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GRAVITY DRAINAGE MECHANISM AND ESTIMATION OF OIL RECOVERY IN IRANIAN CARBONATE CORES

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Abstract

This paper introduces modeling of gravity drainage mechanism, (GD) in Iranian carbonate oil reservoirs. The GD mechanism is an important and active mechanism in fractured carbonate reservoirs through Gas Injection (GI), Water Alternative Gas Injection (WAG) processes and the Gas Invaded Zones (GIZ). It participates in the in oil production and oil recovery and takes place for a long time in such reservoirs. A laboratory set up was constructed for experimental work. Gas at low pressure and low rates was injected in to the top of a vertical holder containing a carbonate single block core at atmospheric conditions. Simulation studies were conducted by Eclipse, a commercial simulator, at lab scale. A proposed simulator model was also proposed in accordance with the properties of Iranian reservoirs carbonate rocks, which is a approach for investigation of GD mechanism. The model was constructed on the basis of laboratory data obtained in the study, implementation of fundamental equations and the correlation which are available for carbonate reservoirs. The proposed simulation model once correlated with experimental data indicates good results in estimation of the ultimate oil recovery at both atmospheric and reservoir conditions. Our model matches the data close than Eclipse. The results of the study show that the maximum oil recoveries in relations to gas gravity drainage in Iranian oil reservoirs cores are about 5 and 4 percent at reservoir and atmospheric conditions, respectively.

Keywords: Gravity Drainage; Simulation; Modelling; Carbonate cores; Fractured Reservoir; Gas Injection; WAG; Oil Recovery

1. Introduction

The major oil reserves in Iran are located in fractured carbonate reservoirs [1]. Oil production from well fractured carbonate reservoirs forms a considerable part of the total oil production in the world and gravity drainage has a major effect on oil recovery in these reservoirs. Barenblatt, proposed a dual-media approach for modelling naturally fractured systems [2]. Kazemi and Rossen presented simulators for modelling fluid flow in fractured reservoirs [3,4]). Laboratory studies of gravity drainage from unconsolidated sands were performed by Higgings and Shea [5]. The results of Hagoort suggest that oil recovery from the gravity drainage mechanism is dependent on three factors, the magnitude of gravitational forces relative to viscous forces, the shape of oil relative permeability curve, and the reservoir geometry and heterogeneity [6]. Kantzas et al. reported gravity drainage laboratory experimental results using unconsolidated media [7]. Modelling of naturally fractured reservoirs allows, evaluating complex reservoir systems and to predict reservoir performance [8].

2. Theory

In fractured reservoir the major forces are capillary and gravity forces, while in non-fractured reservoir the major force is the viscous force. In the gravity drainage mechanism, the difference between the density of the fluids and the elevation of the two contacts are major parameters, which cause the fluid movement in the reservoir block and result in oil production from the matrix blocks. The oil in the fracture recovered because gas from the gas cap or the free gas or injected gas through i.e.

