International Academic Institute for Science and Technology

International Academic Journal of Science and Engineering
Vol. 3, No. 1, 2016, pp. 63-70.
ISSN 2454-3896

International Academic Journal of Science and Engineering

www.iaiest.com

Study the effective factors on gravity drainage process by gas injection (GAGD) for improving oil recovery

Mahdi Behboodi[a] , Abdolmajid Movahedinia[b]

[a]*Master Student of Department of Petroleum Engineering, Omidiyeh Branch , Islamic Azad University, Omidiyeh, Iran*

[b] *Professor Assistant of Department of Petroleum Engineering, Omidiyeh Branch , Islamic Azad University, Omidiyeh, Iran*

Abstract

Gradual and stable relocation of oil by gas, especially when it's with gravity drainage, can have very high coefficient. It is showing, considerable increase of oil recovery measured in compulsory state more than free fall. The most important advantage in gas injection procedure by gravity drainage is using gravity separation between injected gas and oil reservoir that counting as weak side in gas injection processes such as connected gas injection, and recurring injection gas and water .in this study, effects of gas injection, oil production, band number, type and pattern of production and injection wells, heterogeneous porous media, type of injection gas and active aquifer in tank from GAGD process, were considered. If rate of infiltration is under rate of critical injection, dominant forces will be gravity forces that lead to stable floods front and fingered phenomenon will disappear. More numerical of band's number in system leads more recovery of oil. Horizontally injection wells don't help improvement gravity drainage and revenue of vertically injection well helps GAGD. Type of injection gas doesn't affect on rate oil recovery, although rate of co_2 recovery was more than it.

Keywords: gravity drainage, gas injection, type of gas injection, rate of injection, pattern of wells

Introduction:

Enhanced oil recovery operation with common gas injection approaches such as WAG, CGI were used in many field projects that it has increased recovery oil only 5-10%. Over down by chemical method peaked in mid 80s, but now is outdating and flooding thermal generally limits in heavy oil basins. Over down processes such as chemical approaches are very expensive and complex. Gas injection in oil reservoirs has two goals, put pressure on the tank or keeping pressure of the tank and decreasing speed of reservoir pressure.

Theoretical basis of research:

How GAGD works:

In a gas injection method based on the gravity drainage mechanism, gas is injected at the top of pay zone through the vertical or horizontal wells located at the top of the reservoir (Figure 1). The injected gas segregates to create a gas-oil interface which is then slowly displaced towards the simultaneously producing horizontal wells located at the bottom of the pay zone. During this process, the gas injection and oil production volumes are balanced precisely so that the reservoir system remains in the gravity dominated regime. This process is termed as gas assisted gravity drainage method of enhanced oil recovery (GAGD-EOR) (Jadhawar and Sarma, 2008).

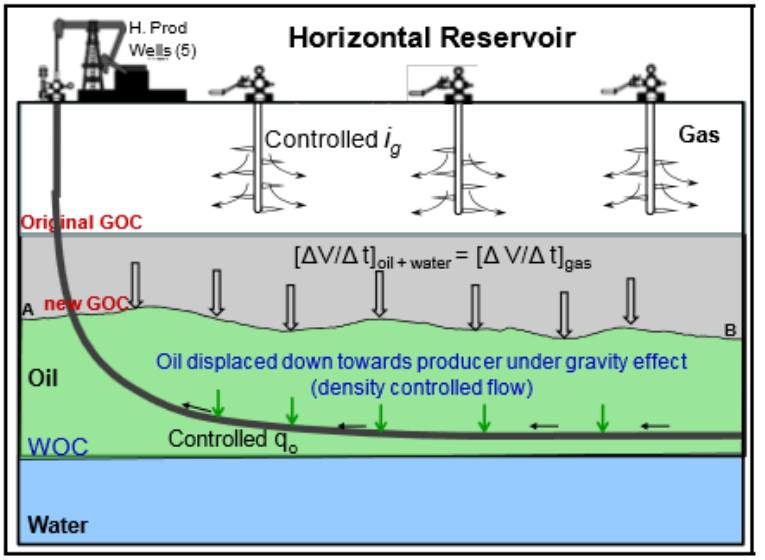

Figure 1: Conceptual GAGD-EOR method (Jadhawar and Sarma, 2008)

