps for each function. The minimum number of steps refers to logarithmic function and the maximum number of steps is for the square function. In this section, five cases are considered which are represented in Table 3. Specified values were assigned to the steps of the least and the most values of sensitivity. These are applied for determining the best number of steps for the optimization.

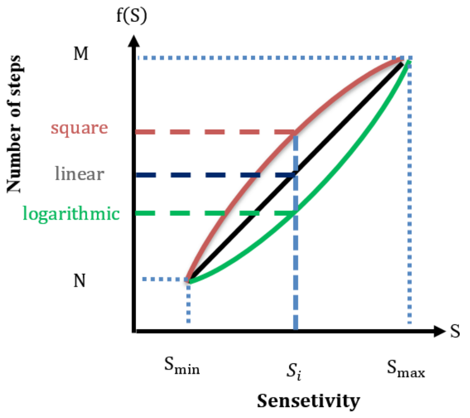

Figure 2. variations of number of steps with sensitivity for the square, linear, and logarithmic function

Table 3. The selected cases for discretization

Cases	Max Steps	Min Steps
Case1	3	5
Case2	3	10
Case3	3	20
Case4	5	25
Case5	10	35

2.2.3 Discretization of continuous parameters

Specified number of steps has been calculated using the sensitivity analysis for different cases in Table 3. Variables should be transferred from the continuous to the discrete space. For variable x in the range of 0 to 1, if the number of steps is equal to n, the length of each segment would be:

$$S_i = (\frac{1}{n}) \times (n_i - 1) \tag{2}$$

The value of F_i in a specified segment would be:

$$F_i = (\frac{1}{n-1}) \times (n_i - 1) \tag{3}$$

For x in the range of 0 and 1:

If :

$$S_i \le x < S_{i+1} \to f(x) = F_i \tag{4}$$

Figure 3 represents the discretization of variable x using three steps. In this figure, the values of S are equal to 0, 0.33, 0.66, 1. Moreover, F values are 0, 0.5, and 1. The initial and end point of each range are also considered in the optimization. Therefore, for x between 0 and 0.33, the value of f(x) would be 0, and for the range of 0.33 to 0.66 it would be 0.5. Briefly, using the sensitivity analysis, the effectiveness of each variable on the objective function was determined. Implementing the linear, square, and logarithmic functions, the number of discretization steps would be determined for each of the selected variables. Finally, using the discretization equations, continuous variables were transferred to the discrete space.

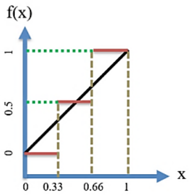

Figure 3. Displaying the discretization of variable x using 3 steps

3. Results and Analysis

3.1 Sensitivity Analysis of the model

Effectiveness of each of the selected variables is represented in Table 4 in which various parameters and their effects are shown on the objective function.

Table 4. Sensitivity analysis results

variables	Range of Variation	Results
SAGD production well height	4-44 ft	23.22
SAGD injection well height	4-36 ft	14.65
SAGD production well BHP	36-76 psi	-15.67
max SAGD injection well rate	7-90 bbl/day	0.152
max SAGD injection well pressure	0-36 psi	4.598
Offset well height	3-21 ft	-15.9
Offset production well BHP	1600-220 psi	-1.64
Soak Time	1000-1400 month	-3.02

Higher values of sensitivity analysis lead to assigning more nodes to the converted discrete variables. The most sensitivity refers to the height of SAGD injection well, and the minimum sensitivity is assigned to the maximum injection rate of SAGD injection well.

3.2 Comparison of different functions with continuous state

The number of steps allocated to each parameter in logarithmic, linear, and square functions is reported in Table 5. The maximum number of steps is attributed to the linear function. On the other hand, the logarithmic function introduced the least repetition of the steps. For all cases, the maximum number of the discretization steps is attributed to the height of production well with value of 20 and the minimum number of the discretization steps is for the maximum injection rate for SAGD injection well with the value of 3.

