Numerical Simulation of Unstable Waterflooding of Horizontal Wellblock

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Abstract

M72 horizontal wellblock of an oilfield has characteristics of low permeability fissured oilfield, and production of horizontal wells decrease rapidly during development, to ensure efficient development of horizontal wellblock, numerical simulation research of Unstable waterflooding method for this block was conducted. Based on Eclipse numerical simulation software, fine geologic modeling and history fit were made for simulated area, and multiple Unstable waterflooding adjustment schemes were designed to determine reasonable waterflooding intensity and cycle for different layer and spot of horizontal wells, predict development index of every scheme, compare effect of different scheme, finally combine every optimal scheme and conclude a set of waterflooding adjustment scheme suitable for horizontal-vertical joint exploration of an oilfield. Results show that for reservoir stratum with small thickness and low permeability it is suitable to increase tip waterflooding and control root waterflooding of horizontal wells with ratio of tip and root waterflooding being 1.14, reasonable waterflooding intensity of block being 2.1 m3/(d.m), reasonable waterflooding cycle being 3 months.

Keywords

Horizontal well , Unstable waterflooding ,Numerical simulation , waterflooding intensity, waterflooding cycle.

1. Introduction

Unstable waterflooding is also called cyclic waterflooding, periodical waterflooding, is a improved waterflooding method specifically aiming at heterogeneous reservoir and low permeability reservoir which can lower water content and increase oil recovery by changing working system of oil-water wells, is an effective means to improve oilfield development effect[1]. M72 horizontal wellblock has characteristics of low permeability fissured oilfield, with main development layer being P oil layer, thin oil layer and low permeability, adopting horizontal-vertical well joint development, at the stage of no water breakthrough. Since development, no periodical waterflooding was conducted during development process, without considering difference of reservoir stratum which the horizontal section of horizontal well is in and lateral anisotropy of reservoir stratum, without targeted waterflooding for different spot of horizontal section, horizontal production decreases rapidly[2]. Hence, the author researched Unstable waterflooding adjustment scheme for this block to extend no-water development period of horizontal wells and increase oil recovery with numerical simulation of oil reservoir, considering waterflooding intensity of different reservoir layer, different spot of horizontal wells[3].

2. Waterflooding intensity adjustment scheme and optimization

Waterflooding is one of important parameters of waterflooding development of oil reservoir, with reasonable waterflooding intensity beneficial to improve development level of oil reservoir. Research on reasonable waterflooding intensity of different spot of horizontal well was conducted, during research, the well operated in the way of fixed fluid, intensifying rip waterflooding controlling root waterflooding, designing simulation of 3 schemes with ratio of tip and root waterflooding being 1.14, 2.42 and 7.55 respectively. During scheme prediction, only changed waterflooding of 12 waterflooding wells with ratio of tip and root waterflooding meeting standards of three prediction scheme, without changing other parameters, obtaining four schemes and index comparison of four wells calculated till 2019 (see table 1).

Table 1 Index comparison of four wells calculated till 2019 when intensifying tip waterflooding

Scheme	The ratio of broken and broken water injection	Oil production (1 d-1)	Accumulative oil production (t)	Water content (%)	Time of initial water break through
Original scheme		3.85	34424.7	62.42	2010-03
Scheme 1	1.14	3.95	34631.6	61.40	2010-02
Scheme 2	2.42	3.61	32924.8	64.75	2010-01
Scheme 3	7.55	3.08	30850.8	69.96	2010-01

According to Table 1, compared to other schemes, in scheme 1 the horizontal well has the highest accumulative oil production, lowest water content, best development effect, which demonstrates that intensifying tip waterflooding and controlling root waterflooding can improve development effect of the block, so scheme 1 is the best one, i.e., ratio of tip and root waterflooding being 1.14. Waterflooding intensity of different reservoir stratum of horizontal well predicted accumulative oil production of single well of 4 wells by intensifying tip waterflooding and controlling root waterflooding through numerical simulation, it can be concluded that after intensifying tip waterflooding and controlling root waterflooding, development effect of well N214-P331 and N216-P327 is better than Original scheme, with ratio of tip and root waterflooding of optimal scheme being 1.14. The two wells encounter non-body sheet sand, with small thickness and low permeability. While for well N218-P335 and N220-P331, after intensifying tip waterflooding and controlling root waterflooding, development effect is not as good as Original scheme, the two wells encounter body sheet sand, with large thickness and high permeability. So for thin and low permeability reservoir stratum, intensifying tip waterflooding and controlling root waterflooding helps to improve development effect of oilfield. Shall applying the method of intensifying tip waterflooding and controlling root waterflooding to well N214-P331 and N216-P327, with 1.14 ratio of tip and root waterflooding, however well N218-P335 and N220-P331 shall not adopt this method. Reasonable waterflooding intensity[4]. During scheme design, adjusted waterflooding intensity of simulated zone since Jan 2010,current waterflooding intensity being 2.5 m^3/(d.m), designed four more schemes to simulate with waterflooding intensity being 2.1, 2.3, 2.7 and 2.9 m^3/(d.m) respectively. When conduction scheme prediction, only change waterflooding intensity without changing any other parameters, obtained index comparison of 4 horizontal well 5 schemes calculated till 2019 (see table 2)

Table 2 Index comparison of 4 horizontal wells calculated till 2019 with waterflooding intensity adjusted

scheme	Waterflooding intensity	Oil production (1 d-1)	Accumulative oil production(t)	Water content (%)	Time of initial water break through
Original scheme	2.5	3.85	34424.7	62.42	2010-03
Scheme 1	2.1	3.89	34536.8	61.81	2010-03
Scheme 2	2.3	3.86	34454.0	62.28	2010-03
Scheme 3	2.7	3.85	34362.0	62.48	2010-03
Scheme 4	2.9	3.83	34240.9	62.64	2010-03

According to table 2, development effect of scheme 1 and 2 is better than other schemes, and waterflooding intensity of both schemes is lower than Original scheme, but scheme 1 has the highest accumulative oil production, lowest water content and best development effect, so scheme 1 is the best one, i.e. reasonable waterflooding intensity is 2.1 m^3/(d.m).

