The identification method of pollution origin and degree of the injection well

LIU   HONGBO

The fifth production plant , Daqing oilfield company. Daqing, 163513, China

Abstract: In order to solve the problem that the pollution causes and the degree of the injection well can not be effectively identified, based on the consideration of the sensitivity of the reservoir and the water quality of injected water. The mathematical models of injection well pollution were established. The causes of pollution and pollution degree were determined.Recommended measures to different factors of pollution are confirmed. It proved that the efficiency of the recommended measures has been greatly improved. Research results show that,according to the degree of pollution to all factors of pollution, the rank from largest to smallest is solid particle, clay swelling, water sensitivity, inorganic scale, acid sensitivity, bacteria, particle migration, velocity sensitivity. Therefore, the major factors of pollution in the reservoir are solid particle and clay swelling.

Key words: skin factor; pollution radius; cause of pollution; application efficiency

0   Introduction

In the process of oil and gas reservoir development, water injection is an important technical measure to make long term high and stable production of oil well. But the injected water quality, reservoir physical properties, construction and other factors, are easy to cause the formation of pore plugging, causing some damage to the reservoir. At present, the damage degree of reservoir has been studied from two aspects: field test method and mathematical model, However, the research on the recommended measures to determine the degree of damage by reservoir is less[1-2]. In this paper, the cause of pollution and pollution degree of injection well, so as to put forward the way to remove the oil layer pollution   in the field of practical scale application. Therefore, it provides a reliable theoretical basis and field guidance for the identification of water injection well and the development of injection enhancement measures[3-4].

1   Analysis of reservoir pollution sources

According to the analysis of the core well clay, the results show that the, the absolute content of clay in Saertu oil layer in XS area is 5.6%,the average of the putaohua oil layer is 7.7%;From the composition of clay, the Saertu oil layer is dominated by illite, which content beteen 56.6% and 76.1%.The Putaohua reservoir of kaolinite and chlorite content increased significantly, which belongs to the kaolinite clay. The swelling of montmorillonite is not high in Saertu and putaohua oil layer,but it is quite stable in the proportion of each oil group, which content about 20%. According to the analysis of the core well clay, the results show that in the XS area, the performance of the oil reservoir in SA is weak speed sensitivity, weak water sensitivity, strong acid sensitivity and weak alkali sensitivity. [5-6]

Suspended solid particles and bacterial particles carried in the water, In the process of displacement, solid particle migration, bacterial reproduction and other hydrocarbon migration channels are blocked, resulting in the reduction of reservoir seepage capacity. A area of Water Quality Monitoring Bulletin shows that oil content, suspended solids content, bacterial content are

different degrees of excessive, resulting in damage to the reservoir[7]. In addition, when injected water and formation water or reservoir is not compatible, especially the type and degree of mineralization vary greatly when injected water meets formation water, inorganic scale is often produced in the reservoir, which leads to the formation of the formation plugging, so that the permeability of the reservoir is decreased.

2 Determination of identification and damage degree of reservoir pollution

2.1 The establishment of mathematical model of skin coefficient

In order to effectively identify the reasons of reservoir pollution, based on the analysis of the source of the pollution sources, combined with the field data of XS area, the derivation of the literature and theoretical formula, 6 mathematical models of the skin coefficient of 6 pollution factors were established,which were the solid particles, clay swelling, inorganic scale, acid sensitivity, bacteria and particle migration mathematical models.(Table 1)

Table 1 Mathematical models of skin factor statistics on different pollution factors