Table 5. The specified number of steps for each of the variables

Parameters	Number of steps		
	Logarithmic	Square	Linear
SAGD production well height	20	20	20
SAGD injection well height	10	16	14
SAGD production well BHP	10	16	14
max SAGD injection well rate	3	3	3
max SAGD injection well pressure	4	9	6
Offset well height	11	17	15
Offset production well BHP	3	6	4
Soak Time	4	8	5
a	0.082	16.96	0.73
b	1.083	5.94	2.86

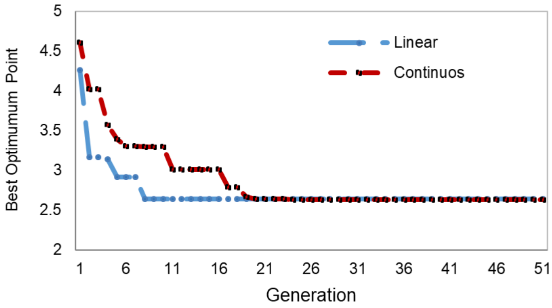

Figure 4. Comparison of the best optimum point in various generations in case 3

Figure 4 represents the accuracy of the results in discretized form for case 3 as the best case in terms of accuracy and the number of repetitions. Values of the best objective functions using the genetic algorithm for the discrete and the continuous states for each generation are represented in this figure. In discrete state, where the linear function was applied to determine the number of steps, results were the same as the continuous state for the least generation. Their difference was the reduced run time for the discrete state. This denotes the significance of the newly developed approach in the oil industry. Using the described discretization approach led to a decrease in the simulation time considerably, while the difference between the optimization results in the continuous and discrete states was less than 3%. To compare the results of discrete and continuous variables, the optimization was performed using the terms reported in Table 6.

Table 6. Optimization conditions for the continuous and discrete parameters

SAGD injection well height (ft)	**SAGD production well height (ft)**	**SAGD injection well max injection rate(bbl/day)**	**Soak Time (month)**	**SAGD injection well max pressure (psi)**	**Offset well height (ft)**	**SAGD production well BHP(psi)**	**Offset production well BHP (psi)**	
4-44	36-68	4-44	0-60	0-36	3-21	1200-2200	1000-2000	**Variable Range**
8	8	8	10	3	3	100	100	**Step Size (x)**
16	16	16	20	6	6	200	200	**Step Size (2x)**

Figure 5 shows the optimization results of the genetic algorithm for the continuous problem and the discretized one with discretization step length of x and 2x. As represented in this figure, the number of function evaluations (NFE) for the continuous state is approximately 2000, while for the discretized states with length of x and 2x, this parameter would be 750, and 400, respectively. This means that the optimization speed for the discrete variables is more in comparison to the continuous state. As most of the recalled data by the optimization procedure are repetitive, omitting them would increase the optimization speed furthermore. So, not only the number of NFE is reduced, but also the number of saved data in databank would reduce. Figure 6 indicates that for this state, the number of saved data for the continuous and two discrete cases are 2000,360, and 140, respectively. This algorithm would not affect the optimization speed in the continuous state, as all the variables have the same variations.

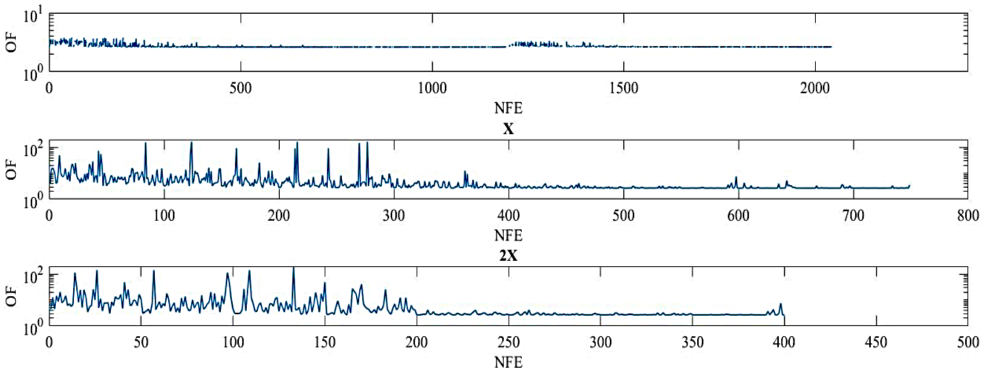

Figure 5. Results of objective function for the continuous and discrete variables

