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Investigation and Simulation Study of Hot Gas Injection in GAGD Process in a Fractured Medium Oil Reservoir

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Abstract

Applying gas assisted gravity drainage (GAGD) process in a fractured medium oil reservoir is led to create a gas invaded zone in the reservoir in which the gravity drainage mechanism caused to produce oil from the matrix blocks of this zone; but whereas gravity drainage mechanism is gradual and slow, so the oil production decreases from matrix blocks of this zone which is caused to reduce the oil production from the reservoir. To solve this problem, this research investigates hot gas injection in the GAGD process in a fractured medium oil reservoir. Hot gas injection in the GAGD process in a fractured medium oil reservoir will accelerate the gravity drainage mechanism in the hot gas invaded zone in two ways: firstly, whereas hot injected gas has got low density, the density difference will be increased in the hot gas invaded zone Therefore, high volume of hot injected gas penetrates into matrix blocks from fractures and leads to more oil production from matrix blocks. Secondly, hot gas injection will increase the oil production from matrix blocks with oil viscosity reduction within matrix block, therefore it leads to create a new process entitled ˝hot gas assisted acelerate gravity drainage (HGAAGD)˝. Simulation results by CMG simulation software show that HGAAGD process has more oil production rate, cumulative oil production, and less gas-oil ratio (GOR) than the GAGD process. Also HGAAGD process has 1.56% more oil recovery factor than GAGD process.

Keywords: GAGD; Hot Gas Injection; Gravity Drainage; Fractured Reservoir; HGAAGD

1. Introduction

Water alternating gas injection (WAG) process, at first, introduced by Caudle and Dyes [1] to solve the problems of the continuous gas injection process such as: gas high mobility, gas viscous fingering and the overriding of gas; but this process had problems such as increasing water saturation in the reservoir which caused the reduction of reservoir permeability and consequently reduce 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]. It is due to 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 that caused to take place the underriding and overriding phenomena there [4]. In this case, the high volume of oil doesn't produce and remain 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 an advantage because it causes to produce more from oil in-place of the reservoir without increasing water saturation there [5-6]. It should be mentioned that GAGD process, at first, has been applied for inclined reservoirs but nowadays it applies for fractured reservoirs by its perfect development. Now, in this research, also, with increasing of injected gas temperature in the GAGD process, is tried to take it more applicable and developed it more for fractured reservoirs; as the oil production increases remarkably from fractured reservoirs.

2. Description of GAGD process in a fractured oil reservoir

GAGD [7] is a process in which used several vertical injector wells for gas injection and one horizontal producer well in bottom of the layer for oil production (Fig. 1). In the beginning of gas injection in the GAGD process in a fractured oil reservoir, injected gas moves towards top of the reservoir and creates 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 [8].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.

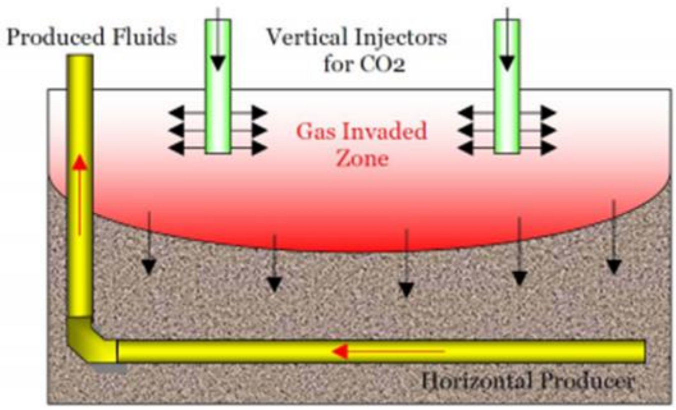

Fig. 1. Schematic of GAGD process [9]

3. Investigation of effects of hot 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, oil produces from the matrix blocks which is affected by gravity drainage mechanism; whereas, this mechanism is gradual and slow, the oil production from the matrix blocks of the gas invaded zone becomes a few. Therefore, to solve this problem, the hot gas injection can be used than ordinary gas in the GAGD process. Hot gas injection in the GAGD process in a fractured oil reservoir effects on 3 factors as below:

3.1. Creating the artificial hot gas cap quickly in the reservoir

Gas volume has a direct proportion to temperature, therefore by increasing injected gas temperature in the GAGD process, this gas occupies more volume in the reservoir, which is caused to create the artificial hot gas cap sooner and begins to expand therefore the oil produces sooner from the reservoir.

