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通过注水提高石油采收率

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摘　要：注水是通过向油藏注水来提高石油采收率的一种简单而廉价的手段。出于经济考量，注入井和生产井必须考虑油藏地质、流体性质和井的方向，进行最佳的布置。本研究的重点是井的位置和方向对注水过程性能的影响。油藏的尺寸为 2500 英尺 × 2500 英尺 × 150 英尺，孔隙度均匀，渗透率不均匀。本研究评估和比较了三个案例的性能。在评估其性能时，考虑了产水率、生产井的孔底压力限制、油井含水率和整个生产期的净现值（NPV）。使用 MATLAB 油藏模拟工具箱（MRST）进行了油藏建模和模拟。调查证实，案例三的最大产量为 1,110,188.6 储罐桶/日，在 1400 天的时间跨度后，随着压力的降低，产量下降到 11,005 储罐桶/日。因此，可以认为这是油井布置方面的一个更好的选择。据估计，它的最大净现值为 198 亿美元，在经济上是可行的。

关键词：EOR；油藏；注水；NPV；MRST；五点法

Enhancing oil recovery through waterflooding

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Abstract: Waterflooding is a simple and cheaper means of improving oil recovery from a reservoir by injecting water into the reservoir. Economic considerations suggest injection and production wells must be optimally placed considering reservoir geology, fluid properties, and well orientation. This study focuses on the effects of well placement and orientation on the performance of waterflooding process. The reservoir has a dimension of 2500 ft by 2500 ft by 150 ft. It is homogenous in porosity and heterogeneous in permeability. The performances of three cases considered in the study were evaluated and compared. Water production rates, bottom hole pressure limits for producer wells, well water cut and net present value (NPV) over the entire production period were considered in evaluating their performances. Reservoir modeling and simulation were carried out using MATLAB Reservoir Simulation Toolbox (MRST). It was verified from the investigation that Case III has a maximal production rate of 1,110,188.6 stb/day (stock tank barrel per day), decreasing to 11,005 stb/day after a span of 1400 days with a pressure decrease. Consequently, it was considered a better choice in terms of well placement. It was also estimated to have a maximal Net Present Value of 19.8 billion dollars, which makes it economically viable.

Keywords: EOR; Reservoir; Waterflooding; NPV; MRST; five-spot pattern

一、引言

EOR Grema Cao 2013
Grema Cao 2016 RF
Ahmed
2006 RF 1 Ahmed
2006

Grema Cao, 2017

$$RF = \frac{OIP_{(Original)} - OIP_{(Now)}}{OIP_{(Original)}} \qquad 1$$

PDEs
Grema RF $OIP_{(Original)}$
Cao 2017 $OIP_{(Now)}$

Adeniyi 2008 Jansen

2008 Jansen 2009

Adeniyi

2008 Grema Cao 2013

Jansen 2008 Jansen 2009 Grema

Cao 2020

Grema

Cao 2016

Jansen

2011

FOPR FWPR FOPT

BHP FWPT

WWCT NPV

二、方法

1.

2500 ×2500 ×150

x y z

5 5 3 8000

0.2 **1** x y z

1.

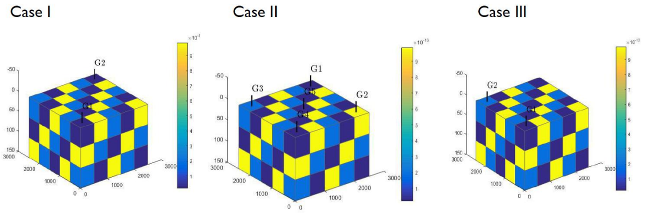
x	200mD	1000mD	200mD
y	150mD	800mD	150mD
z	20mD	100mD	20mD

4500psia 4×10^{-6}psi-1

3

25

1



1.

2.

Adeniyi 2008

Ahmed,2006 MATLAB

-

Lie 2012

2

49lbs/ft^3 63lbs/ft^3 4500psia

2. 1000mD

	K_{rw}	K_{ro}	P_{cow}(Psi)
0.15	0.0	0.9	4.0
0.45	0.2	0.3	0.8
0.68	0.4	0.1	0.2
	0.55	0.0	0.8

NPV

Grema Cao 2016

2 Grema Cao 2016

$$J^k = \left\{ \frac{\sum_{j=1}^{N_{prod}} \left[r_0 (y_{0,j})^k - r_{wp}(y_{w,j})^k \right] - \sum_{i=1}^{N_{inj}} r_{wi}(u_{wi,i})^k}{(1+b)^{\frac{t^k}{r}}} \right\} \Delta t^k \qquad 2$$

r_{wi} r_{wp} r_0 $u_{wi,i}$

y_w $y_{0,j}$ N_{prod}

N_{inj} b Δt^k

t^k τ

0.05 70

6 6 NPV

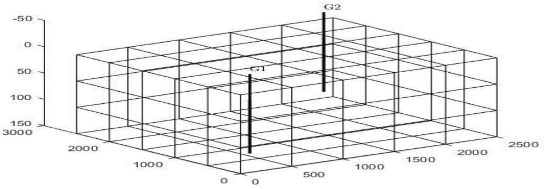
1. 1

1 **2**

Z "G2"