GI and WAG replaces it. The oil in the matrix needs longer time to be drained by gravity to the fractures. It causes fractures to become saturated with gas, and matrix to contain mainly oil. The presence of vertical fractures causes the gas-oil contact inside the fracture network exceeds the corresponding contact in the matrix block. Therefore the gas-oil contact (GOC) in fracture advances ahead of that in the matrix block in the reservoir surrounded by gas and gas gravity drainage mechanism will be started. If a matrix block is surrounded by gas, the gravity forces tend to drain the oil from the matrix and the capillary forces tend to retain the oil. When the only driving force is the gravity force without any external force, it is called free gravity drainage (FGD). The gas tends to penetrate spontaneously into the block by FGD from top of block and oil produced from bottom of block. Oil is produced only if the gravitational force exceeds the capillary force. The key factors to control the recovery rate and ultimate recovery in a single block are the connate water saturation, oil relative permeability and matrix capillary pressure [6]. The saturation profile within the matrix block at the end of the production may be derived by equating the gravity and capillary forces. In the FGD, the ultimate saturation distribution inside the block is governed by the capillary pressure curve of the block, and there would be no breakthrough of gas. In a fractured reservoir reduction of the interfacial tension by increasing the pressure or injecting appropriate fluids, can improve recovery as the result of reduction in capillary pressure (P_c) and/or swelling of oil. When the height of the matrix block is smaller than the capillary threshold height, the oil in the matrix cannot be produced by gravity drainage mechanism. If the total height is greater than the capillary height, the final oil recovery is governed by capillary pressure curve of the matrix rock. If the vertical permeability of the rock and the fluid properties are known, the gravity drainage velocity can be estimated from the theory. A gravity drainage model is available based on the formulation proposed by Quandalle and Sabathier[9]. When the gravity drainage option is in use, the final recovery from the matrix is determined by the balance between the capillary pressure and gravity forces. It should however, be mentioned that the greatest weakness of the existing reservoir simulator is regarding slight information on applicable equations for Iranian fractured carbonate rocks i.e. fracture properties (sizes, distributions, orientations, etc.) and matrix block properties, which usually vary in that reservoirs.

Hagoort introduced a complete mathematical model with exact boundary conditions which could predict the flow from a gravity draining matrix with good accuracy [6]. Even though drawbacks existed in experimental data and simplified assumptions in theory, the match between the experimental data and theory was shown to be reliable10). The variation of saturation with time and the recovery rate are given by:

$$\left(\frac{\Delta z_d}{\Delta t}\right)=\frac{\rho\,.\mathrm{g}}{\mu\,.\varphi}.\frac{\left[k\left(1-\frac{h_t}{L-z_d}\right)-k_d\right]}{(1-S_d)} \quad (1)$$

$$R=\frac{z_d}{L}\left[\left(1-\frac{S_{or}.B_{or}}{S_{oi}.B_o}\right)-\frac{B_{oi}}{S_{oi}}\left(\frac{1-S_{or}}{B_o}\right)\left(\frac{n-1}{n}\right).\left(\frac{\mu.\varphi}{n.\rho.\mathrm{g}.k}\frac{z_d}{t}\right)^{\frac{1}{n-1}}\right] \quad (2)$$

Where, $k_d = k.S_d^{\,n}$ $\quad S_d = f^{-1}\left(\frac{z.\mu\,.\varphi}{\rho\,.\mathrm{g}.t}\right)$

R, ultimate oil recovery; Z_d, the position of the limitation (the boundary between the unsaturated and saturated regions); L, the column length; h_t, the minimum height to which the wetting phase (at 100 percent saturation) will drain; S_d, the saturation an little distance above the limitation, K, the permeability of the medium to the fluid at 100 percent saturation, Bo, oil formation volume factor and K_d, the permeability at the saturation just at a infinitesimal distance above the limitation. For test conditions (B_o=1 and S_{oil} = 1), therefore, equation [2] can be simplified as:

$$R=\frac{z_d}{L}(1-S_{or})\left[1-.\left(\frac{n-1}{n}\right).\left(\frac{\mu\,.\varphi}{n.\rho\,.\mathrm{g}.k}\frac{z_d}{t}\right)^{\frac{1}{n-1}}\right] \quad (3)$$

3. Experimental setup

Schematic of the experimental setup is shown in Figure 1. The experimental setup is comprised of vertical core holder, gas cylinder, and digital balance. The core holder was made of stainless steel in cylindrical and rectangular shape. The top and bottom caps were attached to the model, with a plastic gasket in between. To separate the produced oil and free gas at operation pressure, a 500cc separator was used, which was made of stainless steel. The physical model has two valves, one at the top and one in the bottom of core holder. The top valve is connected to the low injection line coming in core holder. The bottom valve is used to drain the produced oil. Gas cylinder includes methane with purities at laboratory scale at low pressure was used in the experiments. Gas cylinder was equipped with a proper regulator. The oil used in the experiments was taken from Sirri oil field located in the south part of Iran at the offshore. The important rock properties i.e. matrix permeability, matrix porosity, capillary pressure and fluid properties i.e. API, oil viscosity were selected according to Iranian carbonate rocks. The matrix porosity was measured and found to be 12.1 percent. The matrix permeability is 8.4 md. Its API gravity was 31.8 at room temperature. The fracture width was 0.2 cm, of the spacer. Gravity drainage experiments were conducted in single carbonate block through B-1, B-2, and B-3 samples. Other properties of cores and oil are summarized in Tables 1, 2 and 3.

