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Simulation Study of Immiscible Gas Injection in Southwest Iran Petroleum Reservoir

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ABSTRACT

In this study, an eclipse simulator has been used to evaluate gas injection with different flow rate. This is one of the most useful software applications used in the petroleum industry of Iran. It has different modules that each of them is used in specific part of the simulation. The first task in software in this study is to model the static reservoir. The second task is identifying production and injection wells. In continue we entered the field data into the software repository, then will start the gas injection. In this study of 2020 year, reservoir is produced by natural energy and produces no effect whatsoever on the EOR methods and in 2020 year, after 30 years of gas injection means, it continues until 50. Through production graphs, with or without gas injection, we can survey reservoir performance. We discussed about various scenarios on the reservoir. After considering several scenarios with different gas injection rate that is the best scenario for the production of reservoir to predict the future, we calculate the reservoir ultimate recovery. In this study we investigate performance and the effect of the main parameters of the reservoir on the production rate.
KEYWORDS: immiscible injection, displacement efficiency, gravity drainage, segregation.

INTRODUCTION

Since the end of world war II development of enhanced oil recovery processes (EOR) broke out and it continued. Also for the future of all countries a lot of efforts went into EOR reservoirs. Today, the development of human societies and the need for energy in life and the limited resources increased the importance of enhanced petroleum recovery issues [1]. Due to the different stages of production associated with hydrocarbon reservoirs, EOR petroleum resources can not be separated from early stages. We should have an overall plan or plans from the start of production to next EOR methods and to the end of the reservoir age. By this way we can make a right planning and assessment from the beginning of the reservoir production for a long time till we use this information in the future. In order to improve and enhance petroleum recovery and use of resources and the protection of the reservoir we can adopt a comprehensive outline. Now a days some of the big companies regard to the remarkable progresses that has been made in the petroleum industry predicted 75% EOR. This can be a big and dramatic change in the macroeconomic level of countries [2].

By increasing the need of the world to energy and specific attention of costumers to petroleum, more enhancing of petroleum fields and finding new fields are necessary for producer countries in order to handling consuming market [4]. So producer countries are trying to gain more and more petroleum from their fields by using different programs in order to gain more shares in world market. By this way the issue of maintenance of petroleum fields and enhancing recovery from petroleum reservoir has been constantly in attention of producer countries and every year a huge sum of money pay for research budget on enhancing recovery of petroleum reservoir and these reservoir owners are trying to use their sources with new and inexpensive ways [5,6].

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MATERIALS AND METHODS

Geochemical study of considered reservoir

This Petroleum Field which is located in the south western Iran, is under studying with the aim of identifying the source of rocks for petroleum generator, checking thermally mature, the kind of petroleum generator organic materials, and investigating the history of deposits burial with different geo-chemical methods. Deposits of hyper-carbonate rock are petroleum field in reclamation conditions and contains naval organic generator (kerogen type I). On the basis of the amount of sterance C28/C29 ratio in considered reservoir, the age of rock is under Cretaceous and it is thought that the best candidate for this petroleum field is Cretaceous Carbonate lithology and the age of lower Cretaceous in specific area. In this reservoir there is column of petroleum with 400 meters height (petroleum with API 38-39).

Static model (Fig 1)

The static model with grid number, 43 grid in i direction, 97 grid in j direction and 20 grid in k direction, it means that it totally has 83,420 grid (43i*97j*20k).

A dimension of grid in this study is 200 × 200 m. In this model, there are 56 wells totally, 47 producer wells and 9 injector wells. Our static model has 20 shots in the third layer and injection is done in third petroleum layer of this reservoir and in depth of 4440 meters above sea level. The third layer is the deepest. Permeability of the reservoirs considered 10 md. The initial reservoir pressure is 9179 psi and bubble point pressure is 4768 psi. The initial residual petroleum estimated 3.5 billion barrels. Below figure shows the reservoir and the location of wells.

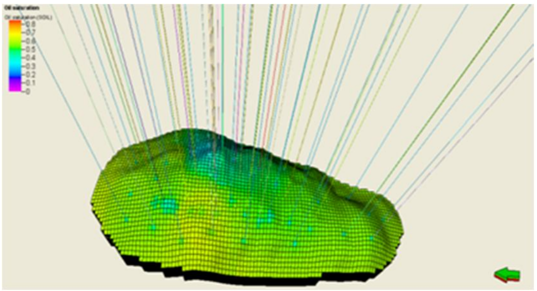


Figure 1. reservoir static model

Immiscible injection.

In this study, the flow gas is displacing gas; it means the depletion process take place. In this process, gas as a non-wetting fluid inject to a reservoir containing an petroleum-injected and it causes petroleum mobility.in this way we investigate two miscible and immiscible displacement mechanism for a system containing gas, as the displacing fluid and petroleum, as the displaced fluid [7].

