Steam PSO

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ABSTRACT BOOK

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THE SECOND INTERNATIONAL CONFERENCE ON OIL AND GAS INDUSTRY, TECHNOLOGIES AND APPLICATIONS (ICOG-ITA 2022)

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ABOUT THE CONFERENCE

The Second International Conference on Oil and Gas Industry, Technologies and Application 2022 (ICOG-ITA2022) is a virtual conference to be held on 14th – 15th September 2022, hosted from Kota Kinabalu, Sabah, Malaysia.

This conference is organized by the Oil and Gas Engineering Programme, Universiti Malaysia Sabah, with the theme of "Current and Emerging Trends in Oil and Gas Industry Technologies and Applications".

ICOG-ITA2022 act as a platform to spur and strengthen the bonding between the oil and gas players, which include the oil and gas companies, industries, technology expert, as well as policymakers to harmonize the way forward for the oil and gas industry in the future.

This conference is also in line with the avenue of the post COVID-19 pandemic, innovative strategies, and best practices to catalyze the exponential growth in moving forward in propagating the technologies and applications with emphasis on the oil and gas arena.

The conference will focus on the keynote addresses, paper presentation, and discussions on the key area of technologies and applications, which impelling sustainability and industrial revolution 4.0 (IR4.0) technologies in the oil and gas industry and other relevant key areas. This is critical to stay relevant in this challenging and competitive climate of the oil and gas landscape.

The Organizing Committee invites technical papers on substantial, original, and unpublished research in the areas relevant to the oil and gas. ICOG-ITA2022 welcomes contributions in the following areas but not limited to:

- Enhanced oil recovery
- Flow assurance (Drag reduction)
- Advanced materials/nanomaterials
- Environment
- Nanotechnology
- Simulation in oil and gas
- Oil and gas applications
- Safety (Oil and gas leak detection)

- Fluid dynamic
- Energy application
- Polymer
- Control and intelligent system
- Renewable energy (Bioenergy)
- Membrane application in oil and gas
- Sustainability in oil and gas
- IR4.0 in oil and gas

We hope the participants of this conference will find something interesting, useful, and informative and inspire them for more advanced and innovative research on the current trend in this field.

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MODELLING AND SIMULATION/FLUID DYNAMICS

ICOG-ITA139

Continuous Steam Injection Optimization using Particle Swarm Optimization

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Abstract

The main advantages of steam flooding are to increase the oil recovery using hot steam that is injected into the reservoir. This research aims to optimize the parameters that affect to oil recovery factor & steam oil ratio. This research will be conducted using CMG STARS and in order to make the work more effective, this research uses particle swarm optimization (PSO) to be able to optimize the parameters. The parameter is used is steam injection rate, pressure, temperature, steam quality. Therefore, it can be known the parameter are right to obtain the best recovery factor. The variation in the injection rate used are in range 700 – 1250 bbl./day, pressure in range 300 – 650 psi, temperature in range 300 – 550, and steam quality 50% - 90%. Of all the scenarios tested the best results are injection rate 1250 bbl/day, pressure 300 psia, temperature 550 F, and steam quality 90%, where recovery factor was 17.5314 % and SOR 1.6102.

Keywords: *Steam flooding; Recovery factor; Particle swarm optimization*

1. Introduction

Crude oil has different viscosity variations based on the gravity index according to the American Petroleum Index (API). This difference causes the oil to be classified into light oil and heavy oil. Heavy type crude oil is very difficult to pump to the surface because of its higher density form. This is because the mass properties it has are different so that it affects the level of liquidity (Sutarna et al., 2016). One of the best methods that has been proven to resolve this problem is using steam flooding (Hidayat & Abdurrahman, 2018). Steam flooding as one of the well-known EOR processes has been used to increase oil rates and oil recovery (Bagheripour Haghighi et al., 2012). Steam flooding works as a succession technology after steam huff and puff to effectively increase the recovery factor. Steam flooding is an EOR process in which steam is continuously injected into a reservoir (Qi et al., 2020). In the steam flooding process, there are several parameters that influence increasing oil recovery factor. Those parameters are steam quality, injection pressure, temperature, injection rate, injection volume, and steam allocation (Kumar et al., 2018). Accordingly, optimal control of the parameters of steam flooding project is crucial to get the highest oil recovery factor.

