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Productivity dynamic analysis of fractured horizontal well in ultra-low permeability reservoir

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Abstract: Daqing Oilfield is rich in low permeability reservoirs. In order to fully understand the development dynamics of ultra-low permeability reservoirs, this paper takes Daqing Oilfield as an example and studies the productivity dynamics of fractured horizontal Wells by numerical simulation method. The results show that the productivity of fractured horizontal Wells decreases exponentially with the decrease of formation permeability. The productivity of fractured horizontal well increases with fracture length and decreases with fracture spacing. With the increase of formation coefficient and reservoir thickness, the productivity increase of fractured horizontal Wells decreases. In the case of small well spacing, the smaller the formation coefficient and reservoir thickness, the higher the productivity of fractured horizontal Wells. Compared with conventional vertical Wells, fractured horizontal Wells have better production performance.

Key words: Fractured reservoir; Fractured horizontal well; Well test analysis.

1. Introduction

With the development of economy, low permeability reservoir reserves are increasing. Daqing Oilfield is the first oilfield of ten million tons built in China, but its low permeability reservoir reserves account for a small proportion of the total reserves. For low permeability reservoir, horizontal well exploitation is one of the effective means to achieve high and stable production [1]. In Daqing oilfield block of Daqing Oilfield, the production of oil well has been greatly increased by using horizontal Wells. Therefore, it is of great significance to fully understand the dynamic characteristics of productivity of low permeability reservoir to effectively guide the development of this kind of reservoir.

2. Basic conditions of ultra low permeability reservoir

Daqing oilfield is located in the central and western part of Heilongjiang Province. It is a structural lithologic reservoir with mudstone and sandstone, followed by fine sandstone, siltstone and limestone. According to mercury injection data, core analysis and core photos, the average porosity and permeability of Daqing oilfield are 9.6% and 0.049×10-3μm2, which belong to extremely low permeability reservoir. According to the regional structural analysis, Daqing oilfield belongs to large complex anticline structure. The Daqing oilfield is mainly composed of braided river deposits with sand bodies developed between channels. The main reservoir group developed shore-shallow lacustrine - delta plain subfacies deposits, with small scale, poor continuity, limited distribution range, large thickness variation, and transverse superimposed multiple layers. According to the analysis of core and mercury injection data, the average pore throat radius of Daqing reservoir group is 0.059μm2 and the average throat radius is 0.122μm2. The natural energy of Daqing oilfield is poor and the formation pressure drops fast. According to the geological characteristics of Daqing oilfield and the results of reservoir numerical simulation, it can be seen that the oil reservoir in Daqing oilfield has the characteristics of low starting pressure gradient and uneven reservoir pressure distribution.

3. Physical model of fracture network penetration in liquid phase of fracturing

For the special low permeability reservoir, the method of horizontal drilling and stage fracturing must be used to produce oil. Due to reservoir lithology, if hydraulic fracturing is carried out in a fractured low permeability reservoir, natural fractures of the reservoir will be opened and connected to each other when the main fractures are formed, and a complex fracture network structure and SRV area R will be generated around them (as shown in Figure 1) [2]. In order to simplify the original fractured reservoir and its internal fracture network structure, the Warren-Root dual medium model is proposed. The one-quarter penetration zone of a single fracture was analyzed, and the permeability in the reservoir was divided into three parts (Figure 2) : Zone O (0< x< x_(f,)0< y< y_e). The reservoir was an initial, fracture-free, secondary medium, Darcy free, slow, secondary permeability reservoir; The study area I (0< x< x_f,0< y< y_e) refers to a two-layer reservoir with quasi-stable permeability centered on the big fault. Where, F (0< x<x_f) is the linear flow of the reservoir in the simulated fracturing process, which is influenced by factors such as reservoir and skin action. The fluid moves from zone 0 to Zone I, then from zone I to the main fracture zone, and eventually from the main fracture zone into the horizontal wellbore.

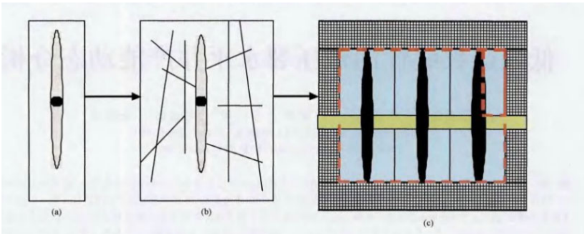

Figure 1. Schematic diagram of fracture morphology of fractured well

The main assumptions of the model are: (1) reservoir up and down as the closed boundary; (2) There are both lithologic and liquid micropressures with constant compressibility; (3) The fracture is distributed vertically through the horizontal wellbore with equal spacing. The half-length of the fracture is x_f, the width is w_f, and the height is equal to the thickness of the reservoir h. The fracture has limited conductivity. (4) the fracture closed, no flow through, closed the border between adjacent cracks, ignoring the influence of the interference of the seam; (5) regional O and I are double medium reservoir, ChuRong ratio and flow coefficient respectively.