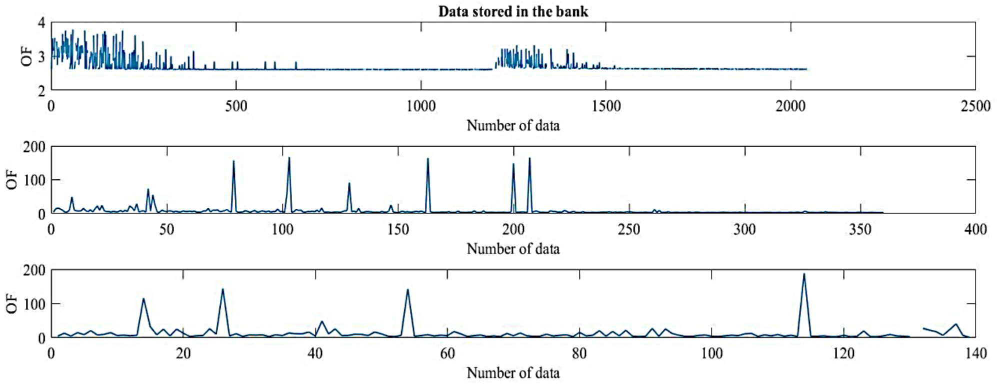

Figure 6. Number of data saved in data bank for the continuous and discrete variables

To compare the results of the continuous and discrete variables, the recovery factor and CSOR values were compared in various conditions. The error values for each technique were also compared. Figure 7 represents the values of the discrete and continuous parameters for the recovery factor, CSOR, and the recovery factor, respectively. These curves are depicted for the optimum values. It is inferred from the figures that the discretization error was for the first 1500 days in which the offset well was injected and the pressure and injection rates were different in the various discretization conditions.

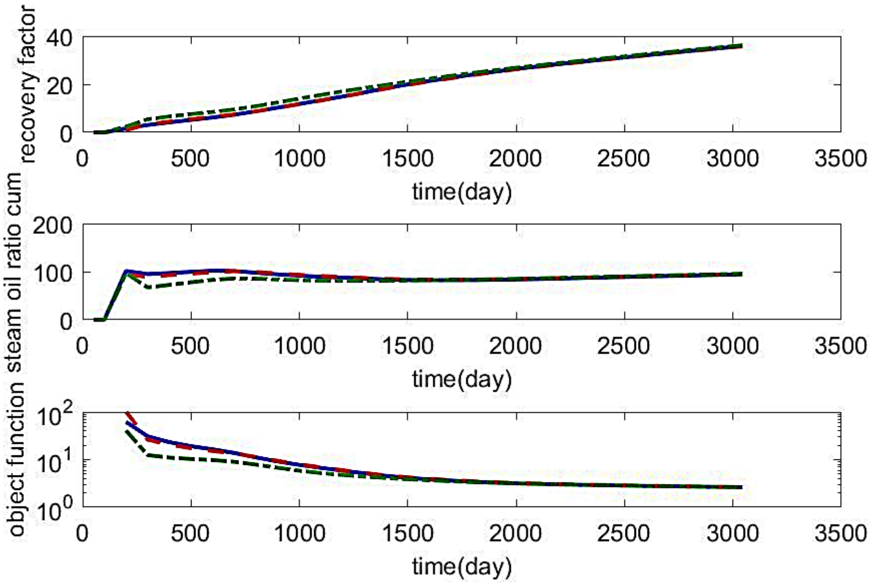

Figure 7. Values of the discrete and continuous parameters for the RF, CSOR, and the objective function

Table 7 reports the error values of the recovery factor and CSOR for the two periods of 5 and 8 years from beginning of the process.

Table 7. Error value for the continuous and discrete parameters

r value for CSOR in 5 years	r value for CSOR in 8 years	r value for RF in 5 years	r value for RF in 8 years	
1	1	1	1	Continuous
0.9961	0.9955	0.9991	0.9999	Discrete x
0.9698	0.9385	0.9932	0.9978	Discrete 2x

It is inferred from the table that by increasing the step size, the error value would increase. But it is not significant. On the other hand, these results were obtained for the reduced values of NFE.

3.3 Simulation results for the fast-SAGD process with two cycles

In this simulation, the first injection cycle was 18 months, the soak time was 2 months, and the production cycle was 6 months. The second cycle included a 6-month steam injection, a 2-month soak time, and production till the end of the reservoir lifetime. The maximum bottom hole pressure of the offset well for the optimum condition is 2000 psi and the maximum steam injection rate is 800 bbl/day obtained from the genetic algorithm. Figure 8 shows that for the injection cycles (green curve) in offset well, the oil production rate increased and the CSOR value decreased. The optimum value for the CSOR is 2.88 and for RF is 69.36%. The recovery factor also increased in this period (blue curve) which is due to the high pressure of the offset well.