3.2. Reducing oil viscosity in the matrix blocks of the hot gas invaded zone

Hot gas injection in the GAGD process in a fractured oil reservoir, creates a hot gas invaded zone in which the matrix blocks are surrounded by hot gas. In such conditions, by heat transferring from hot gas within fractures to matrix blocks, the oil within matrix blocks is heated and reduced its viscosity. Thus, the oil mobility in the matrix blocks is increased and led to accelerate the gravity drainage mechanism in matrix blocks of the hot gas invaded zone and is led to produce more amount of oil from matrix blocks of this zone.

3.3. Increasing density difference in the hot gas invaded zone

Gas density has an inverse proportion to temperature; therefore, by increasing injected gas temperature in the GAGD process, injected gas density is reduced which is led to increase the density difference in the hot gas invaded zone. therefore, the high volume of injected hot gas penetrates to matrix blocks from fractures of this zone and causes to accelerate the gravity drainage mechanism in the matrix blocks of the hot gas invaded zone and results to produce more amount of oil from matrix blocks of this zone.

Hence with respect to effects of hot gas injection in the GAGD process in a fractured oil reservoir on the oil viscosity reduction in the matrix blocks of hot gas invaded zone and on density difference increase in this zone, the gravity drainage mechanism accelerates in the hot gas invaded zone. Therefore, it can be said that the hot gas injection in the GAGD process in a fractured oil reservoir is caused to create a new process under title "Hot Gas Assisted Accelerate Gravity Drainage (HGAAGD)" process.

4. Reservoir description and methodology

The oil reservoir study in this research is an undersaturated fractured carbonate medium oil reservoir.

In this research, for comparing the performance of two GAGD and HGAAGD processes to each other, the reservoir model provides separately in the both of IMEX and STARS simulators, which are shown its properties in table1. Then the wells including one vertical injector well and one horizontal producer well are entered into the reservoir model. Figures 2 and 3 respectively show the two-dimensional view (I-K) and three-dimensional view of the reservoir model and its drilled wells.

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			

Now, GAGD and HGAAGD processes are simulated by IMEX and STARS simulators as in this simulation, from injector well, inject CO_2 gas with constant rate 30 MMScf/day in both GAGD and HGAAGD processes, with a difference that ordinary CO_2 gas injects in the GAGD process but hot CO_2 gas with (284°F) injects in the HGAAGD process; also in this simulation, the injection duration of the ordinary co_2 gas and hot CO_2 gas is 7 years from 2013/09/12 to 2020/09/12 in the GAGD and HGAAGD processes respectively.

