ATLANTIS PRESS
Advances in Engineering Research, volume 123
2nd International Conference on Materials Science, Machinery and Energy Engineering (MSMEE 2017)

Study on Prediction Method of Polymer Flooding Well Fracturing Effect

Hong Pang
No.5 Oil Production Plant of Daqing Oilfield Company, Daqing, 163315, China
email: panghong1997@ 163.com

Keyword: Percolation Mechanism, Geological Factors, Process Factor, Grey Relation, Multiple Linear Regression

Abstract. Using percolation mechanism, the geological factors and technological factors that affect the fracturing fluid were determined. Similar geological conditions and process factor, increased liquid yield of the production wells are also similar. However, the result of the oil increment is very different after fracturing. The influence factors of the oil displacement of polymer flooding are determined by grey correlation method and fuzzy mathematical analysis, which mainly includes water content of polymer flooding, water content of fracturing, single well daily production, effective thickness of fracturing layer, permeability, oil saturation and so on. On the basis of studying polymer flooding mechanism of fracturing oil increase and the variation law, using multiple linear regression method, the prediction equation of polymer flooding fracturing effect has been established. The prediction accuracy of the equation is above 95%.

Introduction

The first polymer flooding industrial block in our factory, from March 2009 when it was put into operation to May 2016, the cumulative oil production is 60.56×10^4t, cumulative oil increment is 53.47×10^4t, which shows a good polymer flooding development performance. Compared with water flooding, polymer flooding is higher in oil production rate and shorter in duration. In a short time of mining, to exploit crude oil from underground as much as possible, the fracturing measures are widely adopted to increase the output of production wells. Up to now, 45 wells in the industrial area have been implemented with fracture, accounts for 35.4% of the total number of oil wells, 5.2 tons of oil of single well daily increases is obtained in the early stage of fracturing.

In Polymer Flooding, Fluid Increment Prediction after Fracturing

The average permeability of one industrial zone is 0.243μm^2, belonging to low permeability reservoir, the fracture conductivity is much greater than the formation permeability after fracturing [1]. In the geological model of fracturing stimulate, formation fluid flows into the fractures and then wellbore [2]. Similar to the infinite homogeneous reservoir, applying the plane radial flow analysis during liquid flowing, the production yield after compression equals the definite integral of the crack length, that is:

$$q=\int_0^L\left[kh\left(Pi-P_l\right)\right]/B\mu r_e dL \tag{1}$$

In the formula: q----yield, t/d; k----formation effective permeability, μm^2; h----effective thickness, m, L----Half the length of the fracturing fracture, m, P_i----formation pressure, MPa, P_l----the pressure of position L in the formation, MPa, B----formation volume factor, μ----underground crude oil viscosity, mPa·s, re----Injection production well spacing, m.

P_l can be calculated by the by the following formula, that is:

$$p_l=p_f+\int_0^L\left[\left(q-dq\right)B\mu L\right]/K_F hW_f dL \tag{2}$$

Bring the formula (2) into the formula (1), solving the above definite integral, we get:

$$q=k\times h\left(p_i-p_l\right)LnL\times K_F\times W_f\ /\left(B\mu r_e\right) \tag{3}$$

In the formula: p_f---- flow pressure of the bottom hole, MPa, K_F----Fracture permeability, μm^2,

W_f----Fracture width, m.

Technically assuming that the added sand content in the process of fracturing is SQ, the crack height is equal to the effective thickness, crack width W_f is proportional to the sand mixing ratio SB. According to the regularity of our factory, generally the sand mixing ratio is 0.25, and the value of the crack width *Wf is* approximately to 0.003m, here is a formula:

$$W_f \approx 0.01 \times SB; L \approx SQ/(0.01h \times SB) \quad (4)$$

Bring the formula (4) into formula (3), liquid production volume after fracturing shows below:

$$q \approx 0.01 \times SB \times k \times h \times K_F(pi - pf)[LnSQ - Lnh - LnSB + 4.6]/B\mu r_e \quad (5)$$

In formula (5), the related geological factors include effective thickness, permeability, formation pressure, fluid viscosity. The related process factors include sand ratio and sand content. Via this formula, the increasing amount of the fluid after fracturing can be predicted.