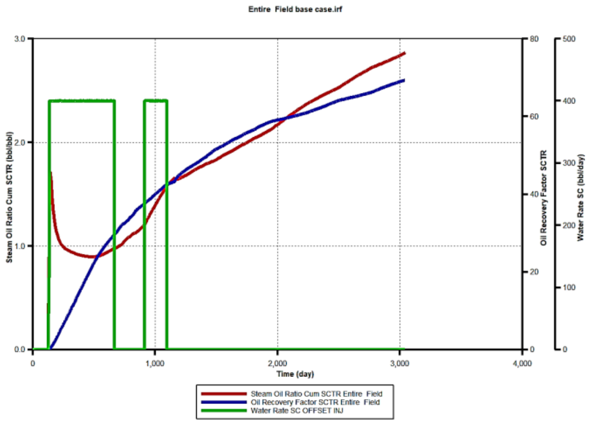

Figure 8. Curves of RF (blue), CSOR (red), and injection cycles in offset well (green)

As the injection pressure of the offset well is more than that of SAGD well, the average reservoir pressure also increased in different injection cycles. In Figure 9, the green and blue curves are the bottom hole pressure and the average reservoir pressures, respectively. As it is clear, for the injection cycles in offset wells the average reservoir pressure also increased.

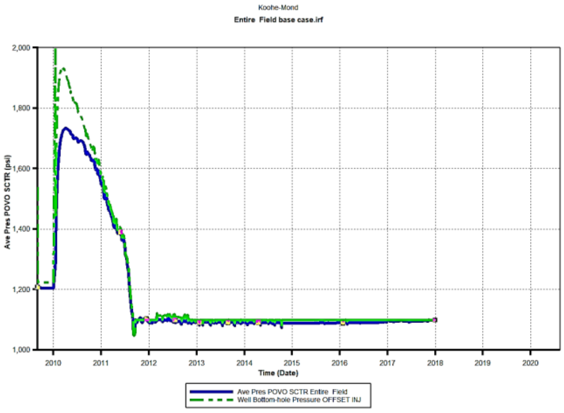

Figure 9. Effect of the injection pressure in offset well on the reservoir average pressure

Pressure distribution for the 3rd, 6th and 9th months after the production are shown in Figure 10. It is clear from this figure that the pressure front is moving to the SAGD well. The temperature distribution is more uniform in the 12th month.

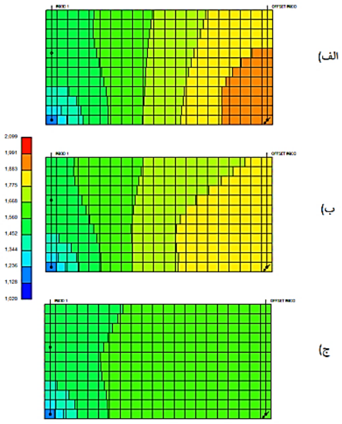

Figure 10. Pressure distribution in offset well for the 3rd, 6th and 9th months

Figure 11 represents the average temperature of the reservoir.

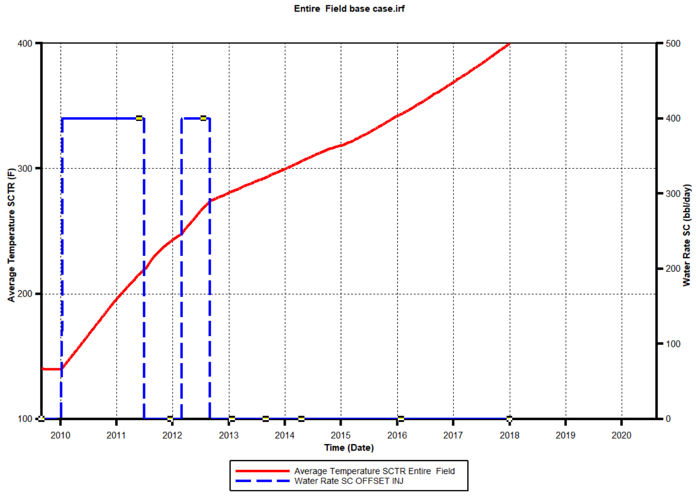

Figure 11. Average reservoir temperature in the injection and production cycles

As the figure clearly shows, the average reservoir temperature is more for the injection cycles. This is due to the high volume of the injected steam to the reservoir.

