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STUDYING THE EFFECT OF INJECTION PATTERN ON WATER ALTERNATING GAS (WAG) INJECTION PROCESS USING ECLIPSE SIMULATOR SOFTWARE IN AN OIL RESERVOIR IN IRAN

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Abstract

Water- alternating-gas (WAG) injection process is one of innovative and new enhanced oil recovery (EOR) methods. This method by improving gas injection microscopic and water injection macroscopic displacement processes, due to water- alternating-gas injection and influenced reservoir intact regions in comparison to conventional water-gas injection approaches, and through creating a three-phase region in reservoir it leads to reducing remaining oil and increasing reservoir production.

Optimal recovery and higher income with minimum cost in reservoir development plan are reservoirs' management main goals. Selecting a proper pattern is one of the most critical plans in developing reservoirs. This paper studies the effect of production and injection wells' pattern through using ECLIPSE simulator software on water- alternating-gas (WAG) injection in a reservoir in Iran. Ultimately, the best injection model will be selected.

Key words: Enhanced oil recovery (EOR); fractured reservoirs; water- alternating-gas (WAG) injection; simulation; injection pattern.

1. Introduction

Significance of huge amount of unrecovered hydrocarbon resources by natural production and its irreversibility made developing and applying EOR optimized methods inevitable in order to achieve oil reservoirs' maximum yield. Thus, different EOR methods introduced and operated [3,4,6].

Optimal injection method is considered the most important efficiency and production factor in EOR. Moreover, surrounding wells, injection and production wells intervals, wells' localization and, in general, injection pattern affect displacement efficiency and performance [1].

To increase displacement process sweeping efficiency various injection schemes with different efficiencies proposed. For instance, linear movement and five-spot scheme are usually used once injection is low and a vast numbers of injection wells are required. Nine-spot model applied in high-permeable areas with high injection ability [1-2, 5].

One primary steps of designing a project is selecting a proper pattern. This step focuses on determining and selecting a proper pattern in which injection fluid has as much as possible contact with crude oil system. This selection achieved as follows [7]:

1. Transforming existing production wells into injection wells.
2. Drilling new injection wells.

The following factors must be considered in selecting pattern:

- Reservoir heterogeneity and directional permeability;
- Reservoir fractures direction;

- Injection fluid entity (water or gas);
- Maximum oil recovery factor;
- Wells' intervals, productivity, and injection ability.

2. Experimental

2.1. Case study field

The field studied here is an asymmetric anticline with the length and width of 10 and 5 km, respectively, in Asmari group. The field was initially in supersaturated condition; then, it reduces overtime reaching to saturation, which caused creating a dome gas in the field.

Table 1 General characteristics of understudied reservoir fluid

°API	39	WOC, ftss	2600
Total thickness, ft	226	Reservoir temperature, °F	120
GOR, ft^3/scf	700	Average Matrix porosity,%	15
Rock compressibility,1/psi	4.29e-6	Oil FVF, Rbbl/stb	1.34
Water compressibility,1/psi	2.12e-6	Water FVF, Rbbl/stb	1.01
Oil density, lb_m/ft3	45	Oil viscosity, cp	0.65
Gas density, lb_m/ft^3	0.049	Gas viscosity, cp	0.019
Datum depth, ftss	2500	Water viscosity, cp	0.854
Average reservoir pressure @ datum depth, psi	1750	Oil saturation,%	76
GOC, ftss	2500	Water saturation,%	24

2.2 Model characteristics

The reservoir in this network divides into 38 and 34 longitude and latitude grids, respectively. Given variant rock material, 7 vertical grids are defined for reservoir. Reservoir gridding data are shown in Table 2 and Figure 1 represents a schematic of the selected sector [8].