"G1"

/


G2
G1
-50
0
50
100
150
3000
2000
1000
0
0
500
1000
1500
2000
2500

2. 1

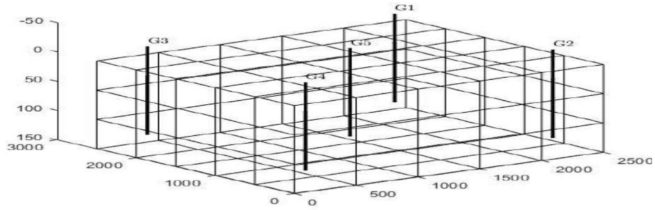
2. 2

2

3

G_1,G_2,G_3,G_4 G_5

3


G1
G3
G5
G2
G4
-50
0
50
100
150
3000
2000
1000
0
0
500
1000
1500
2000
2500

3. 2

3. 3

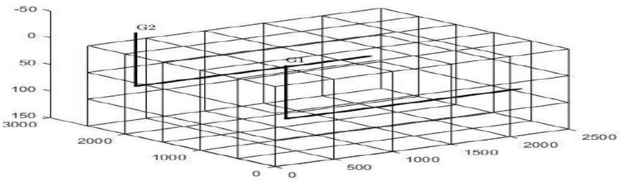
G_1 G_2

4

G_1

G_2

4


G2
G1
-50
0
50
100
150
3000
2000
1000
0
0
500
1000
1500
2000
2500

4. 3

MATLAB

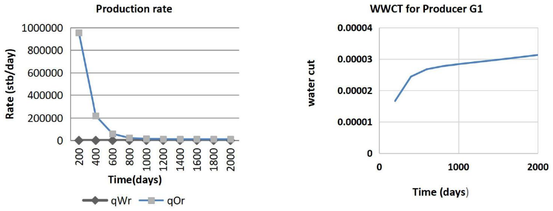
MRST MRST

Lie

2012

1

1 5



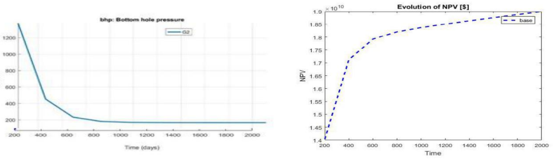
5. 1

5 400

955,346.89 /

6 11,582.45 /

2000



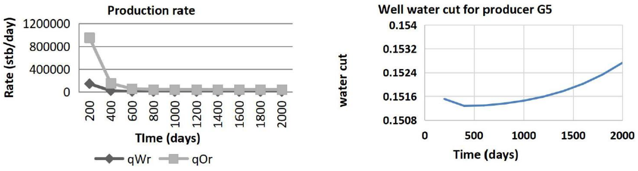
6. 1 BHP NPV

2000 190 6.6

6

2

2 7



7. 2

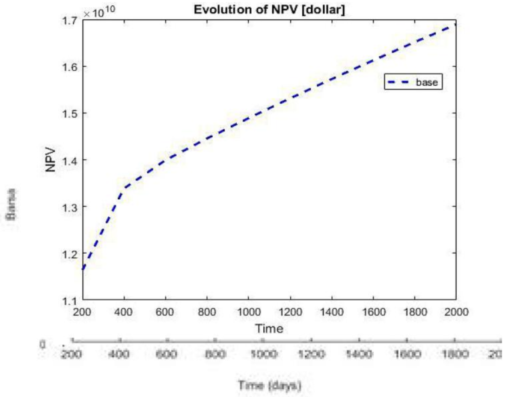
2 400

37,343.089 / 7

2

2000 170 6

8



8. 2 BHP NPV

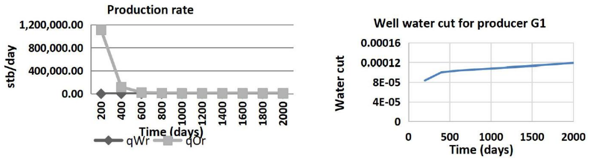
1 2

8

BHP

3

3 9



9. 3

3 1200

1,110,188.60 / 11,019.06

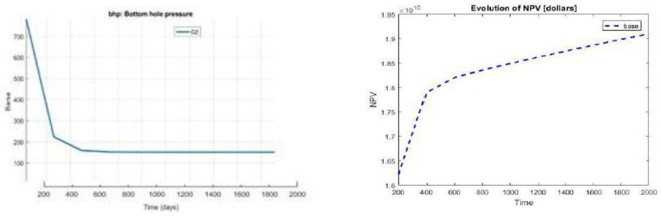
/ 9 1 2

1 2

3 2000

195 6.8

10



10. 3 BHP NPV

3 1 2

BHP

3

NPV WWCT

四、结论

MRST

NPV 1 2

2000

3

3

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