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Simulation Study of Different Gases Injection in GAGD Process in a Fractured Medium Oil Reservoir

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Abstract

In this research, the injection of various immiscible gases, including methane, nitrogen, and carbon dioxide gases through the process of gas assisted gravity drainage (GAGD) in a fractured medium oil reservoir was simulated by black oil (IMEX) simulator of CMG simulation software. The results show that methane gas injection in this process accelerates the gravity drainage mechanism considering its less density in comparison to the other injected gases such as nitrogen and carbon dioxide. This causes an increase in oil production from matrix blocks of the gas invaded zone, which in turn increases the amount of oil production from the reservoir. In fact, methane gas injection in GAGD process causes more oil recovery factor than carbon dioxide gas and nitrogen gas injection, with 3.48 % and 1.48% respectively.

Keywords: *Methane; Carbon dioxide; Nitrogen; GAGD; Fractured Reservoir.*

1. Introduction

Water alternating gas injection (WAG) process, initially, was introduced by Caudle and Dyes [1] to solve certain problems existing in the continuous gas injection process, such as gas high mobility, gas viscous fingering, and the overriding of gas. However, this process in itself had problems, namely increasing water saturation in the reservoir, which caused the reduction of reservoir permeability, and consequently a reduction in oil production from the reservoir [2]. In addition to this problem, this process recovers 5-10% oil in-place which is low oil recovery [3-4]. This is associated with the fact that gravity drainage takes place in the reservoir with high vertical permeability to horizontal permeability ratio. As a result, water and gas injected in the water alternating gas injection process move towards the bottom and the top of the reservoir respectively due to their density difference with oil in the reservoir, which in turn causes the under riding and overriding phenomena there [5]. In this case, a high volume of existing oil in the reservoir is not produced, and it remains as residual in the reservoir. Therefore, researchers innovated the other process named "Gas Assisted Gravity Drainage (GAGD)" process to solve the problems of the water alternating gas injection process in which, contrary to water alternating gas injection process, the gravity drainage between injected gas and oil in the reservoir is considered as an advantage as it will contribute to more production of oil in-place of the reservoir without increasing water saturation there [6-7]. It should be mentioned that GAGD process, at first, was applied for inclined reservoirs. Nonetheless, nowadays, thanks to advancement in this process, it is being applied for fractured reservoirs. Now, this research study by comparing the results derived from the simulation of the injection of different immiscible gases in GAGD process in addition to selecting the best scenario aims to develop this process more and make it more applicable for fractured reservoirs so that the oil production will increase remarkably from fractured reservoirs.

2. The description of GAGD process in a fractured oil reservoir

GAGD [8] is a process in which used several vertical injector wells for gas injection and one horizontal producer well in the bottom of the layer for oil production (Fig. 1). At the beginning of gas injection in the GAGD process in a fractured oil reservoir, injected gas moves towards the top of the reservoir and created an artificial gas cap there due to the density difference between injected gas and oil in the reservoir. By continuous gas injection, this artificial gas cap grows and expands towards bottom and two sides of the reservoir which is caused to enter injected gas into fractures of the reservoir; due to the high permeability of fractures, their oil is produced quickly by more growing the artificial gas cap; but the oil of the matrix blocks due to the low permeability doesn't produce and remains there which is caused to create the gas invaded zone in the reservoir. This zone is full of gas in the fractures and filled with oil in the matrix blocks and also in the gas invaded zone, gravity drainage mechanism affects to produce oil within the matrix blocks.