Numerous optimization algorithms have been developed yet, which based on their principal idea and procedure, can be classified into two main categories: gradient-based methods and population-based schemes. Gradient-based approaches have the advantage of fast convergence to an optimal point using gradient vectors. However, computation of gradient vectors is a very time-consuming procedure when a large number of decision variables exists. Therefore, usually for the problems such as EOR projects – in which the fluid flow physics is very complex and are dealing with a relatively high number of decision variables – instead of using gradient-based approaches population-based methods are more appropriate to be employed (Dréo et al., 2006). Recently, population-based methods such as evolutionary algorithms, particle swarm optimization (PSO), artificial bee colony, and genetic algorithm are used very frequently for optimization of various engineering problems. PSO shows a good performance for optimization of different engineering problems. PSO has also found a great deal of attention in EOR Projects. In a study of (Eshraghi et al., 2016) conducted an EOR project with miscible CO2 injection into the reservoir using PSO, GA and ABC algorithms and compared their performance with each other. They mentioned that all the three algorithm result in favourable outcomes, while in their problem, PSO exhibit the better performance with respect to GA.(Ghadami et al., 2015) optimized a chemical flooding project, made use of PSO and response surface methodology (RSM) techniques to find the optimum oil recovery. They concluded that PSO is a proper choice for optimization of chemical flooding EOR projects.

In this study, it will optimize 4 parameters, those parameters are steam quality, injection pressure, steam temperature, and injection rate, to get the best recovery factor considering to the SOR value. In this study used conventional simulation and particle swarm optimization algorithm. The injection rate range to be used is 700 – 1250 bbl./day, injection pressure 300 – 650 psi, temperature 300 – 550, and steam quality 0.5 – 0.9.

2. Methodology

2.1. Objective Function

The objective function is intended to determine in which direction the steam flood system is optimized. The objective of this study is to get the best value of the oil recovery factor and SOR. Researches used reduced quadratic equation obtained after running 500 Design of Experiment (DoE) using CMG CMOST.

RF :

$$9.11554 + (0.0132562 * Inj\_Rate) - (0.000189658 * Inj\_Press) - (0.00752512 * Inj\_Temp) - (1.0618 * Inj\_Squal) - (4.70036E\text{-}07 * Inj\_Rate * Inj\_rate) + (1.15829E\text{-}06 * Inj\_Rate * Inj\_Temp) - (0.000592545 * Inj\_Rate * Inj\_Squal) + (1.95954E\text{-}07 * Inj\_Press * Inj\_Press)$$

+ (7.94173E-06 * Inj_Temp * Inj_Temp) + (0.00216106 * Inj_Temp * Inj_Squal) + (0.825342 * Inj_Squal * Inj_Squal)

SOR : 1.75398 + (0.00183808 * Inj_Rate) + (1.26731E-05 * Inj_Press) – (0.00226083 * Inj_Temp) – (1.70634 * Inj_Squal) – (4.82233E-07 * Inj_Rate * Inj_rate) – (1.0106E-07 * Inj_Rate * Inj_Temp) – (0.000477947 * Inj_Rate * Inj_Squal) – (3.30071E-08 * Inj_Press * Inj_Temp) + (1.40012E-06 * Inj_Temp * Inj_Temp) + (0.00148826 * Inj_Temp * Inj_Squal) + (0.668886 * Inj_Squal * Inj_Squal)

2.2. Particle Swarm Optimization

The idea of PSO was first proposed by (Kennedy & Eberhart, 1995) for the optimization of continuous non-linear functions. Like other metaheuristic methods which are inspired from the nature, PSO is a stochastic optimization technique and is inspired by the ability of birds to flock and search for foods. In this method a group (swarm) of particles (the candidates for solution) is distributed as points in the N-dimensional space. In which N shows the number of variables that we want to optimize them. Each particle has two N-dimensional vectors including the position and velocity vectors. These vectors show quantity and the rate of variation of decisions variables, respectively. The position and velocity vectors of i th particle are defined respectively as follows:

$$X_i^t = [x_{i1} x_{i2} \ldots x_{iN}]^t$$

$$V_i^t = [v_{i1} v_{i2} \ldots v_{iN}]^t$$

In each timestep, when a particle moves, its direction is adjusted in accordance to the best position of the particle (X_i^l) and also the best position of all the other ones that had been met in the past timesteps (X^g). In this paper, each particle contains information about steam quality, injection rate, injection pressure, and temperature. For each particle, the objective function (fitness) – recovery factor is calculated using its current local position vector and when a particle finds a position that is better than all its previous positions, the best new position will be saved in the local best position vector (X_i^l). Next, the best position among all particles (swarm) in that specific step will be saved in the global best position vector (X^g). The position and velocity vectors are updated in each step according to the following relations:

$$V_i^{t+1} = \eta V_i^t + \alpha_1\gamma_1(X_i^l - X_i^t) + \alpha_2\gamma_2 (X^g - X_i^t)$$

$$X_i^{t+1} = X_i^t + V_i^{t+1}$$

Where η is the inertia weight and controls the effect of the previous particle velocity on its current velocity. $\gamma 1$ and $\gamma 2$ are uniformly distributed variables in the range of (0,1), and $\alpha 1$ and $\alpha 2$ are positive parameters known as the cognitive and the social factors, respectively. They determine the effectiveness of each individual and collective term in the particle's motion (Siavashi & Doranehgard, 2017). In this study the control parameters of PSO are $\eta = 0.729$, $\alpha_1 = \alpha_2 = 1.4962$, number of particles = 35, number of iterations = 1000.

3. Reservoir Models

This research use CMG STARS to simulate the steam flooding process into the reservoir model. Table 1 fluid and rock properties are taken from (Gunadi et al., 2013). This model is a cartesian grid with dimensions 25 x 25 x 5 where permeability is 300 mD, 300 mD, and 150 mD respectively (Fig. 1). The pattern selection was based on previous research (Erfando et al., 2019) which showed that the field with the inverted seven-spot well pattern had the highest recovery factor value than the others.

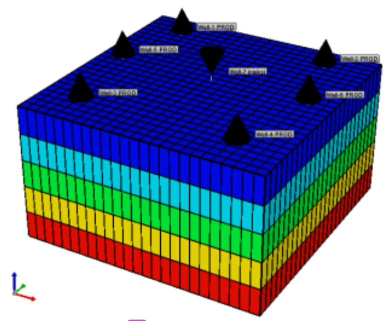

Figure 1 Cartesian Model 3 D

Table 1 Fluid and Rock Properties

Parameter	**Value**	**Parameter**	**Value**
Viscosity	500 cp	Bubble Point Pressure	161 psig
Oil Density	0.99 lb/cuft	Porosity	0.25
Water Density	62.4 lb/cuft	Vertical Permeability	300 mD
API Gravity	11° API	Horizontal Permeability	300 mD
Formation Volume Factor	1.021 bbl/STB	Compressibility	5E-6 psi-1
Type of Oil	Heavy Oil	Wettability	Oil wet

The test parameters in this study is injection rate, injection pressure, injection temperature, and steam quality. That parameters have an effect on increasing oil recovery factor. The value of these parameters is shown by the Table 2.

Parameter	**Range**
Injection pressure	300 – 650
Steam quality	0.5 – 0.9
Injection rate	700 – 1250
Injection temperature	300 - 550

Table 2 Range of the parameters

4. Result And Discussion

To compare the incremental recovery oil values between the base case and using PSO can show in Table 2. Optimization using PSO give the highest recovery factor of 17.5314 % and SOR 1.5952, compared to the base case where the RF & SOR values were only 16.392569 & 1.5052505, recovery factor increased by 6.9% and SOR only increased by 5.9%.

Table 3 Comparing oil recovery factor and SOR in each scenario.

Parameter	*Base case*	Optimization (CMG)	PSO
Injection Rate (bbl./day)	1000	1250	1250
Injection Pressure	500	545	639

(psia)			
Injection Temperature (°F)	450	550	550
Steam Quality	0.9	0.9	0.9
Recovery Factor	16.392569	17.585466	17.5314
SOR	1.5052505	1.6313858	1.5052505