4. Case analysis

Daqing Oilfield is a typical low permeability reservoir. The main development layer of this oilfield is Daqing reservoir with an average permeability of 0.81 mD and an average effective thickness of 14.4m. Through the analysis of the geological characteristics of the oilfield, it can be seen that the Daqing oil reservoir is mainly characterized by low porosity, low permeability and low pressure [3]. In addition, there is a certain degree of water sensitivity in Daqing oil reservoir. The oilfield has entered the middle and late stage of development, but because of the development of fractured horizontal Wells, the reservoir quality has been improved to some extent, and the output of single well has increased significantly. The development effect of fractured horizontal well in this oilfield is studied by numerical simulation method. The geological model is established according to the actual geological parameters, and the fine three-dimensional geological model is established by Eclipse software. On this basis, it is divided into well area and non-well area, and grid division is carried out respectively. Finally, Eclipse software is used for numerical simulation calculation to obtain the distribution of reservoir pressure field under different well spacing. When the well spacing is 500m, the pressure distribution of the oilfield is more uniform, indicating that the development effect of fractured horizontal Wells is better.

Table 1 Relationship between each fracture of Horizontal well and Production (a)

Fracture half-length scheme	crack 1	crack 2	crack 3	crack 4	crack 5
scheme 1	150	110	70	110	150
scheme 2	140	110	70	110	140
scheme 3	130	110	70	110	130
scheme 4	150	70	110	70	150
scheme 5	140	70	110	70	140
scheme 6	130	70	110	70	130
scheme 7	150	150	150	150	150
scheme 8	70	70	70	70	70

Table 2 Relationship between each fracture of Horizontal well and Production (b)

scheme	Production per crack (m^3/d)					Chief ginseng $(m^3/d$
	1		3	4	5	
scheme 1	3.93	1.67	0.96	1.67	3.93	12.16
scheme 2	3.74	1.73	0.97	1.73	3.74	11.91
scheme 3	3.55	1.8	0.98	1.80	3.55	11.68
scheme 4	4.12	0.93	1.90	0.92	4.11	11.98
scheme 5	3.92	0.98	1.92	0.98	3.92	11.72
scheme 6	3.73	1.04	1.94	1.04	3.73	11.48
scheme 7	3.68	1.88	1.73	1.88	3.68	12.85
scheme 8	2.58	1.57	1.42	1.57	2.58	9.72

5. Productivity dynamic analysis

5.1 Influence of starting pressure difference on horizontal well output

Under the condition that the non-factor starting pressure gradient is 0, 0.05, 0.1, 0.3 and 0.5, and under different starting pressure differences, the non-factor production changes over time are shown in Table 3. As can be seen from the chart, the production process of the fractured reservoir is characterized by two steady intervals of decline compared to the homogeneous reservoir. According to the shape of the characteristic curve, the production decline process of low permeability fractured reservoir can be divided into seven periods. The first period is the straight flow from the main fracture to the well hole. In this period, there are no factors, and the production curve is a straight line with slope of 0.5, which exists for a long period of time. Phase II was mainly caused by fissure edge action and initial water injection in the improvement area. Its production law was a straight line, and its slope was close to 1. Phase III is a line formed within the treatment zone, and a line with a slope of 0.5 is formed within the treatment zone. In the reformed zone I, the first stage is the surge from bedrock to micro-cracks. In this period, the seepage flow tends to be stable and the output curve tends to be stable for a long time. Phase V is a reservoir in which the linear flow period of the reservoir is not significant, the initial pressure difference of the reservoir and the permeability of the reservoir are small, the production curve of the reservoir is one line, and the reservoir is a reservoir in a reservoir. The V stage is the channeling period from bedrock to small fissure, and its output variation rule is two relatively stable intervals. Period V is the marginal response period of region 0.001, during which output decreases sharply. In the early stage, starting pressure difference has no obvious effect on oil recovery of oil-water two-phase flow. With the increase of starting pressure difference, the fluid flow resistance in the reservoir increases, the supply capacity of the reservoir weakens, and the productivity of the reservoir in the middle and late period decreases.