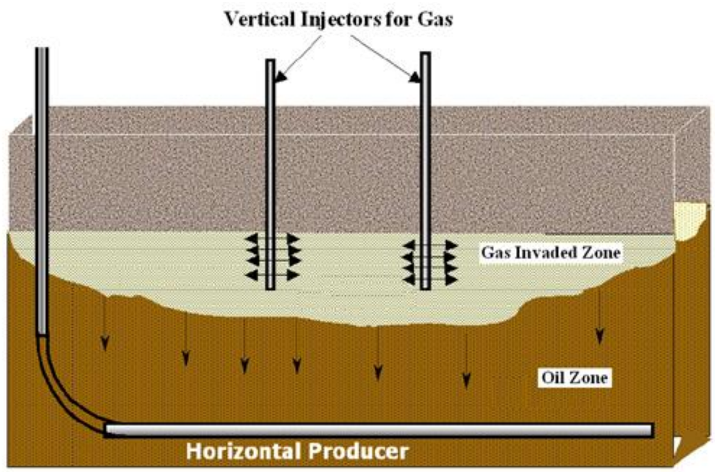

Fig. 1. Schematic of GAGD process [9]

3. The Investigation of the effect of methane gas injection in the GAGD process in a fractured oil reservoir

As mentioned above, in the gas invaded zone created by GAGD process in a fractured oil reservoir, the oil is produced from the matrix blocks which are affected by gravity drainage mechanism. Nevertheless, this mechanism is gradual and slow. Accordingly, the amount of produced oil from the matrix blocks of the gas invaded zone is low [10]. Therefore, to solve this problem, a low-density gas like methane could be injected in the GAGD process. This will result in an increase in density difference in the emergent gas invaded zone. Consequently, a substantial amount of the injected gas, methane, will penetrate into matrix blocks of the gas invaded zone from fractures of this zone, which will accelerate the gravity drainage mechanism in the matrix blocks of the gas invaded zone, and consequently more amount of oil can be produced from matrix blocks of this zone.

4. Reservoir description and methodology

The oil reservoir, studied in this research, is an undersaturated fractured carbonate medium oil reservoir. Also worth noting is that the fractures of this reservoir are microfractures since their permeability is low in the reservoir.

In this research, for investigating the effect of the density of injected gas on the acceleration of the gravity drainage mechanism in the GAGD process, three different gases including carbon dioxide, nitrogen, and methane were injected to the reservoir during this process, and since each of the three gases was injected into the reservoir immiscibly, a reservoir model, whose properties are shown in Table1, is created in the black oil simulator (IMEX) of CMG simulation software. Then the wells – a vertical injector well and a horizontal producer one - are inserted into the reservoir model. The two-dimensional (I-K) and three-dimensional views of the reservoir model, as well as its drilled wells, are depicted, in Figures 2 and 3 respectively.

Table. 1. Properties of reservoir model

Properties	Value	Unit	Properties	Value	Unit
Number of grid blocks in I direction	10		Permeability in K direction (Matrix)	0.19	md
Number of grid blocks in J direction	7		Permeability in I & J directions (Fracture)	2.33	md
Number of grid blocks in K direction	2		Permeability in K direction (Fracture)	8.6	md
Reservoir length	5000	ft	Reservoir temperature	122	°F
Reservoir width	3500	ft	Initial reservoir pressure	2500	Psia
Reservoir thickness	542	ft	Bubble point pressure	1500	Psia
Reservoir has no gas cap and aquifer			API	24.1388	
Porosity (Matrix)	0.059		Rock thermal conductivity	24	Btu/ft.day.°F
Porosity (Fracture)	0.00022		Bottom hole pressure (BHP) for producer well	4000	Psia
Permeability in I & J directions (Matrix)	2.1	md			