3.1. Experimental Procedure

The physical model include fractured porous media was designed using the carbonate block. The space between the matrix and the walls of core holder acts as the fracture. The top and the bottom of the matrix and fracture system had a flow path of thickness 0.2 cm. The flow path covered the matrix and the connection at the top is connected to the gas cylinder as is shown in Figure 1. The bottom is connected to a collection vessel on a digital balance. The online balance was connected to a computer and the data were collected with lab-view software. In was constructed a vertical 1-D physical model considered the matrix as one medium and the fracture (on its faces) as another medium. This study begins with a vertical 1-D model which considers a block of matrix initially saturated with oil at irreducible water saturation. Thus only flow occurs in the vertical direction inside the matrix by gravity segregation. Experimental studies on the physical model can be used to investigate the effect of changes in many variables properties such as block dimensions, rock properties, oil properties, gas properties, fractures properties, experiment conditions, etc. The block dimensions were 0.49 ft in width, 0.49 ft in length and 3, 2 and 1 ft in height as matrix which were placed into the vertical core holder. In this research experiments were conducted at atmospheric conditions. After start of test, the displacing phase is injected at Z = 0.0 (top of physical model) and at a constant low rate and low pressure. The difference pressures less than one bar between inlet and outlet of the physical model are applied and also when the matrix and fracture pressures are same. The displacing direction is positive downward. The cumulative oil and gas production were measured for each experiment.

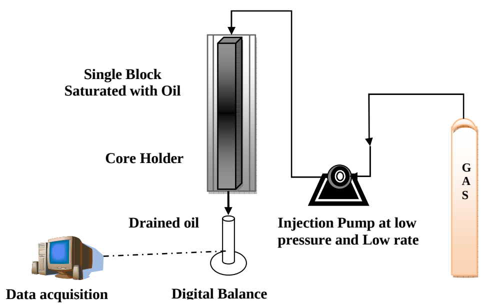


Figure 1 Schematic diagram for the gravity drainage process used in the experiments.

3. 2 A proposed 1-D simulation model

In general modelling refers to the representation of some process by either a theoretical or a physical model. One of the primary objectives of a reservoir study is to predict future performance of a reservoir and find ways and means of increasing ultimate recovery. Reservoir modelling by computers allows a more detailed study of the reservoir by dividing the reservoir into a number of blocks and applying fundamental equations for flow in porous media to each block. Reservoir modelling was developed to study overall field performance and to predict their performance during matching.

A proposed 1-D simulation model, proposed for gravity drainage modelling in single carbonate block at atmospheric and reservoir conditions (high pressure). The total oil production, oil rate, residual oil saturation and etc. for each block height can be predicted by proposed simulation model. In a single-block model, a concept on which many reservoir simulators have been based, it is assumed that, the individual matrix blocks are completely isolated from their neighbours. Consequently, the matrix blocks in gas invaded zone or through GI and WAG in the reservoir behave independently and the overall reservoir performance can be the sum of the entire single matrix block, in that region. Although the actual matrix block have irregular shapes and varying sizes, for the interpretation of reservoir behaviour, a simple geometric shape (e.g. a rectangular box) and average matrix block size is assumed.