However, water ratio after fracturing could not be predicted via formula (5). Under the situation that the geological factors and process factors are similar among the production wells, although the amount of liquid increase after fracturing is not quite different, the oil increase after fracturing is very different.

To Predict the Effect of Fracturing and Polymer Flooding on Oil Increase

Through the analysis of the initial oil increment after the fracturing of 45 wells in the industrial zone in the different stages of polymer injection, the flowing factors were chosen as the main influencing factors of fracturing effect, which include water content in the early stage of polymer flooding, single well daily oil production in the early stage of polymer flooding, water content during fracturing, daily oil production of single well during fracturing, effective thickness of fracturing layer, permeability, porosity and oil saturation, the bottom hole flow pressure. Taking the cumulative oil increment as the dependent variable, analyzing the correlation degree between the independent variables and the dependent variables using gray correlation analysis method, the correlation degree of each influencing factor were obtained [3] (Table 1).

Table 1 correlation degree of each factor with the increasing oil quantity and the effective period

dependent variable	Initial water content of polymer flooding	Water content during fracturing	Single well daily oil production in the early stage of polymer flooding	Daily oil production of single well during fracturing	effective thickness	permeability	porosity	oil saturation	Bottom hole flow pressure
Increasing oil content	0.62	0.83	0.57	0.77	0.79	0.701	0.32	0.824	0.47
Term of validity	0.61	0.78	0.49	0.76	0.76	0.757	0.41	0.797	0.35

The correlation degree of each factor is ranked as below.

Increasing oil content: water content during fracturing>oil saturation >effective thickness > daily oil production of single well during fracturing>permeability>initial water content of polymer flooding>single well daily oil production in the early stage of polymer flooding >bottom hole flow pressure>porosity.

Term of validity: oil saturation>water content of fracturing> daily oil production of single well during fracturing>effective thickness>permeability>initial water content of polymer flooding>single well daily oil production in the early stage of polymer flooding>porosity>bottom hole flow pressure.

By using the result of grey correlation analysis, the first six factors which are correlated with the increase of oil quantity are selected as the independent variables, applying multiple linear regression method together with increasing oil content, I obtain the fitting formula for increasing oil content after fracturing:

$$\Delta Q = -6.2333 + 0.2599 \times X_1 + 0.1018 \times X_2 - 15.8625 \times X_3 - 8.9906 \times X_4 + 0.1199 \times X_5 + 19.5453 \times X_6 \quad (6)$$

Evaluation on Practical Application Effect

The fitting formula is verified by predicting the fracturing effect of 15 wells, the relative error of the prediction of the formula is less than 10% (Table 2 and Table 3).

Table 2 multivariate linear regression analysis of fracturing effect prediction equation

well No.	actual Increased oil volume (t)ΔQ	effective thickness (m) X_1	daily oil production of single well during fracturing (t) X_2	water content during fracturing (%) X_3	permeability (um^2) X_4	oil saturation (%)X_5	initial water content of polymer flooding (%) X_6	predicted oil increment (t)	the difference (t)
A1	3.0	7.3	2.0	0.876	0.201	43.72	0.897	2.9	-0.1
A2	1.5	6.8	0.5	0.972	0.304	40.72	0.983	1.5	0.0
A3	1.1	4.0	0.8	0.929	0.453	50.82	0.966	1.1	0.0
A4	3.1	3.4	1.2	0.950	0.126	43.34	0.985	3.0	-0.1
A5	4.2	6.7	4.8	0.852	0.146	46.85	0.891	4.2	0.0
A6	3.2	3.3	1.0	0.967	0.144	48.79	0.979	3.1	-0.1
A7	3.4	7.0	2.1	0.959	0.280	49.98	0.988	3.4	0.0
A8	2.8	5.8	1.2	0.949	0.108	47.06	0.912	2.8	0.0
A9	2.3	5.0	0.1	0.983	0.242	47.44	0.990	2.3	0.0
A10	7.4	18.0	7.6	0.869	0.333	48.90	0.977	7.4	0.0
A11	2.1	18.2	4.0	0.919	0.158	0.00	0.981	2.1	0.0
A12	5.6	9.0	2.1	0.952	0.163	56.97	0.971	5.6	0.0
A13	6.7	12.0	7.5	0.886	0.231	51.21	0.971	6.6	-0.1
A14	3.1	8.1	1.1	0.983	0.214	45.15	0.988	3.2	0.1
A15	4.1	7.4	3.4	0.870	0.199	49.04	0.911	4.1	0.0
A16	5.8	1.5	1.6	0.723	0.183	47.05	0.970	5.8	0.0
A17	3.6	4.9	3.2	0.857	0.168	45.72	0.918	3.7	0.1
A18	1.8	8.5	1.6	0.916	0.415	47.75	0.929	1.8	0.0
A19	8.7	8.1	9.1	0.784	0.100	49.22	0.988	8.7	0.0
A20	3.1	4.5	2.3	0.935	0.203	44.10	0.990	3.2	0.1
A21	5.6	9.3	6.3	0.881	0.239	47.89	0.984	5.7	0.1
A22	5.8	9.7	5.6	0.906	0.217	50.75	0.982	5.8	0.0