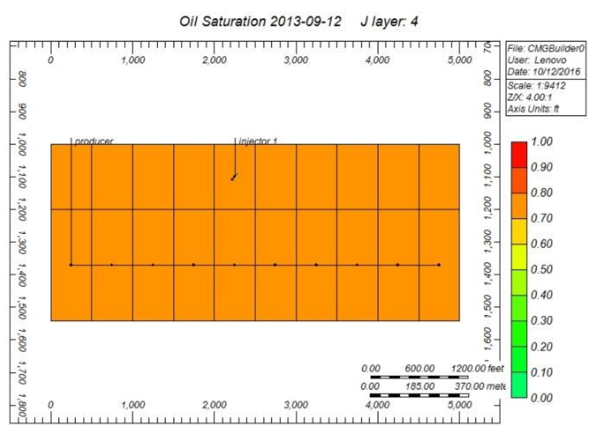

Fig. 2. Two-Dimensional view (I-K) of reservoir model and its drilled wells

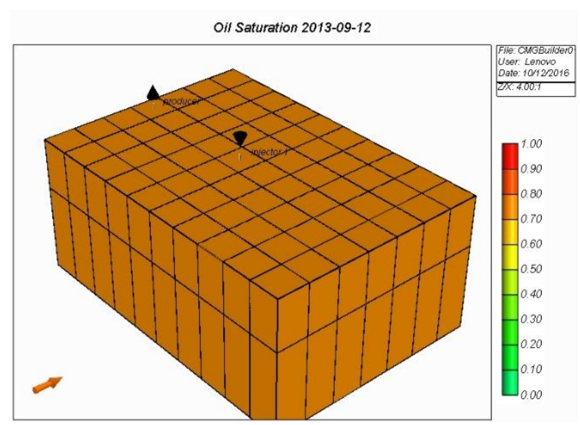

Fig. 3. Three-Dimensional view of reservoir model and its drilled wells

Now, the simulation study of the GAGD process in reservoir model by injecting three different gases, including carbon dioxide, nitrogen, and methane initiated on September 12, 2013, and will have been accomplished by September 12, 2020, a period of 7 years. In this simulation, the rate of injected gas from the injector well was held constant at 30 MMScf/day in every three scenarios.

5. Results and discussion

The injected methane gas in the GAGD process in a fractured medium oil reservoir has less density than the injected nitrogen and carbon dioxide gases in this process. Therefore, the density difference in the gas invaded zone increases remarkably during the methane gas injection scenario in GAGD process in comparison to the other gases injection scenarios in this process. This will contribute to the penetration of a high volume of injected methane gas into the matrix blocks of gas invaded zone from fractures of this zone; accordingly, gravity drainage mechanism is accelerated in the matrix blocks of the gas invaded zone and will result in more oil production from matrix blocks of this zone (figures 4a, 4b, 4c), which increases the oil production rate and cumulative oil production from the reservoir in the methane gas injection scenario in comparison with the other gases injection scenarios (figures 5 and 6).

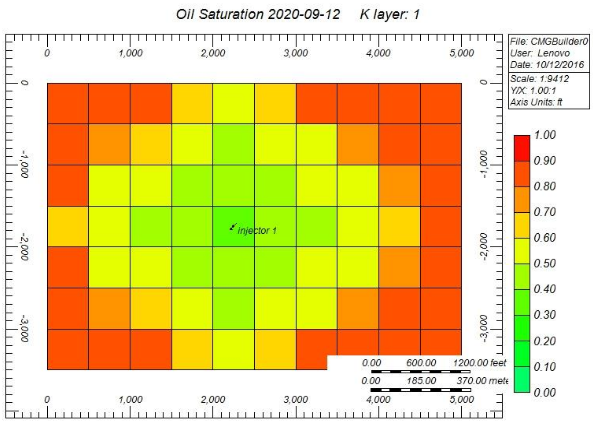

Fig. 4a. Matrix blocks oil saturation in CO2 gas injection scenario in GAGD process after 7 years

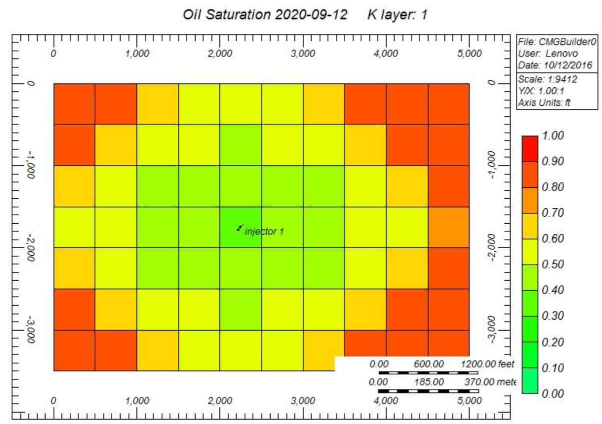

Fig. 4b. Matrix blocks oil saturation in N2 gas injection scenario in GAGD process after 7 years