3. 3 Assumptions used in the proposed simulation model

The program regarding the proposed simulation model, "single block drainage model", describes the interflow of oil and gas between an individual upright block of homogeneous rock material and the surrounding fissure system. The following assumptions have been considered:

1. Gas diffusion is instantaneous, no solution gas drive.
2. Oil may only enter the block when it is totally immersed below the fissure gas/oil level.
3. The fissure gas/oil contact passing the block oil is expelled from same due to gravity drainage.
4. The rock capillary pressure/gas saturation relation can be approximated by a step function.
5. Gas/oil capillary pressure and oil relative permeability are functions of gas saturation.
6. The mobility of gas is infinite.
7. At any time the gas saturation in the block increases with elevation.
8. At any time the oil drainage velocity decreases with elevation.
9. The oil velocity is zero at the top of the block.
10. Drainage occurs at constant pressure.

The program to solve a set of difference equation by computer coding, Fortran and Visual Basic, defining the development of free gas saturation in a block of rock material initially saturated with oil and surrounded by gas throughout. Oil expulsion is due to gravity drainage.

These equations have been derived from the following:

i- The Darcy equations of flow for all oil, water and gas phases.

ii- The Continuity equations for all.

Gravity drainage process is difficult to model theoretically and perforce need to use some assumptions such as 1-D downward flow, isothermal condition, immiscible gas/oil phases, incompressible phases and matrix. The pressure in this process is not expected to vary in any significant way. Three-phase co-existence, but can be simplified as an oil/gas two phase flow problem by assuming connate water saturation for oil-water system is the same for gas- water system. The problem is reduced to an oil/gas two-phase flow problem under the above assumptions. There are two regions in the column, one is the oil bank at connate water saturation and the other is the gas-invaded zone. In the system where oil/gas/water phases coexist, fluids distribution and thus their flow properties depend on interactions between rock and fluids, such as interfacial tension, wetting, and saturation history. Another assumptions in this simulation model i.e. the fracture and matrix media are homogeneous with a permeability of K_{f1} for fracture and Km_2 for the matrix; molecular diffusion and dispersion are negligible; the displacing and displaced fluids are incompressible; viscous fingering is negligible in the fracture and the matrix; no volume change on mixing; the displacement is one dimensional in the matrix and the fracture; matrix permeability in X and Y direction are equal (Kx=Ky). The proposed simulation model made based on carbonate rock and fluid properties. This simulation model describes the interflow of oil and gas between an individual upright block of homogenous rock material and the surrounding fissure system. The other assumptions which used such as gas diffusion is instantaneous, no solution gas drive, oil may only enter the block when it is totally immersed below the fissure gas-oil level , the fissure gas-oil contact passing the block oil is expelled from same due to gravity drainage, the rock capillary pressure/gas saturation relation gas be approximated by a step function, and program to solve a set of difference equation defining the development of free gas saturation in a block of rock material initially saturated with oil and surrounded by gas throughout. Oil expulsion is due to gravity drainage. These equations have been derived from the Darcy equations for oil and gas phases, the continuity equation for the oil phases. Also other assumptions that gas-oil capillary pressure and oil relative permeability are functions of gas saturation, the mobility of gas is infinite, at any time the gas saturation in the block increases with elevation, at any time the oil drainage velocity decreases with elevation, the oil velocity is zero at the top of the block, and drainage occurs at constant pressure. The permeability, porosity and initial oil saturation of the block may differ during a sequence of runs the matrix properties, the gas and oil density, the oil viscosity and the shape of the relative permeability, oil saturation are relation and the capillary pressure curve are fixed. Within a run the oil production rate and the (linearly) changing gas/oil interfacial tension may be defined different for each time interval. All computer coding relevant proposed 1-D simulation models for the gravity drainage mechanism in single carbonate block written by FORTRAN power station software.

