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Influencing Factors and Construction Parameter Optimization Design of Hot Water Huff and Puff in Tight Volcanic Reservoir

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ABSTRACT

Hot water huff and puff (HWHP) technology is an effective means to improve the recovery factor (RF) of the tight volcanic reservoir, but the oil recovery effect still needs to be further optimized. In this paper, taking a staged fracturing horizontal well in a tight volcanic reservoir as the object, the influencing factors and optimal design of construction parameters in the process of HWHP were studied by numerical simulation. The results show that the oil production of HWHP is positively correlated with water injection volume (WIV), water injection pressure(WIP), huff and puff cycles(HPC), well soaking time(WST), and fracture density(FD), and negatively correlated with water injection rate(WIR) and water reinjection pressure(WRP). The weight of influencing factor of HWHP from large to small is WRP, FD, HPC, WIV, WIR, WIP, and WST. The best combination of construction parameters of HWHP for a single fractured well in a tight volcanic reservoir is that the FD is 36, WIV is 15000 m^3, WIP is 50 MPa, WIR is 300 m^3/d, WST is 30 d, HPC is 5, and WRP is 5 MPa. This research can provide an important basis for improving the RF of the HWHP in a tight volcanic reservoir.

Keywords: tight volcanic reservoir; HWHP; influencing factors; parameter optimization; numerical simulation

1. INTRODUCTION

Tight volcanic reservoirs are a kind of extremely complex and special reservoirs [1]. Due to the influence of volcanic eruption and late sedimentation, the distribution of pore structure and fluid seepage of tight volcanic reservoirs are very complex [2-3]. After years of oilfield tests, the coordinated oil production technology of horizontal well, volume fracturing, and HWHP is mainly used in tight volcanic reservoirs [4]. The HWHP refers to injecting hot water into the reservoir through the production well, then soaking the well for some time, and finally producing oil through the same production well. At present, HWHP technology has achieved preliminary results in the development of tight volcanic reservoirs, but the overall oil recovery efficiency is still low [5-6]. Therefore, it is necessary to conduct in-depth research on the influencing factors and parameter optimization design of HWHP.

In this paper, numerical simulation was used to study the HWHP technology of tight volcanic reservoirs, and the influencing factors and optimization design of construction parameters of HWHP were studied. The research results can provide theoretical guidance for the construction of HWHP in oilfields.

2. METHODOLOGY

2.1 Physical model and basic parameters

At present, horizontal wells with multi-stage fracturing are mainly used for the production of tight volcanic reservoirs. Therefore, the basic model in this work is a horizontal well with multi-stage fracturing. In the simulation process, the length of the horizontal section is adjusted according to the number of fractures. The half-length of the fracture is 200 m. Because the seepage capacity of fracture is much larger than that of the matrix, the width of fracture is much larger than the pore size of the matrix. The depth of the reservoir is 1500 m, the pressure is 14.9 MPa, the temperature is 43℃, the porosity is 0.104, the permeability is 0.4 mD, and the crude oil viscosity is 24.5 mPa.s. The grid number of the reservoir is 60×110×5=33000, and the grid size is: length and width of 10m, the third layer is 10m high, and the other layers are 1m high. The permeability of the X and Y direction is 0.4 mD, the permeability in the Z direction is 0.04 mD.

2.2 PVT and Phase permeability curve

At the pressure of 15 MPa, the volume factor of water and dead oil is 1.002 $m^3/m^3$and 1.108 m^3/m^3，the compressibility of water and dead oil is 4.5×10^{-5} bar and 7.918×10^{-4} bar, the viscosity of water and dead oil is 0.655 mpa.s and 24.5 mpa.s, the fluid density of water and dead oil is 992.2 kg/m^3 and 800 kg/m^3, and the rock compressibility is 0.0007918 MPa^{-1}. The oil-water phase permeability curve and capillary force curve are shown in Fig. 1.

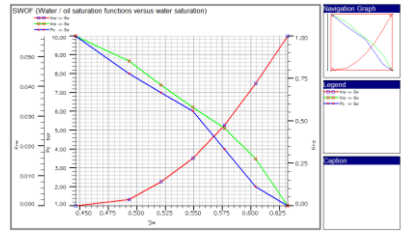

Fig. 1 Phase permeability curve

3. NUMERICAL SIMULATION RESULTS

The influencing factors of HWHP in tight volcanic reservoirs include WIV, WIP, WIR, WST, HPC, WRP, and FD. In the simulation process, the values of each parameter are: WIV: 6000 m^3, 8000 m^3, 10000 m^3, 15000 m^3,and 20000 m^3; WIP: 20 MPa,30 MPa,35 MPa,50 MPa, and 60 MPa; WIR: 300 m^3/d,400 m^3/d, 500 m^3/d,600 m^3/d, and 800 m^3/d; WST: 20 d,30 d,40 d,50 d, and 60 d; HPC: 3,4,5,6, and 7; WRP: 13 MPa,10 MPa,9 MPa,7 MPa, and 5MPa; FD: 16,20,24,28,and 32. The control variable method was adopted in the test process, and the basic data of each test are: WIV is 10000 m^3, WIP is 50 MPa, WIR is 500 m^3/d, the WST is 30 days, the HPC is 5, the WRP is 9 MPa, and the FD is 36.