type	mathematical models	process models
acid sensitivity	$S_{acid} = \left(\dfrac{1}{1-I_a} - 1\right)\left(\ln\dfrac{r_e}{r_w} - 0.75\right)$	$I_a = 308.387 + 27.36 \times K_a^{1.059} - 18877.258 \times K_a/\phi + 4828.647/\phi$ $- 25033.947/\phi^{0.5} - 3266.158/R_2 + 3842.0821/R_2^{0.5}$ $+ 1906.916 \times \left(1 + K_a^{0.5}\right)/\phi^{0.5} + 2969365.750 \times IS_1 - 6.142 \times IS_1^2$ $- 14.723 \times \lg(1 + IS_1) - 1979549.625 \times (S + IS_1 + IS_1 \times ISR) + 36.248 \times C^{0.5}$ $- 11.429 \times Cl^{0.5} - 19.006 \times \phi - 34.343 \times K_a + 25.643 \times R_2$
particle migration	$S = \left(\dfrac{K_c}{K'} - 1\right) \times \ln\dfrac{r_s}{r_w}$	$r_s = \dfrac{Q_h r_w}{Q}$, $Q_h = Q - \pi r_w^2 h$, $K' = \dfrac{2a_1 K_c r_s^2}{r_s^2 - r_w^2} \cdot \ln\dfrac{r_s}{r_w} + \dfrac{2bK_c r_s}{r_s + r_w} + cK_c$
clay swelling	$S = \left(\dfrac{K_o}{K_d} - 1\right)\left(\ln\dfrac{r_e}{r_w} - 0.75\right)$	$Cc = 1000(658.973Mt/Nz + 753.6464Gl/Nz/595.219Sy + 72.2886)$ $K_d = 6.9807 \times 10^{-2} K_c^{1.6016}\left(\dfrac{0.618Cc + 0.8K_C}{140.6257}\right)^{1/C_{分米米}}$
bacteria	$S = \left(\dfrac{K_o}{K} - 1\right)\left(\ln\dfrac{r_e}{r_w} - 0.75\right)$	$R_k = \left[0.81/\lg K_o + 6.6385 \times 10^{-2} \times \lg TGB - 0.4040982\right] \times V_L$ $V_L = \dfrac{V_1}{\pi h(r_e^2 - r_w^2)\phi}$, $K = (1 - R_k) \times K_o$
inorganic scale	$S = \left(\dfrac{K_{前}}{K_{后}} - 1\right)\left(\ln\dfrac{r_e}{r_w} - \dfrac{3}{4}\right)$	$IS_2 = \lg\left(Ca^{2+} \times HCO_3^-\right) + pH - 2.42 + 0.02T - 1.53 \times 10^{-5}T^2$ $- 6.33 \times 10^{-3}P - 2.02I^{0.5} + 0.7272$, $I = \dfrac{1}{2}\sum c_i Z_i^2$, $y = 4.5805 \times (IS_2)^2 + 28.647 \times (IS_2) + 7.6059$, $n = y/12$, $R_{损害率} = a_2 cnt \times 100\%$, $K_{后} = K_{前} \times R_{损害率}$
solid particles	$S = \left(\dfrac{K}{K'} - 1\right) \times \ln\dfrac{r_s}{r_w}$	$D = r_w \times \left[1 - \dfrac{1}{\gamma} \times \ln\dfrac{0.02\alpha}{2(1-\alpha)\gamma\ln(r_e/r_w)}\right]^{0.5} - r_w$, $\alpha = \dfrac{V/\Delta P}{V'/\Delta P'}$, $\gamma = \dfrac{\pi r_w^2 h\lambda_v}{q_w}$, $\phi' = \dfrac{\pi h\phi(r_s^2 - r_w^2) - Q_z V_y \times 10^{-6}/2.6}{\pi h(r_s^2 - r_w^2)}$, $\dfrac{K}{K'} = \left(\dfrac{\phi}{\phi'}\right)^3$

2.2 *Quantitative determination of reservoir pollution degree*

The nearer the wellbore is, the more serious the pollution is, so the permeability of the polluted zone is changed with the radius. Damage radius can be determined by using the relationship between the skin factor S_d and the damage radius r_s.

$$S_d = \frac{h}{h_p}\left\{\left(\frac{K}{K_w}\right)^{\frac{r_s}{r_s - r_w}}\left[-Ei\left(-\frac{r_w}{r_s - r_w}\ln\frac{K}{K_w}\right) + Ei\left(-\frac{r_s}{r_s - r_w}\ln\frac{K}{K_w}\right)\right] - \ln\frac{r_s}{r_w}\right\} \qquad （formula\ 1）$$

Newton iteration method is used to solve the above equations, and the damage radius can be

obtained.