3.4 Simulation by Eclipse

Aguilera[8], pointed out that, the best way to estimate recoverable volumes of fractured reservoir is with the use of a numerical simulator for dual porosity/dual permeability system. Barenblatt [1], proposed a dual-media approach for modelling naturally fractured systems. Kazemi [10] and Rossen [11] presented simulators for modelling fluid flow in naturally fractured reservoirs. The simulation provided data permeability and capillary pressure for core models. The purpose of the work was made a simulation model for using in gravity drainage calculation, simulation of gravity drainage of single carbonate block experiments. In this research a commercial simulator, Eclipse, was utilized to simulate and match the laboratory experimental results using the laboratory scale data at atmospheric and reservoir conditions. In other words, exact properties as in the laboratory experiments were used in the simulator. Fluid viscosities, densities, and other PVT properties were defined at the atmospheric conditions, the room temperature and atmospheric pressure, at which the experiments were conducted. The simulation runs were performed for different scenarios until a good match was obtained with experimental results of physical model and the proposed simulation model. The matrix block is subdivided into 100 grid cells, where the measured physical properties were applied directly to each grid cell. A good match between simulation output, experimental data and results of the proposed simulation model indicates that the accuracy of them is good enough for gravity drainage calculations. The oil production rate, total oil produced, recovery factor, average residual oil saturation and average pressure can be estimated using the proposed simulation model.

4. Results and Discussion

As seen from Table 1 three core samples of blocks, B-1, B-2 and B-3 have the same physical properties with different length, were used in the experiments. Table 2 shows fluids physical properties i.e. oil and gas. Table 3 represents the analysis for the reservoir fluid composition, molecular weight and specific gravity of the hexane plus fraction. Tables 4 compares the experimental, proposed simulation model and Eclipse results for the amount of the oil recovery factor after implementation of the gravity drainage at atmospheric and reservoir conditions at lab scale. The maximum amount of the oil recovery factor in all scenarios is small and the maximum value which observed is about 5.2 and 4.1 percent respectively at reservoir and atmospheric conditions. Because the pressure difference between top and bottom of the block in both scenarios is small and according to rock properties in carbonate rocks, the oil produced during gravity drainage mechanism are less than sand rocks. As can be seen the oil recovery factor obtained after implementation of gas gravity drainage changes with time and various with different height. As shown the maximum experimental, proposed simulation model and Eclipse oil recovery factor is attained using the gravity drainage with block height equal 3 ft. As mentioned the block height can be affected on the oil recovery. As shown the minimum oil recovery, zero, with height equal 1 ft is observed using the gas gravity drainage at the lab scale. Because block height is less than threshold height. Table 4 shows that the amount of oil recovery of proposed simulation model is less than Eclipse results and more than experimental data. Figures 2 to 4 shows respectively variation of the amount of oil recovery factor versus time obtained after implementation of gas gravity drainage through experimental, proposed simulation model and Eclipse results. Figures 5 and 6 show respectively variation of the block average pressure and oil recovery factor versus time obtained after implementation of gas gravity drainage on the block at high pressure scenario (reservoir conditions) through Eclipse and proposed simulation model. As seen the amount of oil recovery in atmospheric conditions is less than reservoir conditions. Because solution gas in live oil helps to increase of oil drainage in downward. Table 5 shows standard deviation of experimental, proposed simulation model and Eclipse results for the amount of oil recovery factor after implementation of the gas gravity drainage mechanism with different height. As seen from Tables 4 the proposed simulation model results are in good agreement with those obtained from experiments and Eclipse model.

Table 1- Physical properties of core samples

Block Sample	Rock type	length (ft)	Cross area (ft^2)	Ave. Φ (%)	Ave. Ka (md)	Ave. Swi (%)
B1, B2, B3	Carbonate	1, 2, 3	0.49*0.49	12.1	8.40	0.20

Table 2- Physical properties of live oil and dead oil

Gas solution in oil (RS)	SCC/RCC	53
Oil volume factor (BO)	Res vol./ Std vol.	1.206
Bubble point pressure	atm.	106
Oil viscosity @ Res. Cond.	cP	0.877
Oil viscosity @ Atm. Cond.	cP	2.308
Oil density @ Atm. Cond.	g/cm^3	0.857
Oil density @ Res. Cond.	g/cm^3	0.779
Gas density @ Res. Cond.	g/cm^3	0.00127

** Reservoir conditions: Temperature = 207 ^oF, Pressure = 280 atm.*
** Atmospheric conditions: Temperature = 60 ^oF, Pressure = 1 atm.*

Table 3- Live oil composition used in the proposed simulation model and Eclipse model at reservoir conditions.