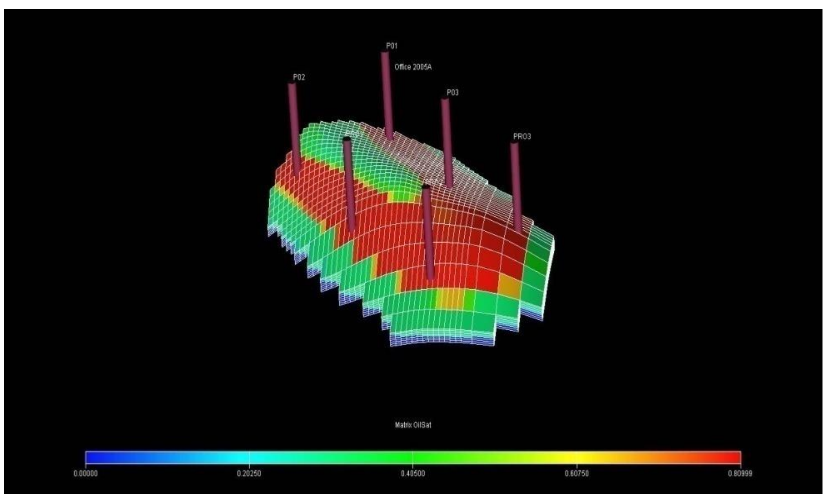


Fig. 1 3D model selected sector

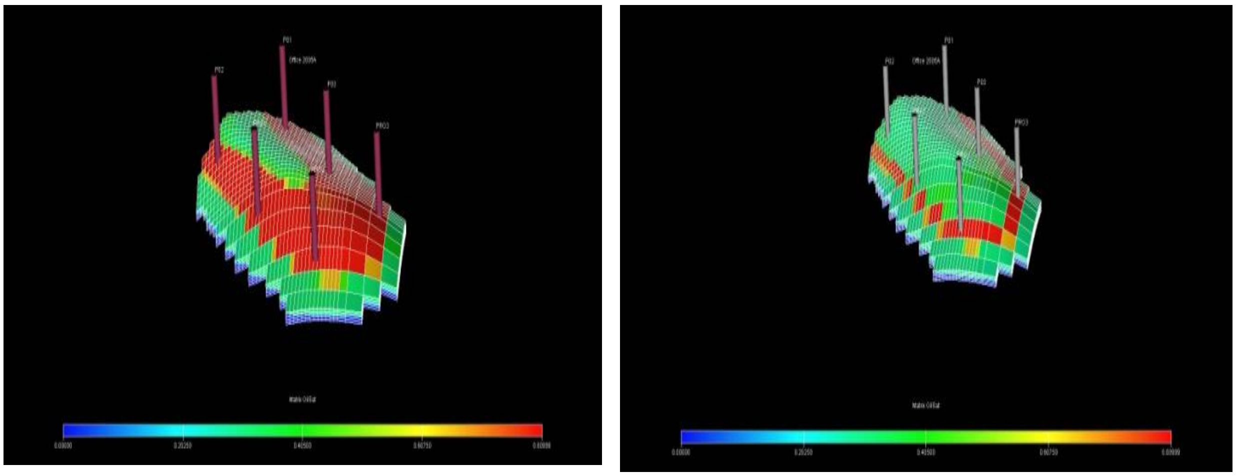
Table 2 Data of reservoir constructed model sector

Type of porous medium	Fractured	X grid block size(Mean),ft	188
Number of cell in X-direction (N_x)	38	Y grid block size(Mean),ft	240
Number of cell in Y-direction (N_y)	34	Z grid block size(Mean),ft	116
Number of cell in Z-direction (N_z)	7	Matrix porosity,%	17
Number of cell	9044	Fracture permeability, md	5800
Dual porosity matrix-fracture coupling,1/ft^2	0.13	Effective matrix block height for gravity drainage ,ft	20

2.3. Studying different production scenarios using simulator

There are three production wells, naming P01, P02, and P03, in the selected sector model. Totally, five other wells consisting of 2 injection and 3 production wells, located in the east of reservoir, are drilled to increase remaining oil recovery of this area.