Research Background

GAGD Gas-assisted gravity drainage EOR process based on gravity dominant flood uses the advantage of density difference between gas (especially N2 and CO2) and reservoir oil. It was first designed and practiced by Rao et al. in 2001 in L.S.U. to overcome the common problems of conventional gas injection methods

Advantages of CO2 injection:

1- Swell Oil 2- Reduce oil viscosity 3- Extract hydrocarbon from crude oil 4- Function as a solution gas drive 5- May be available as waste gas 6 -Non-hazardous and Non explosive 7- Soluble in water, become acidic and may react with rock to improve permeability

Research methodology

Studied reservoir by Behzad Ahmadi that was studied with Eclipse software, is one of the fractured reservoir which existed at western of Iran and it contains three production wells, that produce 9000 barrels daily. This study is based on double porosity and chosen base grid system to build a static model in simulation reservoir, is corner point. Grid system dimension of the model is 30*33*8 which totally has 7920 blocks

Research tools

All devices used in Akhlaghy's experiments consisted nine levels(Figure 2): Hele-Shaw(c), mass flow meter(B), gas cylinders(Methane, nitrogen and carbon dioxide) (A), the vacuum pump(G), digital camera(H), cylinders(I), digital scale(E), data logging system(F) and Fluid storage container(D).

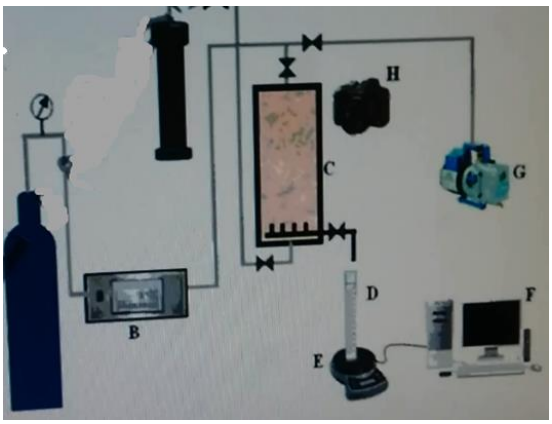

Figure 2: Devices used in Akhlaghy's experiments

The Analysis of Data

Data analysis in this article for the process of GAGD, with the help of simulation software ECLIPS, and by laboratory studies, has been carried out.

Research Findings

1-The effect of gas injection rates and oil production

Maximum injection rate in a reservoir that is used to achieve a stable flood front is called Critical Rate. Indeed in critical rate, effects of favorable gravity force dominance by increasing the amount of viscous forces. For miscible flooding with the stability of gravity, Hill in 1952, introduced a formula for Critical injection speed that at rates higher than that, Viscose instability happens due to viscous forces dominate over gravity forces. This equation assumes a contact area between injected phase and dicplaced phage, without mixing of solvent and oil that is behind the leading front.(Akhlaghi 2012).

$$V_c = \frac{2/741.\Delta\rho.K.\sin\theta}{\phi.\Delta\mu}$$

Equation 1: Critical vertical injection speed

V_C: Critical vertical injection speed (ft/day)

P : The density(gr/cc)
K : Permeability (Darcy)
θ : Angle (Degree-from the Horizon)
$\Delta\mu$: Viscosity Difference (cp)
ϕ : Porosity

Floods speeds by controlling rate of injection determine that according to the force of gravity is the dominant process or not. If rate of injection is high, two negative factors affect GAGD process. Pressure due to increases force viscous rapidly and also increasing CO_2 density, which lead less gravity on process. On other hand, high rate of injection tend to reduction the time for completing process and make it more attractive financially. In addition to, co2 pressure increasing in solution reduce the surface tension. As a result it improves microscopic displacement efficiency. It observed, high rate injection in simulation by Behzad Ahmadi increase finally oil recovery in GAGD process. Moreover, if pressure injection and ratio production doesn't manage, fingered phenomenon can occur due to premature rupture. It is related, fingered in during flood to size of viscous force which related to injection ratio. If ratio of mix injection is high, there are viscous forces and as a result due to fingered phenomenon. If ratio of flood injection is under critical ratio injection, dominant forces will be gravity forces, lead to stable flood and there will not fingered. Jadhawar and Sarma in 2010 consider two approaches in effects of gas injection ratio and oil production.
1-reservoir response to gas injection ratio and oil production for 4 sets of variable values.
2-difference oil production ratio in stable gas injection ration.
They conclude in first state which imposed higher, GOR will increase if imposed ratio goes up. After breaking co2 reservoir pressure is stable in whole there. Second, if oil production increase then GOR and WOR go up. Recovery cumulative oil Reduction will be more in lower layer due to reduction of gravity ratio viscosity. It shows As a result, higher GOR after the first break can decrease due to production rate reduction. (Ahmadi 1392).