Component	% mole
Methane	23.45
Carbon Dioxide	2.05
Ethane	7.26
Propane	8.02
Iso-Butane	1.92
Normal Butane	3.99
Iso-Pentane	1.85
Normal Pentane	2.57
Hexane Plus	48.89
Total	100.00

** Molecular weight of hexane plus = 260*
** Specific gravity of hexane plus = 0.8976*

Table 4- Experimental, proposed simulation model and Eclipse results for the amount of oil recovery factor after implementation of gravity drainage at atmospheric and reservoir conditions.

Condition	Block Height (ft)	Laboratory Oil Recovery (%)	Proposed Simulation Model Oil Recovery (%)	Eclipse Model Oil Recovery (%)
Atmospheric	3	3.96	4.056	4.221
	2	1.47	1.925	2.511
	1	0.26	0.08	0.09
Reservoir	3	-	5.139	5.301
	2	-	1.751	2.914
	1	-	0.261	0.355

Table 5- Standard deviation (%) of experimental, proposed simulation model and Eclipse results for the mount of oil recovery factor after implementation of the gas gravity drainage.

Block Length (ft)	Laboratory	Proposed simulation model	Eclipse	Average value
1	0.048	0.017	0.015	0.027
2	0.297	0.123	0.758	0.393
3	1.101	0.792	1.421	1.105

Table 6- Experimental, proposed simulation model and Eclipse oil recovery data for block length 3ft after implementation of the gravity drainage at atmospheric conditions.

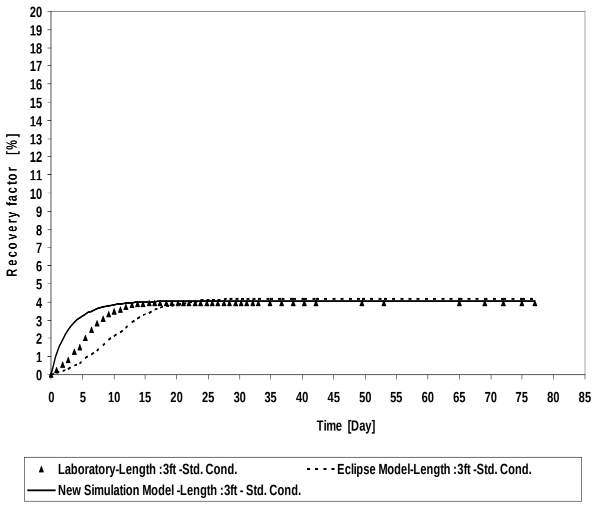
Time (days)	Proposed Simulation Model	Laboratory	Eclipse Model
0.0	0.00	0.0	0.00
0.9	1.14	0.3	0.10
1.8	1.94	0.6	0.20
2.8	2.49	0.8	0.30
3.7	2.87	1.3	0.50
4.6	3.15	1.5	0.60
5.5	3.35	2.0	0.90
6.4	3.51	2.5	1.10
7.3	3.62	2.8	1.30
8.3	3.72	3.1	1.60
9.2	3.79	3.3	1.90
10.1	3.84	3.5	2.10
11.0	3.89	3.6	2.30
11.9	3.92	3.8	2.60
12.8	3.95	3.8	2.90
13.8	3.97	3.9	3.10
14.7	3.99	3.9	3.30
15.6	4.00	3.9	3.40
16.5	4.01	3.9	3.60
17.4	4.02	3.9	3.70
18.3	4.03	4.0	3.80
19.3	4.03	4.0	3.80
20.2	4.04	4.0	3.90
22.0	4.05	4.0	4.00
24.8	4.05	4.0	4.10
26.6	4.05	4.0	4.10
30.3	4.05	4.0	4.20
31.2	4.06	4.0	4.20
32.1	4.06	4.0	4.20
38.5	4.06	4.0	4.20
40.4	4.06	4.0	4.20
42.2	4.06	4.0	4.20
53.0	4.06	4.0	4.20
65.0	4.06	4.0	4.20
72.0	4.06	4.0	4.20
75.0	4.06	4.0	4.20
77.0	4.06	4.0	4.20