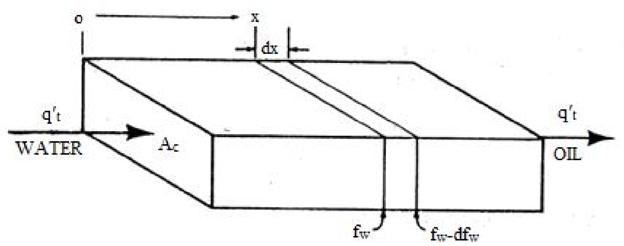
Immiscible Depletion Drainage Mechanism

In immiscible displacement of reservoirs with low slope the equation of Buckley–Leveret is used. This theory will be explained in further. In this theory, capillary pressure and gravity force are neglected. By this relationship we can reach the liquid fractional flow. Generally in a porous medium there are various forces that in the presence of petroleum-gas-water together affected on displacement mechanism [8].

The Buckley-Leveret displacement mechanism.

The process of petroleum displacement from rocks together with water is like fluid displacement by leaky piston. Buckley and leveret developed a theory of displacement based on the relative permeability concept [9]. We will discuss about this theory.

Consider a linear bed containing petroleum and water. Suppose the total throughput, $q_t=q_wB_w+q_oB_o$ in reservoir barrels is equal at all cross sections. Here, we neglect gravitational and capillary forces that may be acting. Suppose S_w is the water saturation degree in any element at time t (days). So, if petroleum displaced of the element, the water saturation degree in (t+dt) time will be equal to (S_w+dS_w). If φ is the total porosity fraction, A_c is the cross section in square feet, and dx is the thickness of the element in feet, So the water increasing rate in the element at time 't' is equal to barrel unit in a day:



$$dw/dt=(\varphi A_c dx/5.615)\times(\partial S_w/\partial t)_x \qquad \text{Eq. (1)}$$

The 'x' subscript on the derivation indicates that this derivation is different in each element. If water share of total flow of q'_t (barrels in per day)is f_w, so $f_w\times q'_t$ is the rate of water entering in left hand side of the element dx. The petroleum saturation degree will be slightly higher in the right-hand side, but the fraction of water flowing will be slightly less, or f_w-df_w. Then the rate of water leaving in each element is $(f_w - df_w)\times q'_t$. The net rate of gain of water in the element at per time is:

$$dw/dt = ((f_w - df_w)\times q'_t) - (f_w\times q'_t)= -q'_t df_w \qquad \text{Eq. (2)}$$

Equating (1) and (2),

$$(\partial S_w/\partial t)_x = ((- 5.615\times q'_t) / (\varphi\times A_c))\times(\partial S_w/\partial t)_x \qquad \text{Eq. (3)}$$

Now for a given rock, the fraction of water 'f_w' is the only function of the water saturation S_w. as water cut equation shows, assuming constant petroleum and water viscosities is fixed. The water saturation degree, however, is a function of both time 't' and place 'x' which may be expressed as

$f_w=F(S_w)$ and $S_w=G(t, x)$. Then

$$dS_w = (\partial S_w/\partial t)_t dt + (\partial S_w/\partial t)_x dx \qquad \text{Eq. (4)}$$

Now, we want to calculate the speed of plane or front advancing in fixed saturation degree 'S_w' or $(\partial x/\partial t)_{Sw}$.

i.e., where is constant. Then, from Eq .(4)

$$(\partial x/\partial t)_{Sw} = (\partial S_w/\partial t)_x / (\partial S_w/\partial x)_t \qquad \text{Eq. (5)}$$

Substituting Eq. (3) in Eq. (5),

$(\partial x/\partial t)_{Sw} = (5.615\times q'_t\times (\partial f_w/\partial x)_t) / (\varphi\times A_c\times(\partial S_w/\partial x)_t)$ Eq. (6)

But

$(\partial f_w/\partial x)_t / (\partial S_w/\partial x)_t = (\partial f_w/\partial S_w)_t$ Eq. (7)

Eq. (6) then it becomes:

$(\partial x/\partial t)_{Sw} = ((5.615\times q'_t) / (\varphi\times A_c)) \times (\partial f_w/\partial S_w)_t$ Eq. (8)

The amounts of porosity, area, and throughput are fixed and for any value of S_w, the derivation of $(\partial f_w/\partial S_w)$ is constant, so the rate of dx/dt is constant. It means in a plane with fixed saturation degree S_w, the rate of front advancing is directly proportional to time and to the value of the derivative $(\partial f_w/\partial S_w)$ at that saturation, or

$x = ((5.615\times q'_t) / (\varphi\times A_c)) \times (\partial f_w/\partial S_w)_{Sw}$ Eq. (9)

The displacement of petroleum by gas, with and without gravitational segregation

The method discussed in the previous section also applies to the displacement of petroleum by gas drive. The treatment of petroleum displacement by gas in this section considers only gravity drainage along dip. Richardson and Blackwell showed that in some cases there can be a significant vertical component of drainage.