2- Bond number effect on oil recovery in GAGD process
These Experiments was prepared on oil recovery and process experiment in rate cc/min 40 was done by Naser Akhlaghi. CR-HP was done by jamming cell with 212-150 grain size of silica, while CR-LP by jamming cell with 106-150. Bond number can be showed by equation 2:

$$N_B = \frac{\Delta P_{(gas-oil)} g\left(\frac{\kappa}{\phi}\right)}{\sigma_{go}}$$

Equation 2: the relating between permeability and bond number dimensionless.

Absolute permeability in that equation depends on particles diameter accumulated in cell:
Equation 3 showed relation between diameter of particles with absolute permeability.

$$\kappa = \frac{D_P^2 \phi^3}{u_2 \tau (1-\phi)^2}$$

Equation 3: The relationship between particles diameter with absolute permeability

Enlarge the size of grain base on 2, 3 equation causes to go up absolute permeability lead to increase the band number. It is gain, two different band number with cell stacking in different size in this section. This figure shows oil recovery in model with bigger grains is getting much because of the grains with larger size provide higher absolute permeability. It leads to higher value of the band number in the system. According the result of this experiment, higher values of the band number in system lead to more oil recovery. NB is floating forces ratio moving forces. As a result shows more oil recovery gain when there is more gravity flow in system instead of capillary flow. Absolute permeability system in CR-HP is more than CR-LP (almost triplicate) and in CR-HP was gained stable gravity falling condition. Table 1 shows, effect of band number on oil recovery at GAGD process. (Akhlaghi 1390)

Table 1: Bond number effect on oil recovery. (Akhlaghi 1390)

Oil (%IOIP)recovery	(N_C)	(N_B)	Experiment name
56	5.45E-08	3.3E-05	CR-HP
53	6.53E-08	7.08E-06	CR-LP

3- Effect of injection and production wells and patterns of injection and production wells on gravity drainage:

Jadhawar and Sarma in 2010 observed there is more GOR in horizontal well compared vertical well, they investigated horizontal injection well can't help to gravity falling improvement and vertical well performance help GAGD. Vertical oil production wells have problems such as: specific issues taper sweep efficiency gas/water, sands problem, high pressure drop. Horizontal well provide swept yield with delay premature rupture of handled fluid. They considered, early co2 penetration occur in production wells. In vertical wells delayed regular well pattern 2-3 years in non-fusion and 12 years in fusion compared horizontal well. GOR is less in co2 injection well compared Horizontal well. Moreover, it is showing, co2 vertical well provide more Horizontal floods compared co2 horizontal well. It delays co2 premature intrusion. Regular well pattern effects on maintaining reservoir pressure compared irregular well pattern. After co2 premature penetration it has observed, oil production has quickly reduction in both processes the enhanced oil gravity falling with co2 miscible and immiscible.

It is showing, regular well pattern provide more co2 flood horizontal or gas-oil surface compared irregular well pattern (Ahmadi 2014).

4- Effect on heterogeneous porous on performance of GAGA process:

In tests has done in this section, incompatible heterogeneous porous effect on oil recovery was examined. In this experiments prepared porous area in cell filled sand grain made silica in two size 150-212 and 106-150 , each half the height of cell (cm5/33) for reach to tangle heterogeneous area. In most geology area

due to overburden pressure, make low-permeable layer lower than high-permeable layer. So, grains size 150-106 with 22 Darcy permeability were stuffed

In this report, three tests have done CR-HT1, CR-HT2 and CR-HT3 with stable gas ratio and CR-HT with stable pressure compared with other test done in recent sections. Because of vertical permeability of porous area (25/11) is less than horizontal permeability of firs layer, therefore gas in this area desire to move horizontally. In layer two, gas has desire to move vertically because vertical permeability of model is more than vertical permeability of this layer (5/7 Darcy). When gas moving from area with higher permeability to lower permeability like figure 3, gas desire to move horizontally due to pressure against moving forward.