Model natural production was studied for three scenarios of 3, 4, and 6. Figure 2 shows remaining oil saturation before and after natural drainage in well 6 scenario [8]. Table 3 and Figure 3-6, also, illustrate obtained results [8].



(a) (b)

Fig. 2 Comparing remaining oil saturation in natural drainage in matrix a. 2012, b.2040

Table 3 The effect of wells numbers on natural drainage scenario

No	No. well	Sor	%RF	Np (MMSTB)
1	3	0/5106	7/3498	11/4114
2	4	0/4782	12/082	18/7586
3	6	0/4141	22/2636	34/5665

It is worth noting that reservoir production rate is 6000 STB/day.

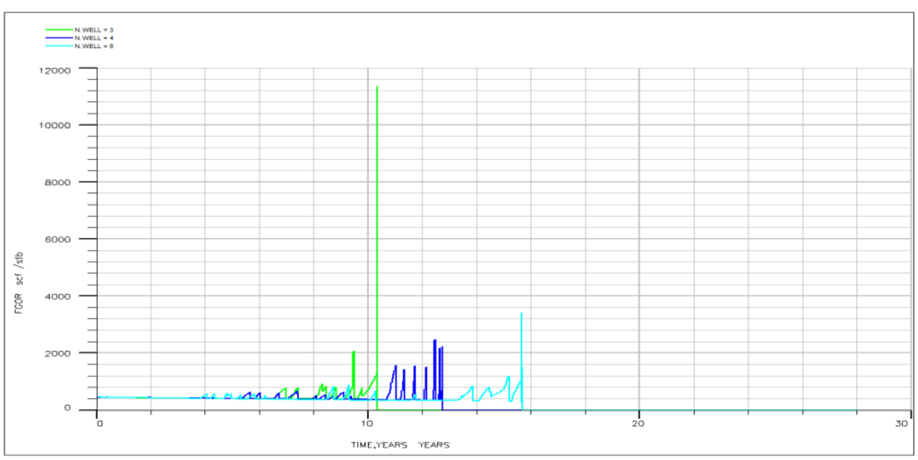


Fig. 3 Gas oil ratio (GOR) resulted by natural drainage to 2040

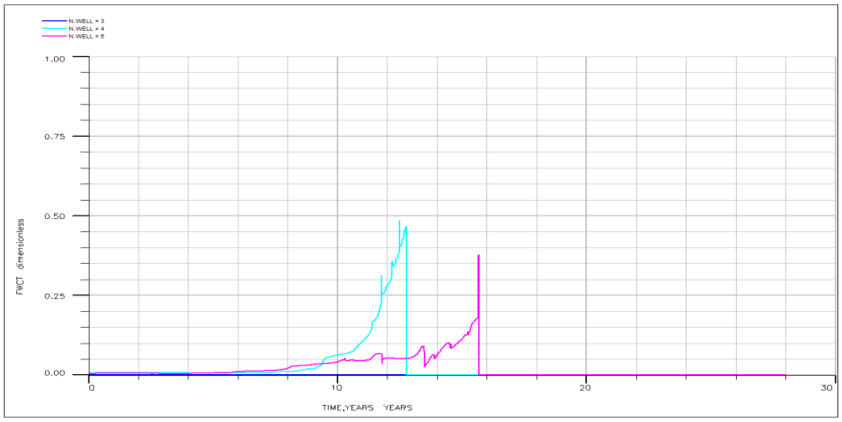