Due to high petroleum-gas viscosity ratio and high petroleum-gas relative permeability ratio at low gas saturations, the displacement efficiency by gas is generally much lower than that by water, unless the gas displacement is accompanied by substantial gravitational segregation. This is basically the same reason for the low recoveries produced under the dissolved gas-drive mechanism. The effect of gravitational segregation in water drive petroleum reservoirs is usually of much less, because of the higher displacement efficiencies and the lower petroleum-water density differences, whereas the converse is generally true for gas-petroleum systems. Welge showed that capillary forces may generally be neglected in both, and he added a gravitational term in water cut equation, as will be shown in the following equations [9]. As water displacement a linear system is assumed, and a constant gas pressure throughout the system is also assumed so that a constant throughput rate may be used. These assumptions also allow us to eliminate changes caused by gas density, petroleum density, petroleum volume factor, and the like. The fractional gas flow equation with gravitational segregation is:

$f_g=[1-\{(7.821\times10^{-6}\times k\times Ac\times(\rho_o-\rho_g)\times\cos\alpha)\times(k_{ro}/q'_t)\}]/[1+((k_o\mu_g)/(k_g\mu_o))]$ Eq. (10)

If the gravitational, forces are small, Eq. (10) reduced to the same type of fractional flow equation as water cut equation, or

$f_g= 1/[1+((k_o\mu_g)/(k_g\mu_o))]$ Eq. (11)

k: permeability md
ρ: density lbm/ft^3
k_r: relative permeability md
μ: viscosity cp
q'_t: Total flow bbl/day
A_c: cross section ft^2

Reservoir simulation

Simulation by using mathematical and computer is important to review the behavior of reservoir surveillance and reservoir performance [10,11]. Conventional methods for the analysis and modeling of reservoir behavior are:

- Material balance
- Decline curve analysis
- Transient pressure analysis
- Numerical simulation

Eclipse software

Eclipse software as most conventional reservoir simulation software is used for fractured reservoirs. The software is also owned by Schlumberger Company and production scheduling capabilities has a great for Iran fractured reservoirs.

Eclipse reservoir simulation software to simulate different choices of numerical methods for fast and accurate solutions for all types of reservoirs with any degree of complexity, construction, geology, fluids and development program that provides and solutions for the entire spectrum of reservoir simulation provides and to help all the tools necessary to complete the analysis and reservoir simulation, the user can be provided. Eclipse pre-and post-processing modules are: FloGrid, Schedule, SCAL, VFPi, and PVTi. Post-Eclipse CPU modules are including: GRAF, FloVize. These modules run with Eclipse simulators run together or individually. The pre-processor modules prepare input data for running simulation of production and post-processor modules used eclipse output to display or manipulate the simulation results. Users can also invoke their desired module of Eclipse Office module; it is an environment to control operations related to simulation [12,13].

In this study, the injection rate 60MM SCF / Day in the third layer of gas is injected in to the reservoir study and permeability is considered to10 md.. In this injection we can make a reservoir with natural depletion production in 2020 year, and we start the injection from 2020 until 2050 years, and we predict production for 30 years. In this study we analyze some of the main graphs like production gas-oil ratio (GOR), production oil (OPR), field pressure (PR) and water cut (WCT). After analyzing each of the graphs all the graphs compared together and the best scenario will be defined for it.

RESULTS AND DISCUSSION

The injection methods: (Table 1-a and b)

- Natural depletion, this graph shows the actual results of the natural reservoir and production gas-petroleum ratio and water cut and original petroleum in place (without gas injection).
- Injection of 60 MMSCF / DAY and bottom hole pressure of 6500 psi from 2020 to 2050 year.
- Injection of 60 MMSCF / DAY and bottom hole pressure of 7500 psi from 2020 to 2050 year.
- Injection of 60 MMSCF / DAY and bottom hole pressure of 7500 psi from 2020 to 2050 year with the limitation that if GOR> 2200, holes perforation are to be closed and production constraints.
- Injection of 100 MMSCF / DAY and bottom hole pressure of 9500 psi from 2020 to 2050 year with this limitation that the GOR> 3000 wells are holes perforation are tobe closed and production constraints.