3. Unstable waterflooding adjustment scheme and optimization

3.1 Analysis of applicable conditions

Anisotropy of reservoir stratum is a main factor to limit oilfield development, and periodical waterflooding is one of effective measures to reduce adverse influence of oil stratum anisotropy. Periodical waterflooding is actually Unstable waterflooding, periodical waterflooding during low water content period (water content less than 10%) can delay water breakthrough time or slow down rise of water content . After analysis of geologic characteristic of M72 horizontal wellblock of an oilfield and contradiction emerged in development, it was determined to conduct periodical waterflooding at the block, its adaptability mainly lies in two aspects:

Deposit characteristic is suitable to improve flooding effect by periodical waterflooding. There are totally 18 deposit units longitudinally at M72 horizontal wellblock of an oilfield, based on cause of oil stratum and distribution of sand body, multiple types of deposit sand body were dived horizontally and various types of sand body emerge alternatively, lithological change is frequent vertically, and thickness and permeability difference of different type of stratum and different spots of same stratum are larger. According to functional mechanism of periodical waterflooding, the more serious the anisotropy of oil stratum, the better the effect of periodical waterflooding.

It needs to control the speed of rise of water content and production decrease. With further development, water content of oilfield will increase gradually, and difference of water content between wells and between stratums increases, with big difference of use condition and imbalanced flooding distribution, which needs periodical waterflooding to improve.

3.2 Reasonable waterflooding cycle and optimization

Conducted periodical waterflooding at simulated zone beginning from Jan 2010, plane alternation of waterflooding wells adopts diagonal method, i.e. 12 wells were divided into two groups diagonally with 6 wells each group, then stop waterflooding of two groups alternatively based on stopping cycle. Total 6 schemes (scheme 1 - 6) were designed to simulate with stopping cycle 1, 2,3,4,5 and 6 months, during scheme prediction only changed stopping state of two groups of wells without changing other parameters, through numeral simulation, obtained index comparison of 7 schemes, 4 horizontal wells calculated till 2019 (see table 3).

Table 3 Index comparison of periodical waterflooding of 4 wells calculated till 2019

scheme	Oil production (1 d-1)	Accumulative oil production	Water content (%)	initial water breakthrough time
Original scheme	3.85	34424.7	62.42	2010-03
Scheme 1	5.38	38425.8	47.43	2010-02
Scheme 2	5.56	38949.4	45.74	2010-03
Scheme 3	5.64	39434.2	45	2010-03
Scheme 4	5.37	38267.9	47.54	2010-08
Scheme 5	5.20	37883.9	49.21	2010-09
Scheme 6	5.20	37888.2	49.2	2010-10

According to table 3, though initial water breakthrough time of scheme 3 is earlier than latter 3 schemes, it has the largest accumulative oil production, lowest water content, with better development effect than other schemes, so scheme 3 is the best one, i.e., reasonable waterflooding cycle is 3 months. The cause of periodical waterflooding improving oilfield development effect, is that periodical change of waterflooding causes Unstable pressure field in stratum, changing oil-water plane and vertical seepage, resulting in constant redistribution of fluid in stratum to promote capillary absorption and seepage action, and causing additional pressure difference between high and low pervious bed perpendicular to non-homogeneous pay to produce additional fluid channeling which can result in even vertical distribution of flooding of oil stratum, helpful to displacement of at low flooding oil stratum and remaining oil of poor oil stratum, thus increasing swept volume of waterflooding, flushing efficiency and development effect. Finalization of adjustment scheme. Based on comparison and optimization of earlier schemes, finalized optimal scheme as Unstable waterflooding adjustment scheme of M72 horizontal wellblock of an oilfield. The optimal scheme is: designed waterflooding intensity is 2.1 $m^3/(d.m)$, periodical waterflooding with cycle of 3 months, for well N214-P331 and well N216 - P327, intensify tip waterflooding and control root waterflooding, with ratio of tip and root waterflooding being 1.14; for well M218 - P335 and well 220 - P331, don't adopt the method of intensifying tip waterflooding and controlling root waterflooding. It can be seen by comparing optimal scheme and Original scheme that Original scheme has oil production of 3.85 t/d, accumulative oil production of 34424.7 t, water content of 62.42% and oil recovery of 29.4%, while optimal scheme has oil production of 5.56 t/d, accumulative oil production of 38794.9 t, water content of 45.7%, and recovery of 32.1%. After using optimal scheme, oil production increases, water content decreases and recovery increases by 2.7%.

4. Conclusions

Based on fine geological modeling and history fit, optimizes Unstable waterflooding adjustment scheme of M72 horizontal wellblock of an oilfield using numerical simulation of oil reservoir, determining reasonable Unstable waterflooding adjustment scheme, meeting expected index. The chem is feasible.

After determining reasonable waterflooding intensity of different oil stratum and different spot, for reservoir stratum with small thickness and low permeability adopts method of intensifying tip waterflooding and controlling root waterflooding which helps to improve development effect of waterflooding well.

Periodical waterflooding can improve development effect of oilfield and increase economic benefits, for oil reservoir suitable for periodical waterflooding, shall conduct waterflooding as soon as possible. M72 horizontal well block of an oilfield is suitable for improving flooding development effect by periodical waterflooding, determining reasonable waterflooding of simulated zone being 3 months through numerical simulation.

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