Fig. 4 Water cut resulted by natural drainage to 2040

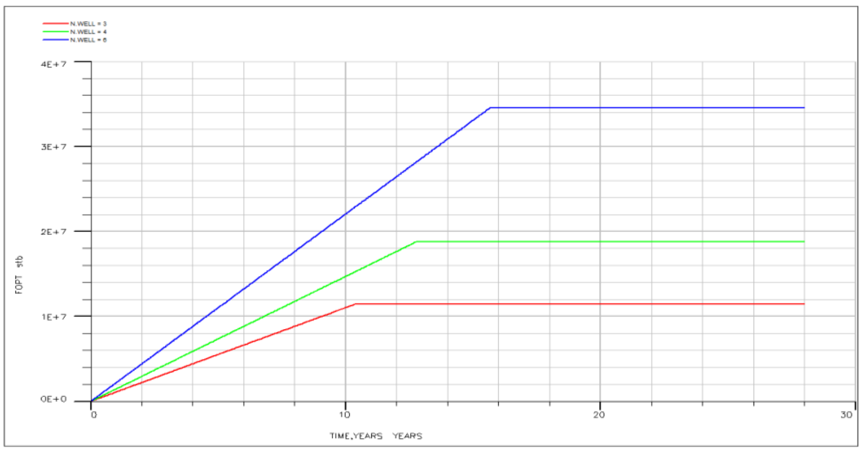


Fig. 5 Amount of oil produced by natural drainage to 2040

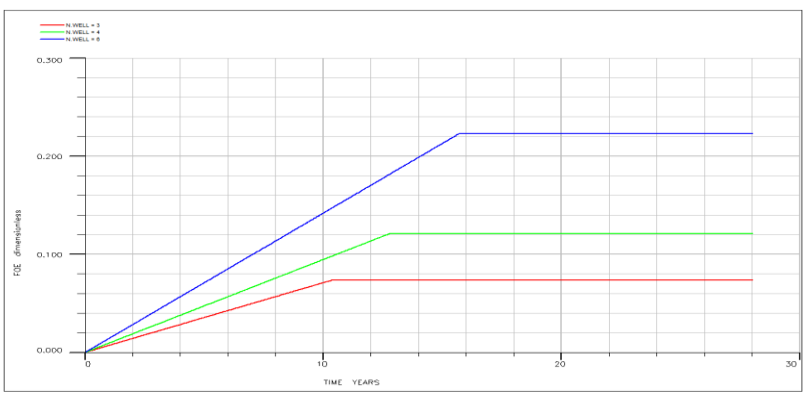


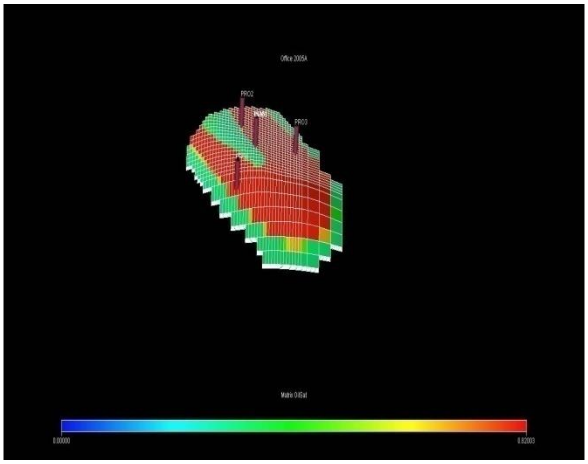
Fig. 6 Oil efficiency resulted by natural drainage to 204

2.4. Effect of production and injection wells pattern on water- alternating-gas (WAG) injection process

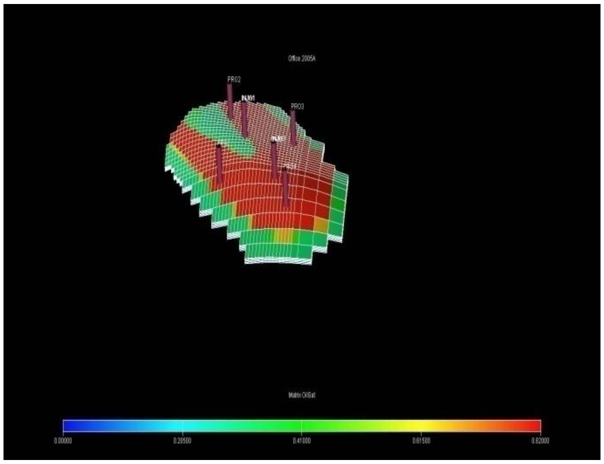
This research tried to study and evaluate the effect of production and injection wells' pattern on WAG injection process. To do this, four patterns are tested and the results are provided in Table 4 and figures 7-11. According to results, 5 spot-dual pattern is the best and most efficient for desired model [8].