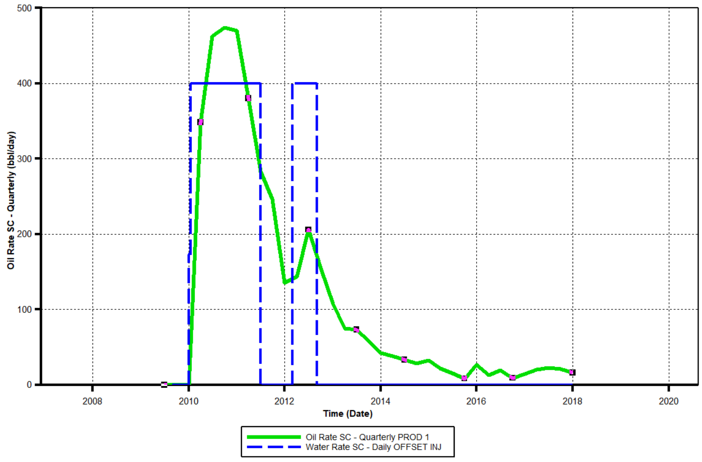

Figure 12. Oil production curve for the produced oil from SAGD well and injected steam to offset well

In addition, as Figure 12 clearly shows for the injection cycles in SAGD well, the produced increases which is due to the high pressure of the injected steam which pushes oil to the SAGD well.

4. Conclusions

1- By applying the new technique, the optimization speed increased three times and the accuracy of the results remained constant. The difference between the optimization results in the continuous and discrete states was less than 3%.

2- In the newly presented approach, the discretization is based on the sensitivity analysis without the exact recognition of the reservoir parameters. Mathematical analysis was applied to forecast the reservoir behavior and to perform the discretization of the continuous variables.

References

1. Hemmati-Sarapardeh, A., et al., Experimental determination of interfacial tension and miscibility of the CO2–crude oil system; temperature, pressure, and composition effects. Journal of Chemical & Engineering Data, 2013; 59(1): 61-69.

2. Wang, X., S. Zhang, and Y. Gu, Four important onset pressures for mutual interactions between each of three crude oils and CO2. Journal of Chemical & Engineering Data, 2010; 55(10): 4390-4398.

3. Ayirala, S.C. and D.N. Rao. Comparative evaluation of a new MMP determination technique. in SPE/DOE Symposium on improved oil recovery. Society of Petroleum Engineers; 2006..

4. Namdar Zanganeh, M. and W. Rossen, Optimization of foam enhanced oil recovery: balancing sweep and injectivity. SPE Reservoir Evaluation & Engineering, 2013; 16(01): 51-59.

5. Hashemi-Kiasari, H., et al., Effect of operational parameters on SAGD performance in a dip heterogeneous fractured reservoir. Fuel, 2014; 122: 82-93.

6. Deutsch, C. and J. McLennan, Guide to SAGD (steam assisted gravity drainage) reservoir characterization using geostatistics. Centre for Computational Excellence (CCG), Guidebook Series Vol. 3, University of Alberta, April 2003, 2005.

7. Austad, T., Water-based EOR in carbonates and sandstones: new chemical understanding of the EOR potential using smart water. Enhanced Oil Recovery Field Case Studies, 2013: 301-335.

8. Gates, I.D., et al. Steam injection strategy and energetics of steam-assisted gravity drainage. in SPE International Thermal Operations and Heavy Oil Symposium. Society of Petroleum Engineers; 2005.

9. Gates, I.D. and S.R. Larter, Energy efficiency and emissions intensity of SAGD. Fuel; 2014. 115: 706-713.

10. Kam, D., et al., An optimal operation strategy of injection pressures in solvent-aided thermal recovery for viscous oil in sedimentary reservoirs. Petroleum Science and Technology; 2013. 31(22): 2378-2387.

11. Coskuner, G., A new process combining cyclic steam stimulation and steam-assisted gravity drainage: Hybrid SAGD. Journal of Canadian Petroleum Technology, 2009; 48(01): 8-13.

12. Ghanbari, E., et al. Improving SAGD performance combining with CSS. in International Petroleum Technology Conference. International Petroleum Technology Conference; 2011.

13. Li, D.D. and M.L. Greenfield, High internal energies of proposed asphaltene structures. Energy & Fuels; 2011. 25(8): 3698-3705.

14. Xu, J., et al. Numerical thermal simulation and optimization of hybrid CSS/SAGD process in Long Lake with lean zones. in SPE Heavy Oil Conference-Canada. Society of Petroleum Engineers; 2014.

15. Jeong, S., et al. Optimal Operation of Fast-SAGD Process Considering Steam Channeling among Vapor Chambers. in The Twenty-third International Offshore and Polar Engineering Conference. International Society of Offshore and Polar Engineers; 2013.