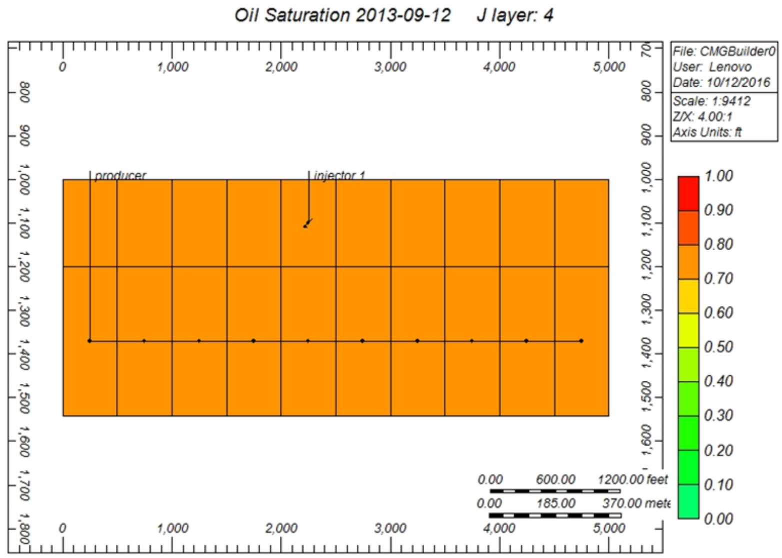

Fig. 2.Two-dimensional view (I-K) of reservoir model and its drilled wells

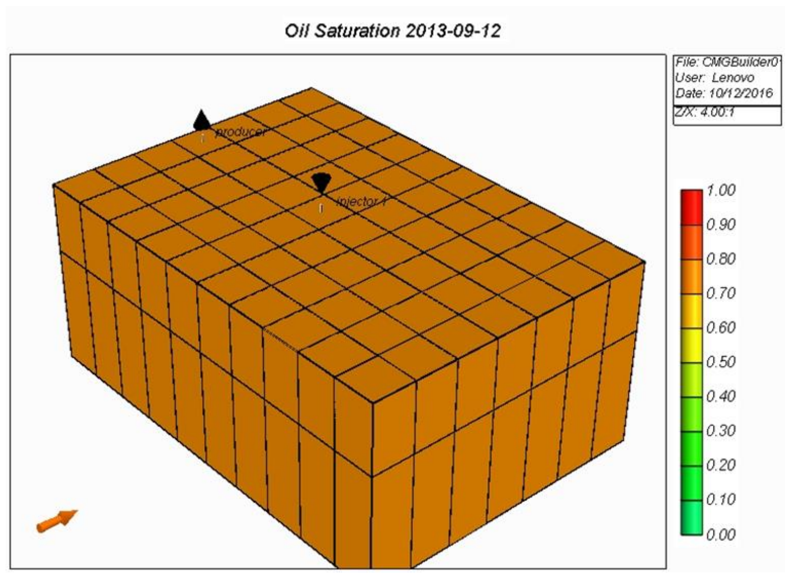

Fig. 3.Three-dimensional view of reservoir model and its drilled wells

5. Results and discussion

Since, the hot injected co_2 gas in the HGAAGD process occupies more volume in the reservoir than ordinary co_2 gas in the GAGD process, therefore the artificial hot gas cap in the HGAAGD process is created and begins to expand in the reservoir 31 days sooner than the artificial gas cap in the GAGD process. Thus the oil produces from the reservoir 31 days sooner in the HGAAGD process than the oil production in the GAGD process (beginning of the fig. 5). Also in the HGAAGD process, because the heat arised from hot injected co_2 gas causes to oil viscosity reduction within matrix blocks of the hot gas invaded zone and increases the density difference in this zone, Hence, gravity drainage mechanism is accelerated and result in more oil production from matrix blocks of the hot gas invaded zone (figures 4a and 4b), which is caused to be significant increase of the oil production rate and cumulative oil production from the reservoir in the HGAAGD process than the GAGD process (figures 5 and 6).