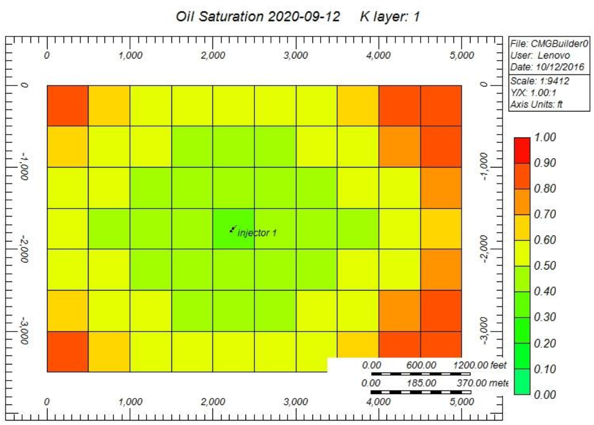

Fig. 4c. Matrix blocks oil saturation in CH4 gas injection scenario in GAGD process after 7 years

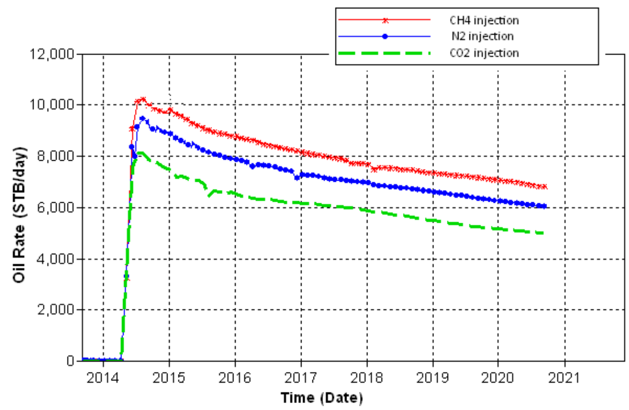

Fig. 5. Oil production rate from reservoir versus time

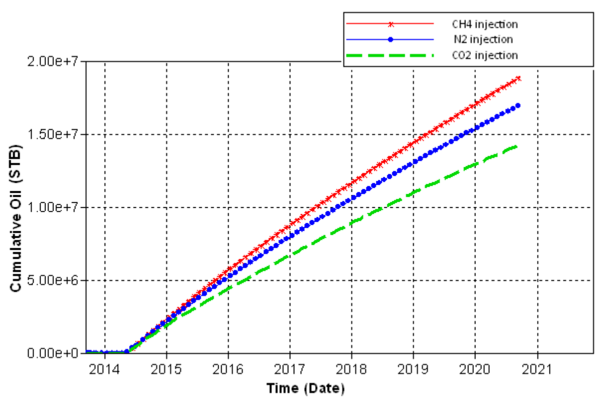

Fig. 6. Cumulative oil production from reservoir vs time

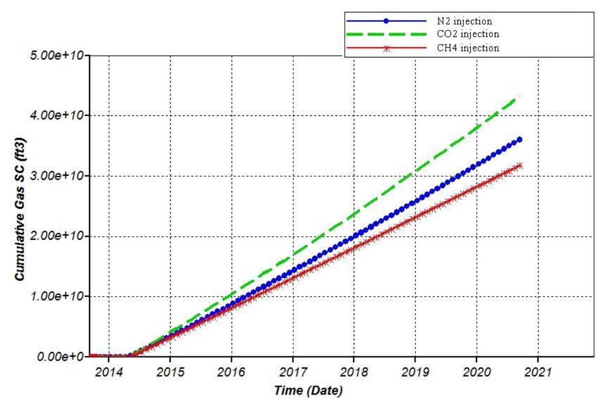

Fig. 7. Cumulative gas production from reservoir vs time

As shown in Figure 8, the gas-oil ratio (GOR) in the methane gas injection scenario in the GAGD process is reduced significantly in comparison to the other gases injection scenarios in this process, and this can be attributed to two factors:

1. Considering that methane gas has less density than the nitrogen and carbon dioxide gases, a high volume of injected methane gas penetrates into the matrix blocks of gas invaded

zone from the fractures of this zone, which causes the reduction of cumulative gas production from the reservoir (Fig. 7), hence depletion in GOR.