16. Kamari, A., et al., New tools predict monoethylene glycol injection rate for natural gas hydrate inhibition. Journal of Loss Prevention in the Process Industries, 2015; 33: 222-231.

17. Polikar, M., T. Cyr, and R. Coates. Fast-SAGD: half the wells and 30% less steam. in SPE/CIM International Conference on Horizontal Well Technology. Society of Petroleum Engineers; 2000.

18. Sarapardeh, A., et al. Application of fast-SAGD in naturally fractured heavy oil reservoirs: A case study. in SPE middle east oil and gas show and conference. Society of Petroleum Engineers; 2013.

19. Shin, H. and M. Polikar, Review of reservoir parameters to optimize SAGD and Fast-SAGD operating conditions. Journal of Canadian Petroleum Technology, 2007; 46(01).

20. Shin, H. and M. Polikar, Fast-SAGD application in the Alberta oil sands areas. Journal of Canadian Petroleum Technology, 2006; 45(09).

21. Shin, H. and M. Polikar. Experimental investigation of the fast-SAGD process. in Canadian International Petroleum Conference. Petroleum Society of Canada; 2006.

22. Rios, V.D.S., P. Laboissiere, and O.V. Trevisan. Economic Evaluation of Nitrogen Injection on SAGD Process. in SPE Latin American and Caribbean Petroleum Engineering Conference. Society of Petroleum Engineers; 2010.

23. Kamari, A., et al., On the evaluation of Fast-SAGD process in naturally fractured heavy oil reservoir. Fuel; 2015; 143: 155-164.

24. Ameli, F. and K. Mohammadi, A novel optimization technique for Fast-SAGD process in a heterogeneous reservoir using discrete variables and repetition inhibitory algorithm. Journal of Petroleum Science and Engineering, 2018; 171: 982-992.

نشریه فناوری نفت، گاز و پتروشیمی۶ (۱): ۳۹-۵۰، تابستان ۱۳۹۸

مقاله تحقیقاتی

کاهش زمان بهینه سازی در شبیه سازی مخازن نفتی

کاوه محمدی، فروغ عاملی*

دانشکده مهندسی شیمی، نفت و گاز، دانشگاه علم و صنعت ایران، کد پستی ۱۶۸۴۶، تهران، ایران

مشخصات مقاله

تاریخچه مقاله:

دریافت ۲۷ فروردین ۱۳۹۸

دریافت پس از اصلاح ۹ خرداد ۱۳۹۸

پذیرش نهایی ۲۴ خرداد ۱۳۹۸

کلمات کلیدی:

گسسته سازی

بهینه سازی

شبیه سازی مخزن

فرایند Fast-SAGD

* عهده‌دار مکاتبات؛

رایانامه: Ameli@iust.ac.ir

تلفن: ۰۲۱-۷۷۲۴۰۵۵۰

دورنگار: ۰۲۱-۷۷۲۴۰۵۵۰

چکیده

تکنیکهای حرارتی افزایش تولید نفت شامل فرایند Fast-SAGD منجر به افزایش بهره وری تولید در مخازن نفت سنگین می شود. در این پژوهش، مطالعات بهینه سازی مربوط به این فرایند انجام شده است. تابع هدف به عنوان نسبت تجمعی بخار تزریقی به نفت تولیدی تقسیم برمیزان بازیافت نفت تعریف شده است. فرم گسسته پارامترهای موثر در این مطالعه مورد استفاده قرار گرفته است. در این روش، گسسته سازی براساس نتایج تجزیه و تحلیل آنالیزحساسیت بدون شناسایی دقیق پارامترهای مخزن صورت می پذیرد. با استفاده از این تکنیک، سرعت بهینه سازی سه برابر افزایش یافت در حالی که دقت نتایج ثابت باقی ماند. تفاوت بین نتایج بهینه سازی در حالت های پیوسته و گسسته کمتر از ۳٪ بود. علاوه بر این، نتایج شبیه سازی فرآیندFast-SAGD با دو سیکل، از نظر RF، CSOR، توزیع دما، فشار و میزان نفت تولیدی ازچاه SAGD و مقدار بخار تزریقی به چاه انحرافی ارائه شده است.

نحوه استناد به این مقاله:

Mohammadi K, Ameli F. On the Reduction of Optimization Time in Simulation of Oil Reservoirs. Journal of Oil, Gas and Petrochemical Technology, 2019; 6(1): 39-50. DOI: 10.22034/JOGPT