Table 4 The effect of production and injection wells' pattern on WAG injection process

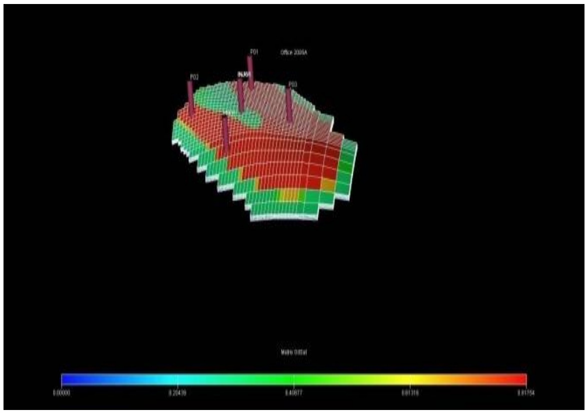
No	Pattern	Sor	%RF	Np (MMSTB)
1	4Spot	0.4243	18.6636	30.8764
2	4Spot – Dual	0.4052	26.5153	41.1685
3	5Spot	0.3916	26.5153	41.1685
4	5Spot – Dual	0.3705	32.4009	50.3057



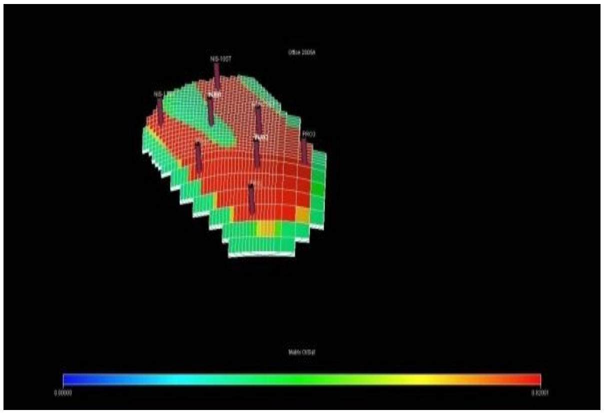
4Spot



4Spot – Dual



5Spot



5Spot Dual

Fig. 7 A schematic of patterns used in WAG injection process

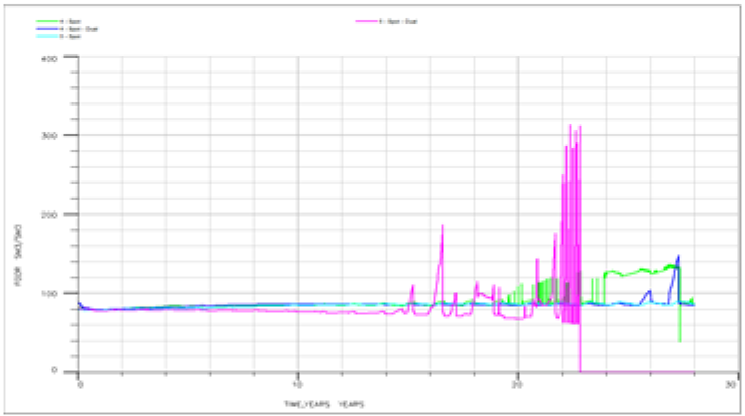


Fig. 8 Effect of production and injection wells' pattern on GOR in WAG injection process