5.2 Influence of the number of fractures on productivity during horizontal well fracturing

The results show that the degree of fracturing of artificially fractured horizontal Wells is closely related to the degree of fracturing. As can be seen from the figure, with the increase of the number of fractures, dimensionless production of fractured horizontal Wells is higher, but the increase is smaller. When the increase exceeds a certain range, the increase changes little. At the same time, the number of cracks increased, increased the construction cost, improve the construction difficulty. The results show that when the length of horizontal well is fixed, the number of fractures in horizontal well hydraulic fracturing has an optimal range in terms of economy and construction cost.

5.3 Influence of fractures on horizontal well production during fracturing

For horizontal Wells, assuming that five major fractures are opened longitudinally, the production decline trend of fractured horizontal Wells is shown in the table below when the adjacent fractures (d,) are 100,200, and 300 m respectively. As can be seen from the chart, as the proximity increases, the output increases in the middle and middle stages of production, and the downward trend of output flattens out. Under the condition that the number of main fractures in artificial fracturing remains unchanged and the distance between fractures is larger, the scope of reconstruction region I is larger, and the supply range and capacity of the peripheral region to region I is larger.

5.4 Effects of major fractures on the production of fractured horizontal Wells

The following figure shows the variation law of fractured horizontal well productivity under artificial fracturing conditions without affecting production. The results show that the permeability after fracturing has a great effect on the initial production. The higher the permeability, the higher the initial production and the smaller the permeability. Its effect on fracturing effect decreases with the extension of production cycle. Under fixed pressure, both the output and supply of the main fracture are larger, and the linear flow of the fracture is maintained for a long time.

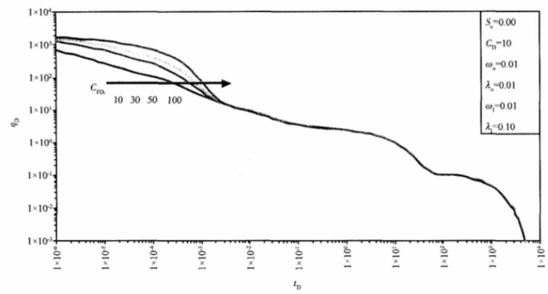

Figure 2 Influence of diversion capacity on productivity decline curve of fractured horizontal Wells

5.5 Influence of storage capacity ratio and micro-fracture channeling coefficient on productivity of the reconstruction area

Under the condition that other parameters remain unchanged, the output decline curve of fractured horizontal Wells is shown in the figure [4] after the storage capacity ratio and channeling coefficient are adjusted to different values in the reconstructed region I. Results: With the increase of o value, the downward trend of output in the middle and late period was gradually moderated, while the linear flow state lasted longer. The larger the input ratio, the larger the medium-term output, but the smaller the decline. The higher the elastic storage capacity ratio o, the higher the elastic capacity of the fracture system and the ability to supply the main fracture system, and the longer the linear flow cycle, so the medium-term output is larger, but the downward trend is relatively stable. The larger the channeling coefficient in the inner zone, the smaller the permeability difference between the inner zone, the matrix and the micro fracture, the stronger the matrix supply to the micro fracture, the larger the medium-term yield, the gentler the attenuation, and the earlier the inner zone boundary appears [5].

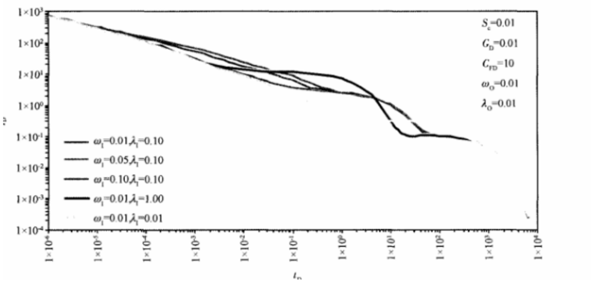

Figure 3. ω_I、入$_I$ Effect on productivity decline curve of fractured horizontal well

6. Conclusion

Based on the stress sensitive horizontal well productivity equation, this paper proposes a method suitable for fractured horizontal well productivity analysis in low permeability reservoir, and takes Daqing oilfield as an example. When the permeability of the fractured horizontal well is reduced to 0.1×10-3 mD, the production of fractured horizontal well will show an exponential decline law. When the fracture spacing is less than a certain value, the production of fractured horizontal well decreases with the increase of fracture length. When the fracture spacing is greater than a certain value, the production of fractured horizontal well increases with the fracture spacing. Compared with conventional vertical Wells, the lower the formation coefficient and reservoir thickness, the higher the productivity of fractured horizontal Wells.

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