Order
$$f(r_s) = -Ei\left(-\frac{r_w}{r_s - r_w}\ln\frac{K}{K_w}\right) + Ei\left(-\frac{r_s}{r_s - r_w}\ln\frac{K}{K_w}\right) - \left(\frac{K}{K_w}\right)^{\frac{r_s}{r_s - r_w}}\left(\ln\frac{r_s}{r_w} + \frac{h_p}{h}S_d\right) \qquad （formula 2）$$

That
$$f'(r_s) = \frac{\left\{\left(\frac{K}{K_w}\right)^{\frac{r_w}{r_s + r_w}} - \left(\frac{K}{K_w}\right)^{\frac{r_s}{r_s + r_w}}\left[1 + \left(\ln\frac{r_s}{r_w} + \frac{h_p}{h}S_d\right)\frac{r_w}{r_s - r_w}\ln\frac{K}{K_w}\right]\right\}}{r_s - r_w} \qquad （formula 3）$$

Therefore
$$r_{sn+1} = r_{sn} - \frac{f(r_{sn})}{f'(r_{sn})} \qquad （formula 4）$$

3 Field application of identification method

3.1 *Determination of blocking radius of reservoir pollution*

According to the *The designed method to the optimization of measures in increasing injection in the first area and the third area of xingnan development area in xingshugang oilfield* combined with field data of XS area, the acidification radius is determined for different types of formation. Among them, the acidification radius of the clay mineral is 2.5~3.0m, the organic matter is blocked by 0.5~1.0m, the slurry is blocked by 0.8~1.2m, and the mechanical impurity is blocked by 2~3m. In order to effectively remove the oil reservoir blockage, the maximum pollution radius can be considered as 3m. That is, a certain level of pollution radius is less than 3m, the recommended measures for acidification; pollution radius is greater than 3m, then the use of a greater strength of the fracturing measures.

3.2 *Field application verification*

At present, the method has been applied in the XS area to solve the blocking measures, and the identification of the causes and the degree of pollution in the 145 layers of the 49 injection well is given and the recommended measures is given at the same time. After the implementation of the measures for the implementation of the 49 wells, the effectiveness of the recommended measures was 93.88%, and the efficiency increased 5.88 percentage points compared with the previous measures.

Table 2 the results of field application of pollution cause and pollution degree method

Serial number	Injection well	section	main pollution type	contaminated radius (m)	recommended measure	measure time	measure effect evaluation
1	31-330	S311S322	Particle migration	0.44	acidification	201608	effective
2	31-330	S341S353	Particle migration	0.48	acidification	201608	effective
3	31-330	S361S361	Particle migration	0.48	acidification	201608	effective
4	31-330	S371S3111	Particle migration	0.35	acidification	201608	effective
5	22-W471	S211S272	Inorganic scale	0.48	acidification	201606	effective
6	22-W471	S2111S2161	Solid particles	9.36	acidification	201606	effective
7	22-W471	S361S3112	Inorganic scale	0.49	acidification	201606	effective
8	2-132	S222S241	acid sensitivity	0.10	acidification	201607	effective
9	2-132	S251S282	Clay swelling	0.38	acidification	201607	effective
10	2-132	S283S2111	Clay swelling	0.37	acidification	201607	effective
11	2-131	S271S291	Inorganic scale	0.36	acidification	201608	effective
…	…	…	…	…	…		…
141	10-241	P1111P1122	Inorganic	0.26	acidification	201610	effective
142	10-241	P1323P1422	Inorganic	2.11	acidification	201610	effective
143	D1-244	S211S2161	Inorganic scale	0.46	acidification	201610	effective
144	22-S11	S211S243	acid sensitivity	0.48	acidification	201607	effective
145	22-S11	S251S283	Particle migration	0.61	acidification	201607	effective

4 Conclusion

In this paper, we put forward the concept of total skin factor of reservoir, which is defined as the skin factor of various types of reservoir damage.

This paper systematically discusses the formation cause of contaminated reservoir, and combined with the characteristics of reservoir and water quality in XS area, the mathematical model of skin coefficient and pollution radius is established, which not only can effectively identify the cause of formation of reservoir pollution, but also can quantitatively describe the degree of reservoir pollution.

After the application of the mathematical model of skin factor calculation, there are six reasons for the reservoir contamination in XS area, from the largest to smallest, solid particles, clay swelling, inorganic scale, acid sensitivity, bacteria and particle migration. Among them, the main pollution factors are the expansion of solid particles and clay.

Acknowledgments

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