The study of a new development method which integrates CO2 huff and puff with factory fracturing in tight oil reservoirs

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The result becomes worse and worse with the increase of multicycle huff and puff. In order to stabilize the oilfield production in tight oil reservoirs, this study proposes a new development method which integrates CO2 huff and puff with factory fracturing technology. Based on the advanced seepage mechanics and reservoir engineering theory, this study considered the Non-Darcy flow and took one oil block named W for an example to raise 8 design projects. This paper chose the best one by numerical simulation software. The results prove that: (1) under the same reservoir conditions, the technique of CO2 huff and puff in multi-stage fractured horizontal wells (MSFHW) in tight reservoirs can complement the formation energy and improve recovery efficiency, this method also have an advantages over water or gas injection in the combination spacing of vertical and horizontal wells; (2) the effective integration of CO2 huff and puff with factory fracturing technology can not only improve exploitation effectiveness in high oil saturation bank on either side of old manual fissure, but also can complement the formation energy, so that recovery percentage can be increased by 3.79% over the single technology of CO2 huff and puff. The study can serve as a guideline for the secondary development in tight oil reservoirs.

Keywords: Factory fracturing technology; Repeated transformation; CO2 huff and puff,; Tight oil reservoirs; Development method

1. Introduction

In recent years, nonconventional oil and gas reserve is taking a gradually increasing proportion, thus reservoir reform has become the “trump card” of petrol engineering technology[1-4]. The factory fracturing technology is commonly used for shale gas development in north America and has three major advantages: fast construction speed, short period of production, low cost of winning. Many countries such as the US and Canada have adopted gas drive oil production, within which the CO2 drive oil production accounts for 23.6%of the total EOR oil production[5]. The CO2 huff and puff can reduce the viscosity of crude oil, expand the crude oil volume and reduce the interfacial tension. It can be used for high/low permeability reservoir and high/low viscosity oil reservoir [6,7].Since 2002, researchers have performed a series of experiments focusing on the influence of huff and puff occasion and depression mode[8].In 2005, Xu Y. C. and Wang Q. et al showed that CO2 huff and puff technology is an effective well stimulation for oil reservoir no perfect injection and recovery relation and with low stratum energy[9]. In 2008, Zhao G. M. and Wang D. et al performed laboratory experiment of CO2 huff and puff and explain the well stimulation mechanism by CO2 huff and puff technology, aiming at solving the problems of low permeability, insufficient natural energy, water injection difficulty and rapid production decline of 48 fault block of Daqing oil field [10]. In 2014, Sun K. did laboratory experiments and field tests of CO2 huff and puff and the result is good [11].

These research results are crucial but new fracturing technology has to be developed because tight oil reservoir cannot realize its exploit value by conventional fracturing technology for its tight structure and low permeability [12].Therefore in this paper, based on the research results of predecessors, technology and development is combined and a new exploit method is developed by combining CO2 huff and puff technology and factory fracturing technology for tight oil reservoirs. By using numerical simulation software, the new design and idea for new develop method of combining CO2 huff and puff technology and factory fracturing technology for tight oil reservoirs and the influence on this new method from multiple factors is studied.

2. Design and idea of the new development method combining CO2 huff and puff technology and factory fracturing technology

In 2014, Yang Zhengming, Zhang Zhonghong, and Liu Xuewei et al have established physical simulation experiment for multi-stage fractured horizontal wells and researched the permeability rule of multi-stage fractured horizontal wells in tight oil reservoirs based on the numerical simulation software of tight oil reservoirs and nonlinear seepage reservoir. In this paper, the design is based on the result of this physical simulation experiment [12-14].

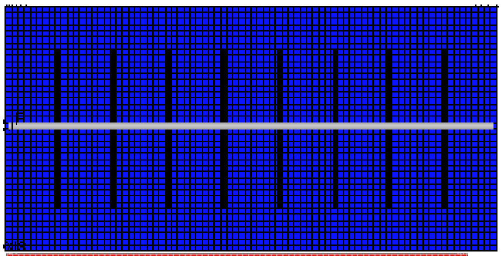
2.1 Establishment of numerical model

The average porosity of Block W of Oilfield C is 10.8%, the permeability is between 0.1mD to 0.64mD, and the average permeability is 0.4mD. Conditions for well pattern: the body width is from 800 to 1400m; the spacing between horizontal well is 400m; there are 5 to 10 stages, the semi-length of artificial fracturing fissure; the space between fissures is around 100m.