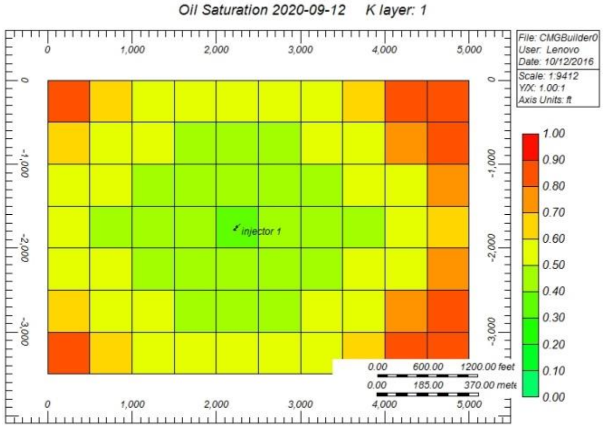

Fig. 4a. Matrix blocks oil saturation in HGAAGD process after 7 years

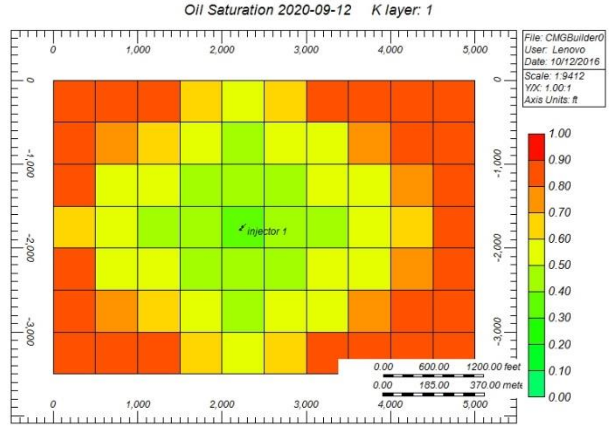

Fig. 4b. Matrix blocks oil saturation in GAGD process after 7 years

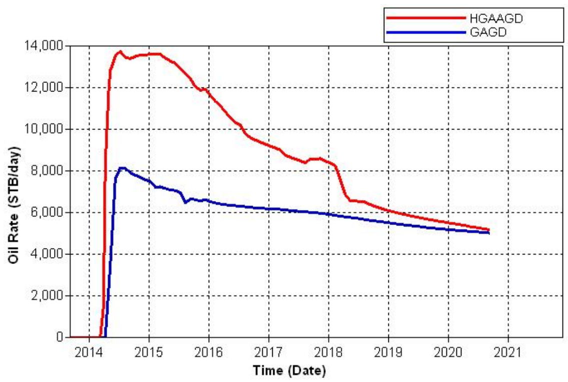

Fig. 5. Oil Production Rate from Reservoir versus Time for GAGD and HGAAGD Processes

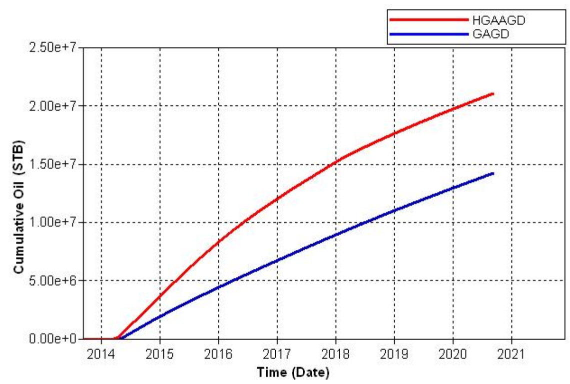

Fig. 6. Cumulative Oil Production from Reservoir versus Time for GAGD and HGAAGD Processes

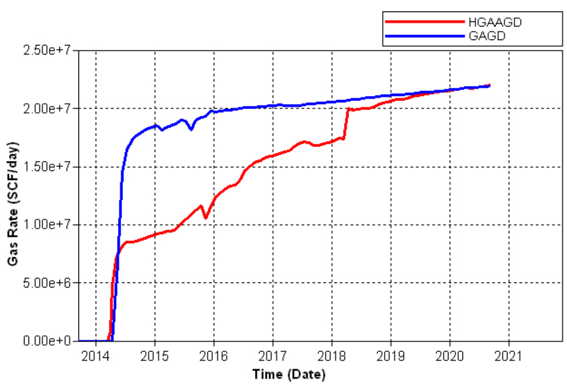

Fig. 7.Gas Production Rate from reservoir versus time for GAGD and HGAAGD processes