Table 7- Experimental, proposed simulation model and Eclipse oil recovery data for block length 2ft after implementation of the gravity drainage at atmospheric conditions.

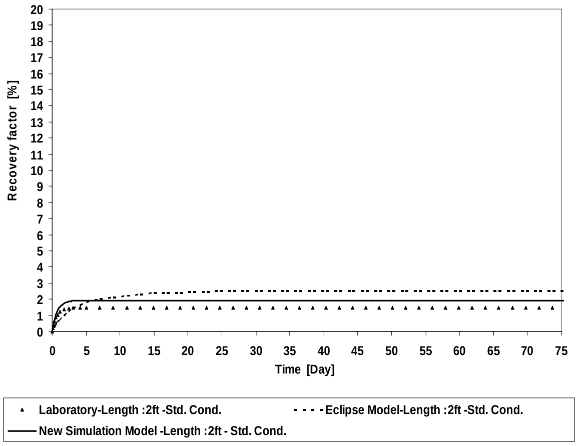
Time (days)	Proposed Simulation Model	Laboratory	Eclipse Model
0.0	0.00	0.0	0.00
0.2	0.42	0.4	0.10
0.3	0.77	0.7	0.20
0.5	1.04	0.9	0.40
0.8	1.24	1.0	0.60
1.2	1.40	1.2	0.70
1.8	1.52	1.4	1.00
2.5	1.61	1.4	1.20
3.1	1.68	1.5	1.40
4.1	1.73	1.5	1.60
5.1	1.77	1.5	1.80
7.0	1.80	1.5	2.00
9.0	1.83	1.5	2.10
11.0	1.85	1.5	2.20
12.9	1.87	1.5	2.30
14.9	1.88	1.5	2.40
16.8	1.89	1.5	2.40
20.8	1.90	1.5	2.44
22.7	1.91	1.5	2.45
24.7	1.91	1.5	2.50
30.5	1.92	1.5	2.50
36.4	1.92	1.5	2.50
40.3	1.92	1.5	2.50
50.1	1.92	1.5	2.50
61.9	1.92	1.5	2.50
65.8	1.92	1.5	2.50
77.5	1.92	1.5	2.50

Table 8- Experimental, proposed simulation model and Eclipse oil recovery data for block length 1ft after implementation of the gravity drainage at atmospheric conditions.

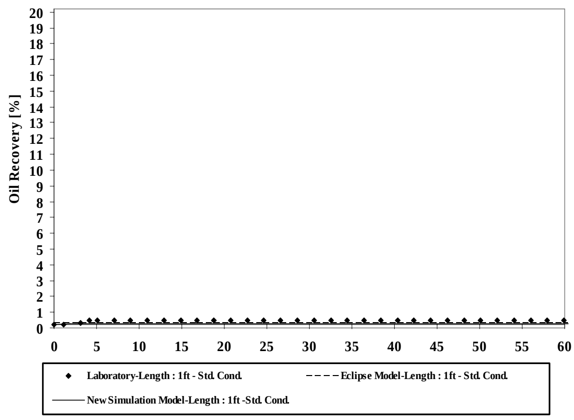
Time (days)	Proposed Simulation Model	Laboratory	Eclipse Model
0.0	0.00	0.0	0.00
1.9	0.00	0.1	0.00
3.7	0.00	0.3	0.00
7.5	0.00	0.3	0.00
9.4	0.00	0.3	0.00
15.0	0.00	0.3	0.00
20.6	0.00	0.3	0.00
31.8	0.00	0.3	0.00
50.5	0.00	0.3	0.00
61.7	0.00	0.3	0.00
71.1	0.00	0.3	0.00
74.8	0.00	0.3	0.00
76.7	0.00	0.3	0.00