Compositional numerical model and block grid system are used in a model dimension of 800m×400m×10m, a permeability of 0.47mD, a porosity of 10.18% and a horizontal well length of 800m. In 2014, Zhou Tuo, Liu Xuewei, et al. have optimized number of fractured stages of horizontal wells, semi-length of fissure, spacing between fissures and number of injected PV. By referring to this method, the number of horizontal well fracture stages of 8 is calculated. The fissure semi-length is 130m, the spacing between fissures is 90m, the number of injected PV is 0.22HCPV, the flow conductivity of the fissure is 50D•cm, the injected rate is 75000m3/d-90000m3/d and the huff and puff cycle is 1.5 year. See Table 1 for high pressure physical property parameters. Choose typical wells in this block for history matching. The parameters modified based on matching results are used for calculating of numerical models. Numerical model is shown in Fig.1 where grey segment is horizontal well, dark segments are fractures.

Table 1 High pressure physical property parameters

Parameter	Value
Stratum depth(m)	1725.9
Formation pressure (MPa)	17.87
Formation temperature (℃)	80.5
Saturation pressure（MPa）	7.93
Formation oil viscosity（MPa•s）	2.35
Volume coefficient	1.1599
Compression coefficient (1/MPa)	0.001349
Gas oil ratio of single degassing (m3/m3)	38.52
Crude oil density of formation (g/cm3)	0.7821
Relative density of natural gas	0.75



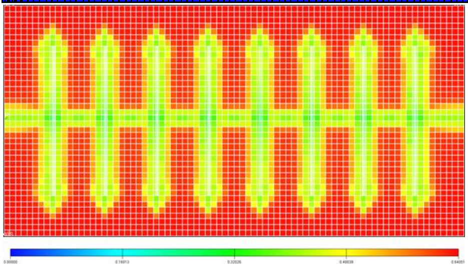


Fig.1 Numerical modelFig.2 Schematic diagram for high oil content area

2.2 Project design

For well groups after one transformation, along with more huff and puff operation, high oil content blocks with inferior production exist along the two flanks of the horizontal fracture (see Fig. 2 for reference). Therefore, the factory fracturing technology and repeated design is used. By making new fractures, the high oil content area with inferior production is connected to increase its oil recovery, thus 8 projects are designed as shown in Table 2.

Table 2 Numeric simulation scheme

NO.	Content
0	No repeated transformation by factory fracturing technology
1	Increase the semi-length of joint by 30m
2	Increase the semi-length of joint by 60m
3	Intensify old joints, reserve semi-length of 130m for new joints
4	Intensify old joints, fully blocked, reserve semi-length of 130m for new joints
5	Intensify old joints, semi-blocked, reserve semi-length of 130m for new joints
6	Intensify old joints, reserve semi-length of 190m for new joints
7	Intensify old joints, fully blocked, reserve semi-length of 190m for new joints
8	Intensify old joints, semi-blocked, reserve semi-length of 190m for new joints

Fig.3 is the schematic diagram for the project, the horizontal black segments indicate multi-stage fractured horizontal wells and the red ones indicate joints from one fracturing (hereinafter referred to as the "old joint") and the yellow ones indicate repeatedly transformed joints from factory fracturing technology (hereinafter referred to as the “new joint”). The vertical black segments indicate that the old joints are blocked in Fig. 3.

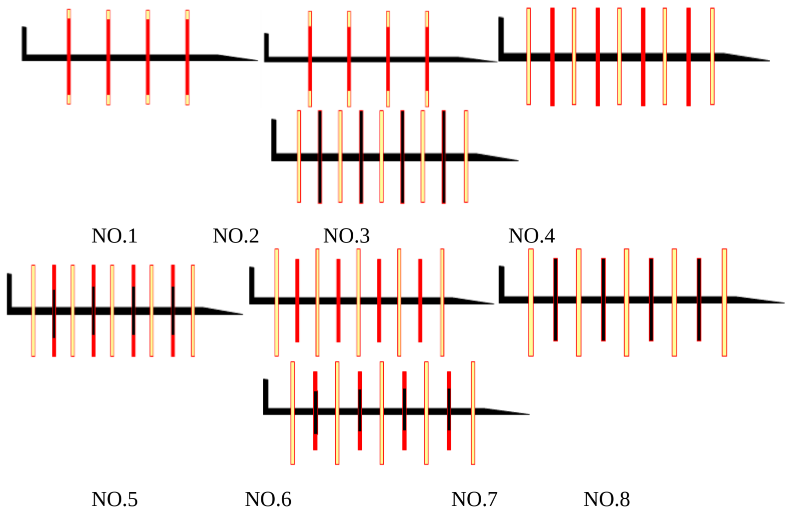


Fig.3 Schematic diagram of numeric simulation scheme

3. Research on influence on the new design from different projects

3.1 Comparison of cumulative recovery degree

Before repeated transformation of factory fracturing, the block produces an annual recovery percentage of 3.83%. The cumulative recovery degrees of the former four stages are: 6.36%，9.39%，12.00% and 3.85%. As the production increase slowed down after these four cycles of huff and puff, repeated transformation of factory fracturing technology is used. See Table 3 for the calculated cumulative recovery degree.