3.1 Influencing factors

According to basic parameter settings, the effects of WIV, WIP, WIR, HPC, WST, and FD on the oil production of tight volcanic reservoirs are shown in Fig. 2.

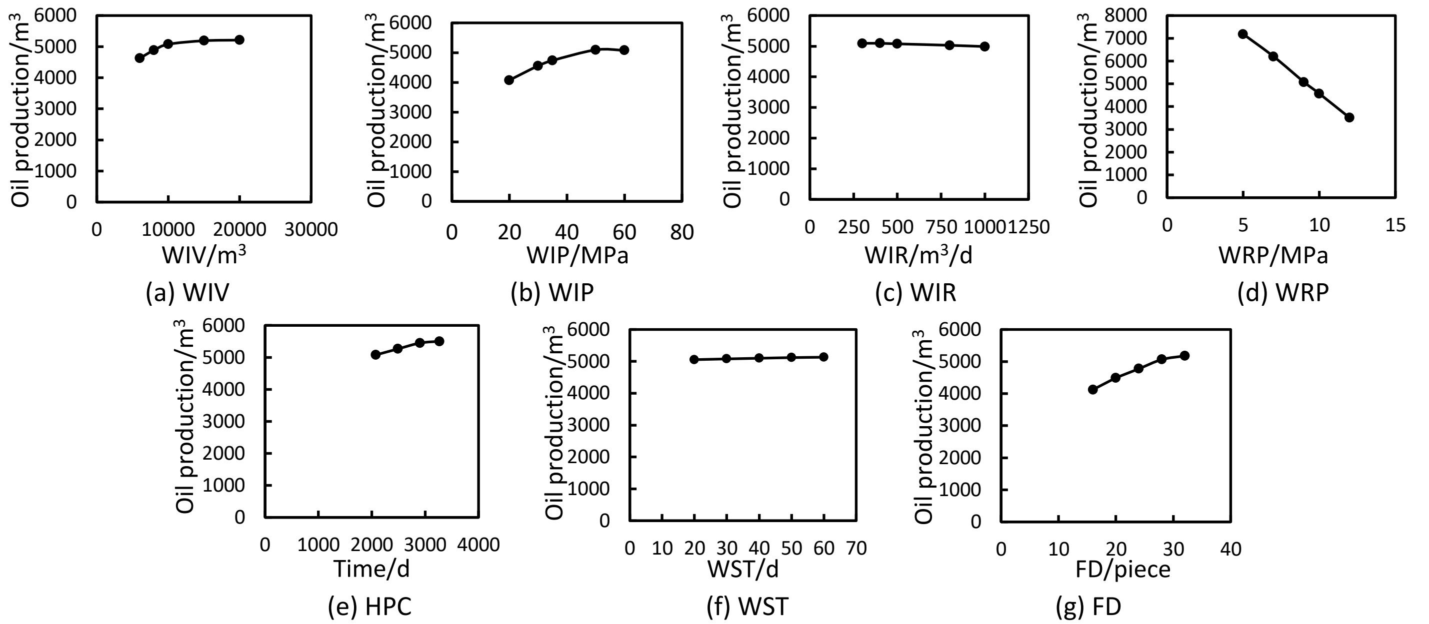

Fig. 2 Influence of various influencing factors on total oil production of HWHP

Fig. 2 shows that among the seven influencing factors, the oil production increases with increasing WIV, WIP, HPC, WST, and FD, and decreases with increasing WRP and WIR. Fig. 2 (a) shows that when the reservoir WIV reaches 15000m^3, the effect of increasing WIV on enhancing the oil displacement effect of HWHP is no longer obvious. Fig. 2 (b) shows that when the WIP increases from 20 MPa to 35 MPa, the increase in the cumulative oil production of the reservoir is greater than that of 35 MPa to 60 MPa. Therefore, when the WIP continues to increase, the cumulative oil production of the reservoir does not increase linearly or exponentially, but there is an optimal value. In the higher pressure stage, simply continuing to increase the WIP will have an unsatisfactory oil increase effect. Fig. 2 (c) shows that when the injection rate increases, the oil production of the reservoir decreases. This is because too fast injection rate may reduce the sweep efficiency of the injected water. However, when the injection rate is too low, it will affect the oil production rate. The reasonable injection rate should be 500 m^3/d. Fig. 2 (d) shows that the oil production decreases with increasing WRP, there is a good linear negative correlation between the two when WRP is higher than 5MPa. However, if the WRP is too low, it will cause difficulty in restarting part of the crude oil, resulting in a large amount of remaining oil. Therefore, the WRP should neither be too low nor too high. Fig. 2 (e) shows that with increasing HPC, the increase range decreases gradually, and there is an optimal HPC. Fig. 2 (f) shows when the WST exceeds 20 days, as the WST increases, the cumulative oil production will increase, but it is not obvious. Fig. 2 (g) shows that when the number of FD is less than 28, the oil production increases obviously, but after 28, the oil production begins to increase slowly.