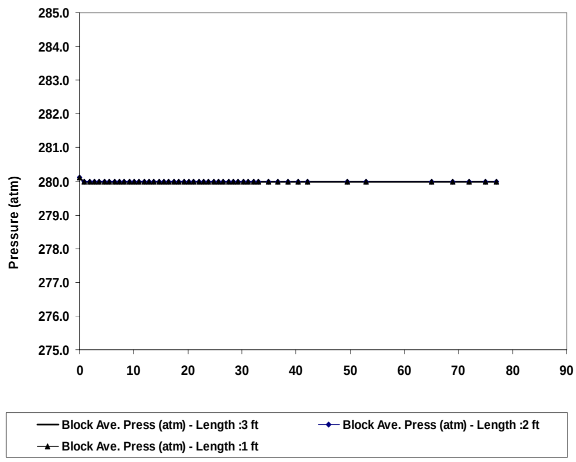
Figures 2 Variation of the oil recovery factor obtained after implementation of gravity drainage.



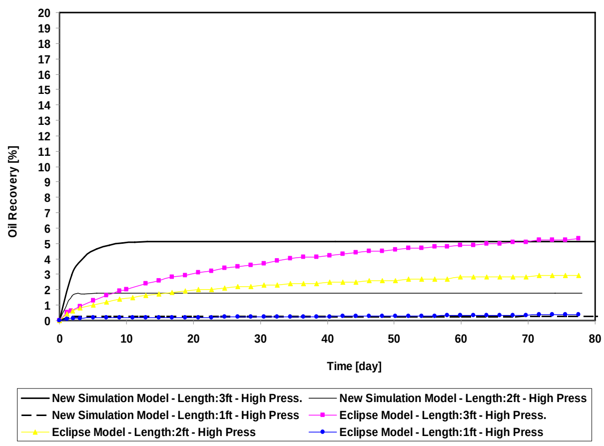
Figures 3 variation of the oil recovery factor obtained after implementation of gravity drainage



Figures 4 variation of the oil recovery factor obtained after implementation of gravity drainage



Figures 5 - Variation of the block average pressure



Figures 6 - Oil recovery factor versus time obtained after implementation of gas gravity drainage processes on the block scale at high pressure scenario (reservoir conditions) through Eclipse and proposed simulation model results.

5. Conclusions

In Iranian fractured carbonate reservoirs gravity drainage mechanism is as a dominant and active mechanism through GI, gas injection, WAG, water alternative gas injection and in the gas invaded zone. The proposed simulation model compared to experiments and Eclipse data and indicates that it can successfully estimate the ultimate oil recovery at atmospheric and reservoir conditions with a good accuracy. It was found out that the amount of oil recovery in atmospheric conditions is less than reservoir conditions. The maximum oil recovery observed relevant gas gravity drainage in Iranian carbonate cores is about 5.2 and 4.1 percent respectively at reservoir and atmospheric conditions. If the block height to be less than critical height then gas gravity drainage processes can not be started. The results showed that implementation of the gas gravity drainage with great block height and exist of solution gas (live oil) can lead to a higher oil recovery comparing to small block length and without any solution gas (dead oil). The experimental results were compared with the results obtained from an Eclipse and proposed simulation model and it was concluded that good agreement exists between them.

Acknowledgments

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Nomenclature

GIZ	gas invaded zone	μo	oil viscosity
OIP	oil initial in place	μg	gas viscosity
GOC	gas-oil contact	Pc	Capillary pressure
FGD	free gravity drainage	$\Delta\rho$	density difference between oil and gas
RF	oil Recovery Factor	H	elevation between oil and gas contact

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