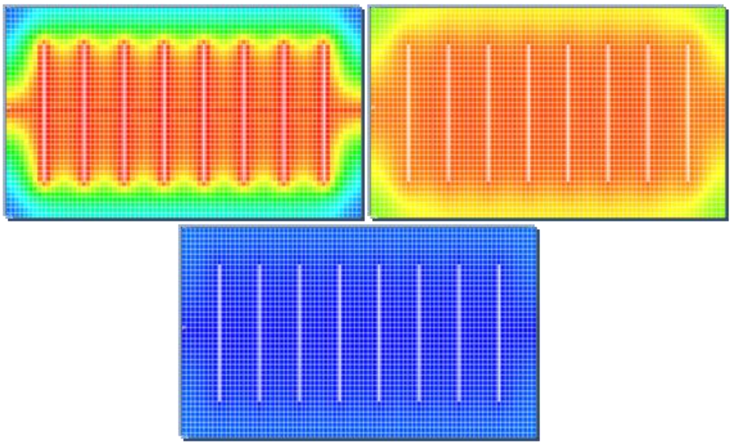
Table 3 Cumulative recovery degree after repeated transformation of factory fracturing technology

NO.	Project	5th cycle (%)	6th cycle (%)	7th cycle (%)	8th cycle (%)	Order
0	No repeated transformation by factory fracturing technology	15.24	16.82	18.23	19.59	9
1	Increase the semi-length of joint by 30m	15.87	17.47	19.09	20.65	8
2	Increase the semi-length of joint by 60m	16.61	18.44	20.31	21.93	5
3	Intensify old joints, reserve semi-length of 130m for new joints	16.41	18.40	20.28	22.08	4
4	Intensify old joints, fully blocked, reserve semi-length of 130m for new joints	15.77	17.76	19.62	21.35	7
5	Intensify old joints, semi-blocked, reserve semi-length of 130m for new joints	15.85	17.84	19.74	21.50	6
6	Intensify old joints, fully blocked, reserve semi-length of 190m for new joints	17.01	19.23	21.35	23.38	1
7	Intensify old joints, fully blocked, reserve semi-length of 190m for new joints	16.32	18.27	20.23	22.16	3
8	Intensify old joints, semi-blocked, reserve semi-length of 190m for new joints	16.39	18.32	20.31	22.28	2

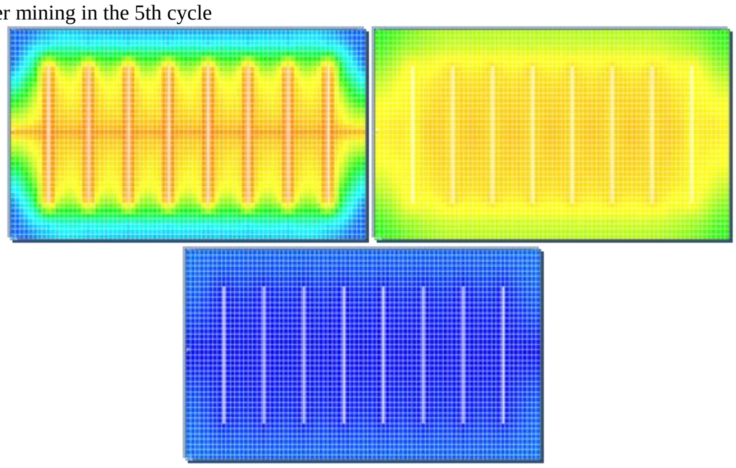
As shown inTable 3, the recovery degree of project 6 is the highest, 3.79% higher than that of project 0 without repeated transformation by factory fracturing technology. The recovery degree is influenced by the blocking and repeating method of the joints: under uniform conditions: the joint is blocked with decreased diversion capacity and smaller recovery rate; intensify the old joints and the semi-length of new joints is greater than that of old joints so the recovery degree increases. Under uniform geological conditions, the highest recovery degree of water injection and gas injection in the combination spacing of vertical and horizontal wells for 20 years is below 20%.

3.2 Pressure distribution chart

See Fig.4 for the pressure distribution diagram of Project 0 and Fig.5 for the pressure distribution diagram of Project 6 with the best recovery degree. The comparison is made among the fifth cycle and eighth cycle and different moments (after CO2 injection, after soaking and after mining) of every scheme.