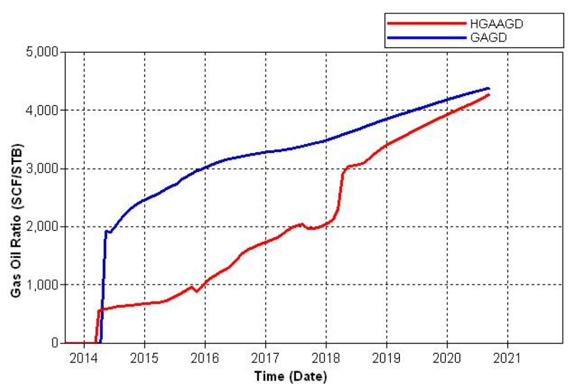

Fig. 8. Gas-Oil Ratio (GOR) versus time for GAGD and HGAAGD processes

As shown in the fig.8, gas-oil ratio (GOR) in the HGAAGD process is reduced significantly than the GAGD process due to the 2 factors as below:

1. Because density of the hot injected CO_2 gas is low, therefore the density difference increases in the hot gas invaded zone; Hence the high volume of the hot injected CO_2 gas penetrates into matrix blocks from hot gas invaded zone fractures which is caused the reduction of the hot injected co_2 gas rate which are moved from fractures towards the producer well (fig. 7) and is resulted in GOR reduction.

2. Whereas gravity drainage mechanism is accelerated in the HGAAGD process and more amount of oil produce from matrix blocks of the hot gas invaded zone therefore, the oil production is increased from the reservoir and is resulted in GOR reduction.

As it is shown in table 2 which is provided according to fig. 9, HGAAGD process has 1.56% more oil recovery factor than the GAGD process due to the more oil production from the reservoir in the HGAAGD process than the GAGD process.

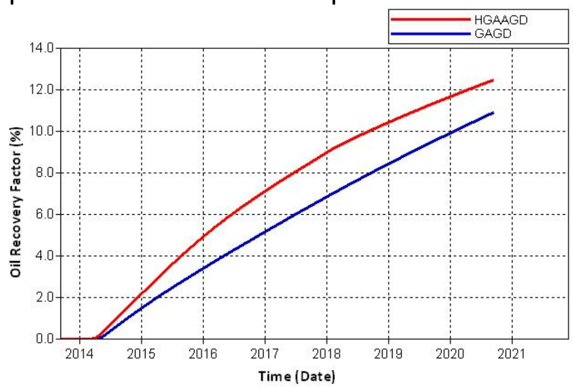

Fig. 9.Oil recovery factor versus time for GAGD and HGAAGD processes

Table. 2. The Comparison of oil recovery factor in the GAGD and HGAAGD processes

Process	Injection rate of injector well (MMScf/day)	Simulation time (year)	Oil recovery factor (%)
GAGD	30	7	10.90
HGAAGD	30	7	12.46

6. Conclusions

1. Hot gas injection in the GAGD process in a fractured medium oil reservoir will accelerate the gravity drainage mechanism in the hot gas invaded zone in two ways: firstly, whereas hot injected gas has got low density, the density difference will be increased in the hot gas invaded zone Therefore, high volume of hot injected gas penetrates into matrix blocks from fractures and leads to more oil production from matrix blocks. Secondly, hot gas injection will increase the oil production from matrix blocks with oil viscosity reduction within matrix block.
2. Hot gas injection in the GAGD process will accelerate the gravity drainage mechanism in the hot gas invaded zone, therefore it will create a new process entitled ˝hot gas assisted acelerate gravity drainage (HGAAGD) ˝.
3. Whereas gravity drainage mechanism is accelerated in the hot gas invaded zone in the HGAAGD process therefore, the oil production from matrix blocks increases and consequently increases the oil production from the reservoir; thus, the HGAAGD process has more oil production rate, cumulative oil production and oil recovery factor than GAGD process.
4. Because the oil production from the reservoir in the HGAAGD process is more than GAGD process and also the gas production from the reservoir in the HGAAGD process is less than GAGD process, therefore the gas-oil ratio (GOR) in the HGAAGD process becomes less than GAGD process.
5. Whereas the oil production from a fractured medium oil reservoir in the HGAAGD process is more than GAGD process hence, applying HGAAGD process is more suitable than GAGD process in the fractured medium oil reservoirs.

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