Given that the gravity drainage mechanism is accelerated in methane gas injection scenario in GAGD process in comparison to the other scenarios, a larger amount of oil is produced from the matrix blocks of the gas invaded zone. Accordingly, the oil production from the reservoir will augment, and as a result, the GOR will drop.

As it is shown in table 2 which is provided according to fig. 9, methane gas injection scenario in GAGD process has 3.48% and 1.48% more oil recovery factor than the carbon dioxide gas injection scenario and nitrogen gas injection scenario in this process respectively due to the more oil production from the reservoir in the methane gas injection scenario than the other scenarios.

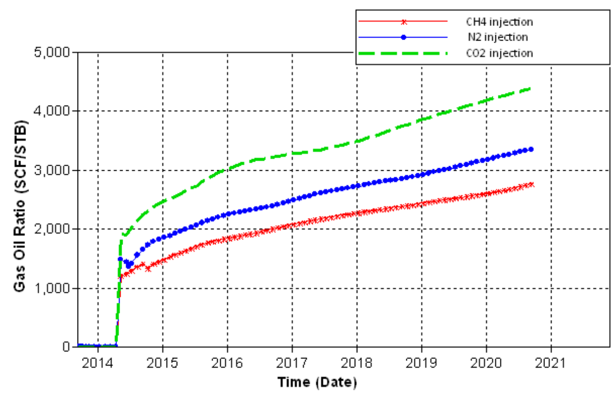

Fig. 8.Gas-oil Ratio (GOR) versus time

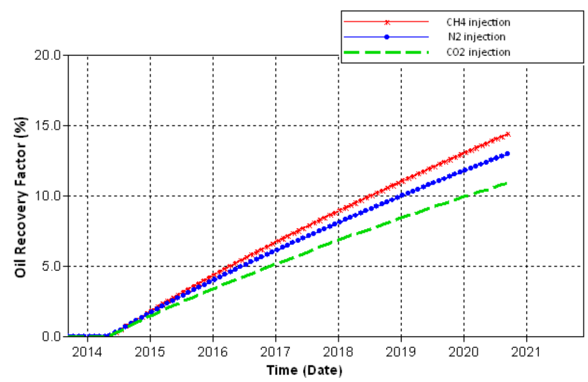

Fig. 9. Oil recovery factor versus time

Table. 2. The comparison of oil recovery factors during different immiscible gases injection in the GAGD process

Oil recovery factor (%)	Simulation time (year)	Injection rate of injector well (MMScf/day)	Scenario
CO_2 injection	30	7	10.90
N_2 injection	30	7	12.93
CH_4 injection	30	7	14.38

6. Conclusions

1. On account of the fact that the gravity drainage mechanism is accelerated more in the gas invaded zone during the methane gas injection scenario in the GAGD process than the nitrogen and carbon dioxide injection scenarios, the oil production from matrix blocks will increase, and this is followed by an increase in the oil production from the reservoir. Therefore, it is concluded that the methane gas injection scenario has more oil production rate, cumulative oil production, and oil recovery factor than the other scenarios.
2. Because the gas production from the reservoir as a result of methane gas injection in the GAGD process is less than nitrogen and carbon dioxide gases injection scenarios in this process, and also the oil production from the reservoir in the methane gas injection scenario in the GAGD process is more than the other scenarios in this process. Therefore the gas-oil ratio (GOR) in the methane gas injection scenario in the GAGD process becomes less than the other scenarios in this process.

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