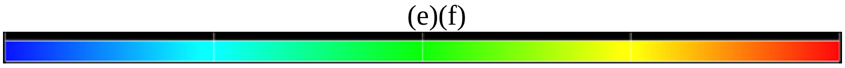


(a)after CO2 injectionin the 5th cycle; (b) after CO2soakingin the 5th cycle;
(c) after mining in the 5th cycle



(d) after CO2 injectionin the 8th cycle; (e) after CO2soakingin the 8th cycle;
(f) after mining in the 8th cycle

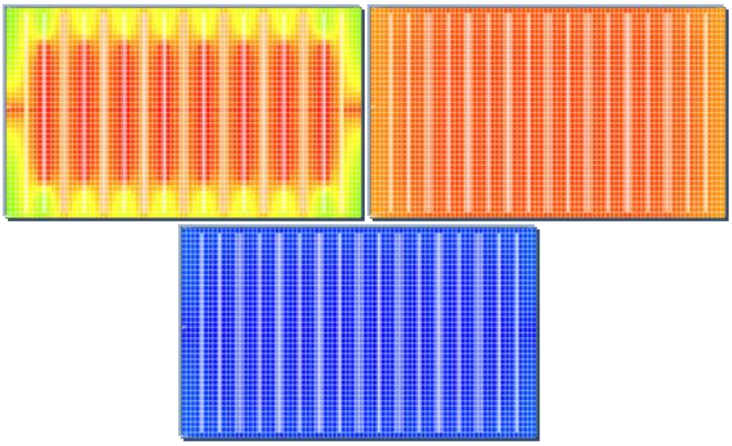
(e)(f)



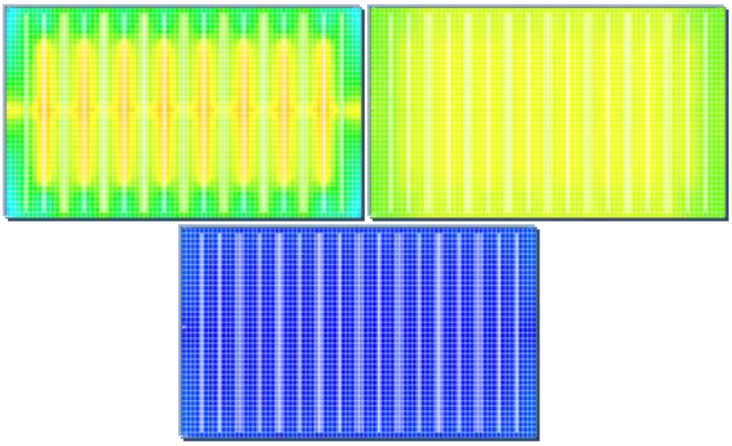
80.04 101.00 121.95 142.90
163.85

Fig.4 Pressure distribution diagram of Project 0

Compare Fig.4 with Fig.5, it is not difficult to find out that the energy supplementary condition is better than that of Project 0. Under uniform conditions after soaking time, the pressure distribution of Project 6 is more even than that of Project 6, in favour of enhancing the oil recovery. Therefore, the repeated transformation of factory fracturing has significant effects on production stability, underlying energy supplement and enhancing the recovery degree.



(m) (m)after CO2 injectionin the 5th cycle (n) after CO2soakingin the 5th cycle
(x) after mining in the 5th cycle



(y) (y)after CO2 injectionin the 8th cycle (z) after CO2soakingin the 8th cycle
(w) after mining in the 8th cycle

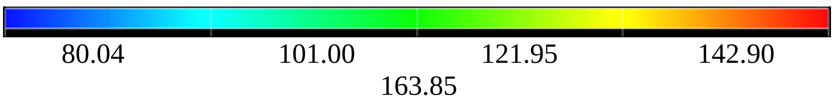


Fig.5 Pressure distribution diagram of Project 6

4. Summary

Considering the non-Darcy seepage flow characteristic, the new development method combing CO2 huff and puff technology with factory fracturing is proposed. Take Block W of Oilfield C as example, the design and thinking of this new method is introduced and influence from different schemes on the new method is studied.

First of all, under uniform reservoir conditions, using huff and puff technology of CO2 in multi-stage fractured horizontal wells for tight oil reservoirs can effectively supplement the stratum energy and enhance the oil recovery better than water or gas injection in the combination spacing of vertical and horizontal wells; second, combining repeated transformation of factory fracturing with CO2 huff and puff technology can not only improve the production of high oil content area at both flanks of the artificial joint, but also supplement the underlying energy and enhance the well yield with a recovery rate increase of 3.79%.

Acknowledgements

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