In the study of factors influencing HWHP in tight volcanic rock, the change of each influencing factor actually changes a certain oil production mechanism of HWHP, for example, the change of WIP actually affects the elastic displacement oil production. The change of WIR affects the oil displacement efficiency. The WST affects the amount of imbibition displacement, and the FD affects both the elastic displacement and imbibition displacement.

3.2 Optimization design of construction parameters

The orthogonal test method was used to optimize the influencing factors of the HWHP in tight volcanic reservoirs. In the simulation process, the value of each influencing factor is: WIV: 8000 m^3, 10000 m^3, and 15000 m^3; WIP: 35 MPa, 50 MPa, and 60 MPa; WIR: 300 m^3/d, 400 m^3/d and 500 m^3/d; WST: 20 d, 30 d, and 40 d; HPC: 5, 6, and 7; WRP: 9 MPa, 7 MPa, and 5 MPa; FD: 28, 32, and 36. The orthogonal test scheme is shown in Table 1. The weight analysis is shown in Table 2.

According to Table 1, when the total oil production is taken as the evaluation standard, scheme 18 is the best combination of construction parameters. The best combination of construction parameters of HWHP in tight volcanic reservoirs is as follows: the FD number is 36, the WIV is 15000 m^3, the WIP is 50 MPa, the WIR is 300 m^3 per day, the WST is 30 days, the HPC is 5, and the WRP is 5 MPa, and the cumulative oil production is 7753.005 m^3. Table 2 shows that WRP has the greatest impact on the oil production of HWHP in tight volcanic reservoirs, followed by FD, HPC, WIV, WIR, WIP, and WST.

The actual tight volcanic reservoirs have strong heterogeneity, and their oil production laws of HWHP will be much complex.

Table 1 Orthogonal test scheme

Test num.	Influencing factors							Oil production
	FD/piece	WIV/m^3	WIP/MPa	WIR/m^3/d	WST/d	HPC/cycle	WRP/MPa	
1	28	8000	35	300	20	3	5	6078.999
2	28	10000	50	400	30	4	7	5709.867
3	28	15000	60	500	40	5	9	5231.091
4	32	8000	35	400	30	5	9	5185.253
5	32	10000	50	500	40	4	5	7140.049
6	32	15000	60	300	20	4	7	6194.032
7	36	8000	50	300	40	4	9	5196.282
8	36	10000	60	400	20	5	5	7744.14
9	36	15000	35	500	30	3	7	6012.832
10	28	8000	60	500	30	4	5	6477.912
11	28	10000	35	300	40	5	7	5699.332
12	28	15000	50	400	20	3	9	4586.22
13	32	8000	50	500	20	5	7	6428.924
14	32	10000	60	300	30	3	9	5091.997
15	32	15000	35	400	40	4	5	7345.061
16	36	8000	60	400	40	3	7	5998.846
17	36	10000	35	500	20	4	9	4993.412
18	36	15000	50	300	30	5	5	7753.005

Table 2 Weight analysis

Influence factor	FD	WIV	WIP	WIR	WST	HPC	WRP
Mean 1	5630.570	5994.369	5985.815	6002.288	6004.288	5818.157	7089.861
Mean 2	6330.886	6063.133	6135.725	6194.898	6138.478	5986.094	6007.305
Mean 3	6283.086	6187.040	6123.003	6047.370	6101.777	6440.291	5147.376
Range	700.316	192.671	149.910	192.624	134.190	622.134	1942.485

4. CONCLUSIONS

(1) HWHP technology can effectively improve the RF of tight volcanic reservoirs and has a good oilfield application prospect.

(2) The oil production increases with increasing WIV, WIP, WST, FD, and HPC, and decreases with increasing WIR and WRP, but whether it increases or decreases, the variation amplitude always decreases gradually and finally tends to be stable. Most injection production parameters have optimal values.

(3) The optimal combination of parameters for HWHP in tight volcanic reservoirs is FD number 36, the WIV 15000 m^3, WIP 50 MPa, WIR 300 m^3/d, WST 30 d, HPC 5, and WRP 5 MPa.

(4) WRP has the greatest impact on the oil production of HWHP in tight volcanic reservoirs, followed by FD, HPC, WIV, WIR, WIP and WST.

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