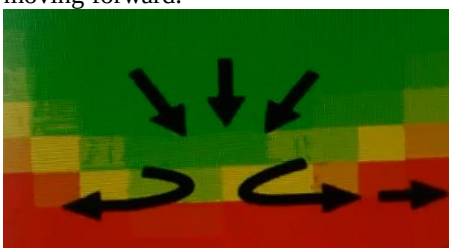

Figure 3: how to move gas in incompatible area from area with high permeability to lower permeability

In first series of tests, when injection with low ratio had done (cc/min5), gas contact with first layer flow horizontally, due to horizontal permeability is higher than vertical permeability and has sufficient time for gas front formation on top of the porous area .In addition to more oil production in heterogeneous area improve time of attain to gas break point in this area and has longer delay compared test in homogeneous area. In second series of tests, injection ratio was quadruplicated (cc/min20). In this injection ratio, observed rate of production in most of the time in both homogeneous and heterogeneous is same. Considering rate increase gas hasn't had sufficient time to stable resistance front and so moving downward in model like figure 4 more than moving toward. It is occur 2 min later, time to reach break point in heterogeneous area.

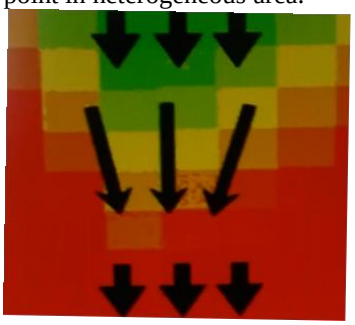

Figure 4: How to move gas in heterogeneous environments at high injection rate

In third series, ratio injection increased tenfold (cc/min50). Increasing injection ratio compared last series, production measure in homogeneous was more than in heterogeneous. One reason for increasing of production in porous homogeneous area is more vertical permeability in model compared heterogeneous. As explained, increasing permeability can increased rate of production.

In forth series, gas injection pressure was kept constant and effect of gas injection on heterogeneous area was observed. Oil recovery at heterogeneous area is more than homogeneous due to constant injection

pressure that you can related to the items were mentioned above. It is equal, time to reach gas break point in these tests (Akhlaghi 2012).

Table 2: Effect of heterogeneous porous media and flow rate on oil recovery (Akhlaghi 2012).

CP-HT	CR-HT3	CR-HT2	CR-HT1	Name of test
Oil-co_2	Oil-co_2	Oil-co_2	Oil-co_2	Fluid-fluid system
4 Psig	50 (cc/min)	20 (cc/min)	5 (cc/min)	Gas injection ratio /gas injection pressure
75	61.2	65.5	72	**%**Oil recovery

5-How type of gas injection Effects on GAGD process:

Three tests named CR-N2, CR-CO2 and CR-CH4 in order with nitrogen, carbon dioxide and methane was done to consider effect type of injection gas on oil recovery. All the tests conditions were chosen same (except type of injection gas).

All of test in constant ratio (cc/min20) was done. Table 3 shows, type of gas injection can't effect on oil recovery in GAGD process.

Table 3: type of gas injection Effects on GAGD process (Akhlaghi 2012).

Co_2	N_2	CH_4	Type of gas
65.5	61.2	64	%Oil recovery

As you saw in table 3, difference oil finally production in all three tests is little (approximately 4%) and type of injection gas can't effect on GAGD performance at immiscible displacement. But can communicate this difference in oil recovery to more carbon dioxide solubility in oil and more solubility of methane than nitrogen gas. . (Akhlagh 2012).

6. Effect of water influx

In order to evaluate the aquifer effect on the performance of GAGD, an aquifer with Fetkovich model and a productivity index (PI) equal to 100 (STBD/psia) was considered to simulate the active water influx that surrounded the major part of the mentioned oil field. Moreover, two other cases of aquifer with a productivity index of 0.1 and 1 were simulated to fulfill the partial and weak aquifer as well.