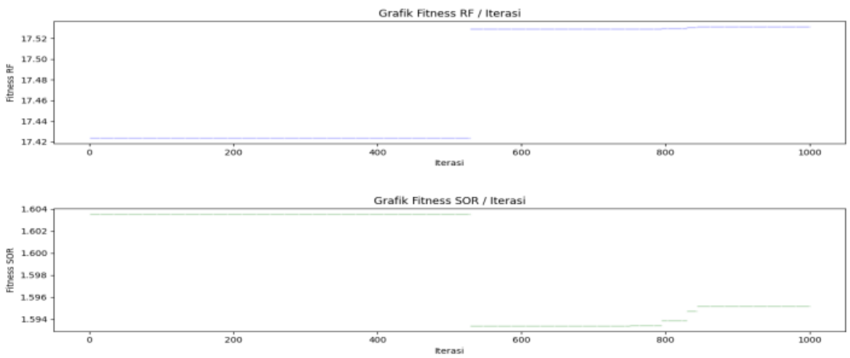

Figure 2 Optimization process using PSO

Optimization using PSO, get the best result are obtained after running on the 804 iteration with RF values 17.5314 and SOR 1.5952. Meanwhile, from Table 3. It can be seen that the increase of RF in optimization using CMG is 7.2% and SOR 8.3%. Based on the results of the comparison between using of PSO gets more optimal results because seen from the increase in RF it is not much different from using CMG but the increase in SOR has more difference.

To verify the above findings, the relationship between the objective function and each parameter are plotted in Figure 3. From the Figure 3 shows that a higher injection rate will lead to a higher oil recovery. This is according with the research conducted by srockviksit where the higher injection rate will lead to a higher SOR too.

In the relationship between the objective function and each parameter. The higher injection pressure will lead to a higher oil recovery. According to the research by Agarwal, steam injection with the higher pressure will increase the volume oil produced. But in this study, shows a more scatter distribution of points, which indicates that the objective function is not very sensitive to steam injection rate.

The relationship between the injection temperature and the objective function shows that a higher temperature will result in a higher recovery factor. This is according to the research of wang & qiu where a higher temperature obtains a higher recovery factor, this is because the higher temperature will reduce the oil viscosity, and the mobility of the oil will be increase. However, it should be noted, the recovery factor will be lower when the temperature is below 520 °C, after the temperature is above 520 there is a jump in the recovery factor increase.

In Figure 3. The relationship between steam quality and objective function. In a study by salam stated that the low steam quality has a greater pressing efficiency, but less sweeping efficiency. On the other hand, high quality of steam has a greater sweeping efficiency and a lower pressing efficiency. Therefore, higher steam quality will produce a high recovery factor compared to low steam quality. The relationship between SOR and steam quality shows than same results as RF, where the higher steam quality, will give the higher SOR.

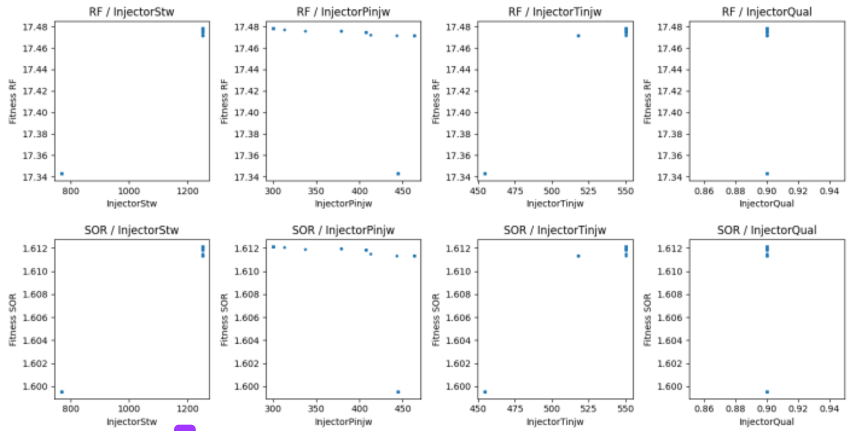

Figure 3 Relationship between the objective function and each parameter (PSO)

5. Conclusion

The metaheuristic method of particle swarm optimization (PSO) has been implemented successfully to find optimal values of decision variables. Base on the range of parameter and implementation of PSO, the best recovery factor is 17.5314 with SOR 1.59525 were obtained from the following optimization results: injection rate 1250 bbl./day, injection pressure 300 psia, injection temperature 550 °F, steam quality 0.9. Furthermore, when viewed from the results that injection pressure is not very sensitive to the objection function.

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