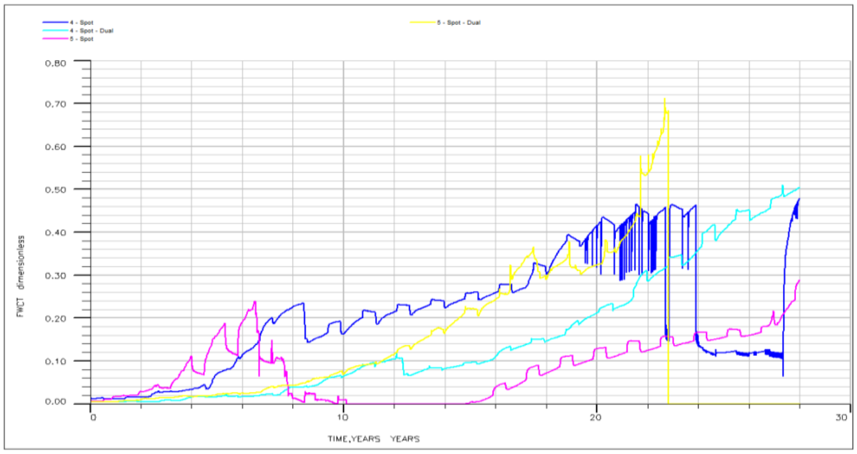


Fig. 9 Effect of production and injection wells' pattern on water cut in WAG injection process

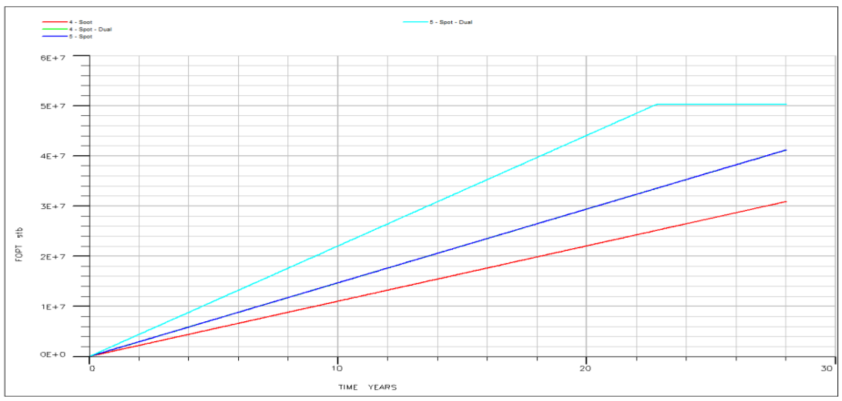


Fig. 10 Effect of production and injection wells' pattern on oil production in WAG injection process

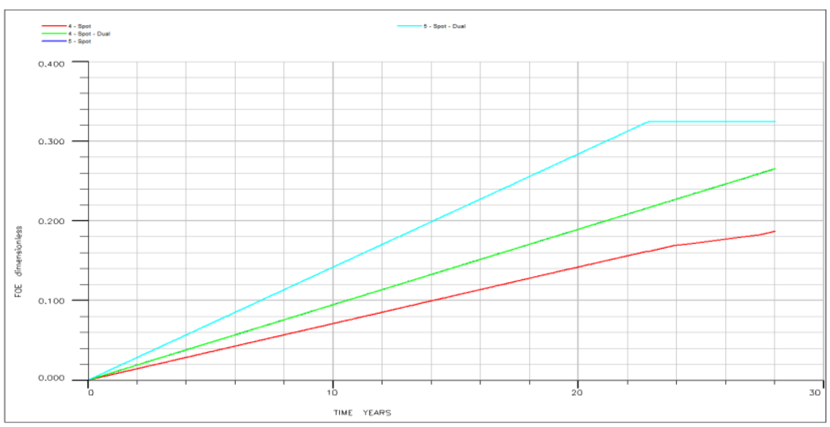


Fig. 11 Effect of production and injection wells' pattern on oil recovery in WAG injection process

3. Results and discussion

1. Increasing production wells in natural drainage scenario resulted in higher recovery of well 6 scenario in comparison to other scenarios. For instance, well 6 scenario has almost 10% recovery factor larger than well 4 scenario.
2. In studying the effect of production and injection wells' pattern, 5-Spot-Dual model with recovery factor of 32.4009 was the most efficient and best pattern for the desired model.

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