The results with and without aquifer were observed and were in agreement with our expectations. Due to aquifer strong pressure maintenance, the injected gas could not deplete the mass of oil out of the matrix and, as a result, was trapped at the crest point. This phenomenon continued until fractures sufficiently depleted bulk of oil and drawdown helped the gas to find a path toward the production well. Therefore, without any significant impact on the matrix, gas passed and no gravity drainage process existed. Active aquifer further diminished the GAGD performance and disabled the gravity drainage process. In addition, partial and weak aquifers, which do not maintain the reservoir pressure very much, provided a better condition for the gravity drainage process to respond better. As a result, compensating the drawdown in GAGD EOR was not helpful at all and made the process act as a useless method wasting money and time. To fulfill the GAGD EOR in such conditions, we should have omitted this issue, or at least debilitated the aquifer strength, to let the reservoir pressure descend and then inject CO2 to form the desirable gravity drainage process. In the case in which aquifer was widespread enough to affect the reservoir severely, two vertical wells were intended to be bored in the water zone and depleted the water twice as much. The highest efficiency was gained when two vertical wells were completed in aquifer zone with a productivity index of one. (Delalat and Kharrat. 2013)

Conclusion:

1- Increase band number and oil recovery due to increasing absolute permeability.
2- Increasing ratio of gas injection can increase oil recovery but if ratio of gas injection is more than critical, oil recovery reduction is observed. Indeed, if ratio of injection is critical dominant forces will be gravity forces. Fingering phenomenon doesn't exist.
3- To study, three gases were chosen for gas injection, methane, nitrogen, and carbon dioxide. It is showing, slight increasing oil recovery in test with carbon dioxide due to higher solubility of gas in oil.
4- If active aquifer exists in reservoir due to aquifer strong pressure maintenance, the injected gas could not deplete the mass of oil out of the matrix and, as a result, was trapped at the crest point. This phenomenon continued until fractures sufficiently depleted bulk of oil and drawdown helped the gas to find a path toward the production well.

Practical suggestions:

It is better injection rate be less than the Critical injection rate and it is possible to use the available gas in each region (regardless of the type of gas) for injection to carried out the GAGD operations. Since strong aquifer had a reverse effect on the influence of GAGD and almost completely disabled the gravity drainage mechanism, it's better to reduce the power of the aquifer with drilling of production wells in aquifer region. The proposed model can be investigated as a multi-objective optimization problem and then solved using the metaheuristic algorithm such as: NSGA-II (Li et al., 2016), MOPSO (Mobin et al., 2017), etc.

References:

Ahmadi, Behzad (2014). Gas-assisted gravity drainage simulation in fractured reservoirs and study the factors that affect this process, MSc Thesis, Islamic Azad university of Tehran.

Akhlagh, Naser (2012).Study of GAGD process in one of the Iranian offshore oil fields and Optimization of horizontal wells and history matching with artificial neural network, MSc Thesis, Islamic Azad university of Tehran.

Al-Mudhafar and Rao (2015). Optimization of Gas Assisted Gravity Drainage (GAGD) Process in a Heterogeneous Sandstone Reservoir: Field-Scale Study SPE-174579, Louisiana State University.

Jadhawar and Sarma, (2008). Scaling and Sensitivity Analysis of Gas-Oil Gravity Drainage EOR. SPE 115065. Australian School of Petroleum, University of Adelaide.

M. Delalat and R. Kharrat. (2013). Investigating the Effects of Heterogeneity, Injection Rate, and Water Influx on GAGD EOR in Naturally Fractured Reservoirs. Iranian Journal of Oil & Gas Science and Technology, Vol. 2 (2013), No. 1, pp. 09-21

Li Z., Mobin M., Keyser T. (2016). Multi-objective and Multi-Stage Reliability Growth Planning in Early .Product Development Stage, IEEE Transaction on Reliability, 65(2), 769-781.

Mobin M., Li Z., Komaki M. (2017). A Multi-Objective Approach for Multi-Stage Reliability Growth Planning by Considering the Timing of New Technologies Introduction, IEEE Transaction on Reliability, DOI: 10.1109/TR.2016.2638124.