Table 1-a: The injection methods, without gas injection (2020 yaer)

GRAPH	FGOR(SCF/STB)	FOPR(STB/D)	FPR(PSI)	FWCT
NATURAL DEP.	950	30000	4400	0.125
BHP6500(Q60)	1000	50000	5100	0.053
BHP 7500(Q60)	1100	60000	5300	0.048
BHP 7500 (GOR>2200)(Q60)	1100	60000	5300	0.048
BHP 9500(Q100)	1200	80000	5700	0.044

Table 1-b: The injection methods, with gas injection (2050 yaer)

GRAPH	FGOR(SCF/STB)	FOPR(STB/D)	FPR(PSI)	FWCT
NATURAL DEP.	850	10000	3800	0.165
BHP 6500(Q60)	2200	<20000	4700	0.08
BHP 7500(Q60)	5000	20000	5200	0.07
BHP 7500 (GOR>2200)(Q60)	1400	>20000	5500	0.06
BHP 9500(Q100)	1850	25000	6900	0.051

Graphs Comparison

In this comparison all the FGOR, FOPR, FPR and FWCT graphs being compared together that their differences are clear in figures. Here you can clearly see which one is better and present the best scenario for the proposed reservoir (Figure, 2, 3,4 and5).

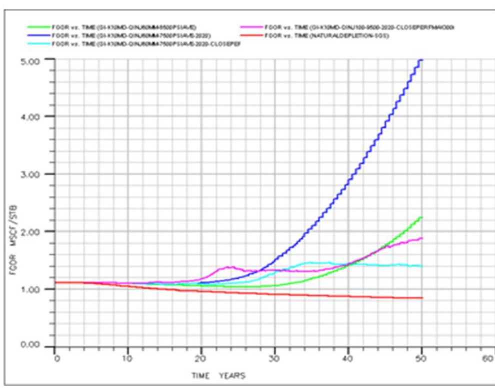


Figure 2. field oil production rate for all cases

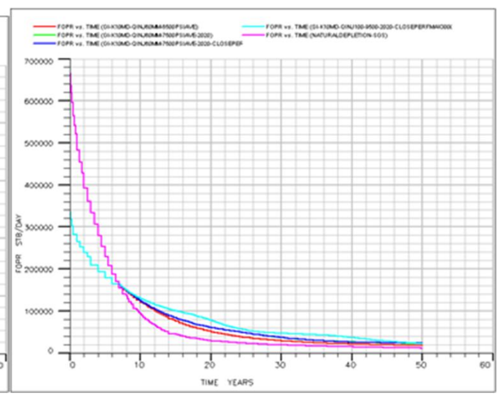


Figure 3. field GOR for all cases

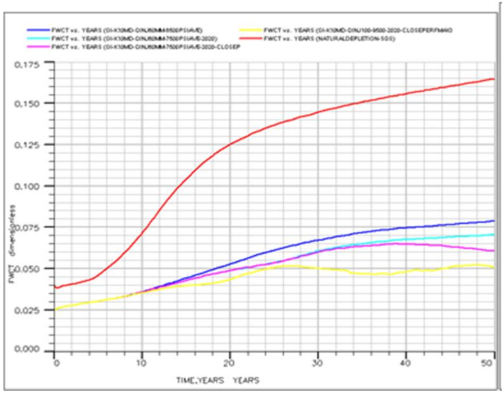


Figure 4. field water cut for all cases

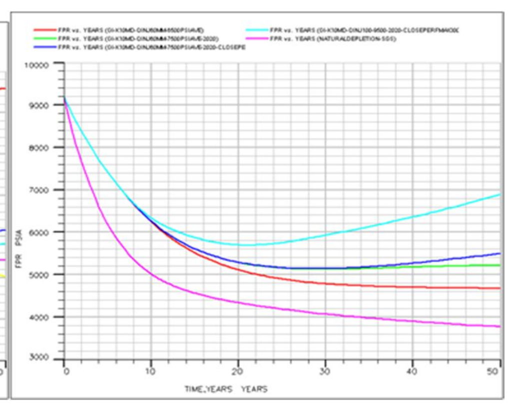


Figure 5. field pressure for all cases

CONCLUSION

- In this reservoir gas injection was evaluated with different flow rate. After evaluation and examine operating charts with different flow rates and by knowing the number of petroleum wells we evaluated various scenarios.
- Among these scenarios, the gas injection rate scenario100 MMSCF / DAY bottom hole pressure well with 9500 psi limitation that if the GOR> 3000, the wells were closed and production of them will be stopped.
- It is the best scenario because recovery factor rate 7.2 percent increased. (Table 2),
- This scenario has been studied without considering any economic constraints but if we consider the economic constraints, pressures up to 9500 psi a very strong compressors require gas injection rate100 MMSCF / DAY required well head equipment is robust and high-tech, that the availability of necessary.
- But now with the availability of gas and it lower costs than other methods such as the injection of miscible EOR and chemical EOR is best option to heat the reservoir.

Table 2: Recovery factor rate

INJECTION METHODS	Recovery factor
NATURAL DEP.	0.37431
BHP 6500(Q60)	0.39215
BHP 7500(Q60)	0.40275
BHP 7500(GOR>2200)(Q60)	0.40304
BHP 9500(Q100)	0.44654

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