Table 3 prediction equation of fracturing effect

well No.	actual Increased oil volume (t) ΔQ	effective thickness (m) X_1	daily oil production of single well during fracturing (t)X_2	water content during fracturing (%) X_3	permeability (um^2) X_4	oil saturation (%) X_5	initial water content of polymer flooding (%) X_6	predicted oil increment (t)	the difference (t)
B1	5.6	9.0	9.1	0.794	0.411	49.37	0.985	5.9	0.3
B2	3.0	10.2	2.2	0.950	0.431	49.98	0.990	3.0	0.0
B3	6.5	14.2	6.3	0.901	0.194	44.86	0.983	6.7	0.2
B4	12.8	8.2	3.6	0.893	0.157	44.87	0.979	5.2	-7.6
B5	4.7	12.9	4.4	0.910	0.182	44.43	0.906	4.5	-0.2
B6	3.9	9.3	1.3	0.937	0.329	54.24	0.925	3.1	-0.8
B7	7.5	11.7	10.6	0.771	0.335	49.80	0.940	7.0	-0.5
B8	5.6	16.1	1.0	0.975	0.172	44.01	0.988	5.6	0.0
B9	3.9	10.2	0.2	0.990	0.141	45.57	0.981	4.1	0.2
B10	2.4	10.7	1.7	0.965	0.201	45.38	0.927	3.2	0.8
B11	3.4	7.5	0.7	0.943	0.147	45.24	0.948	3.5	0.1
B12	4.6	9.8	1.5	0.959	0.152	45.49	0.986	4.6	0.0
B13	4.3	9.1	6.3	0.902	0.244	44.87	0.953	4.3	0.0
B14	3.2	11.5	3.2	0.927	0.352	45.10	0.991	4.0	0.8
B15	5.6	13.8	1.8	0.940	0.154	44.04	0.977	5.6	0.0

At the same time, to study the fracturing effect of polymer flooding oil well [4], one geological model including 1 production well and 4 injection wells was established, with oil bearing area of $0.15km^2$, geological reserves of 4.92×10^4t, pore volume of $9.79\times10^4m^3$, permeability of 400-200mD, 120m well spacing, initial water content of 98%, injection rate of 0.14PV/a, injection concentration of l000mg/L, polymer dosage of 700mg/L. Numerical simulation results show that the fracturing effect of major reservoir is better the when the oil well is in the stage of water content descending or lower water content (Table 4), the fracturing effect of the thin and poor reservoir is better when the oil well is in water content recovery period. Via studying the production data of thin and poor oil layer, I found it is in the stage of low water content while the major reservoir is in the water content rising time, due to its poor reservoir conditions and effective time delaying. It can be concluded that polymer flooding formation fracturing should be optimally done when the oil well is in the stage of water content descending or lower water content. Conclusion also can be drawn from the statistical table of fracturing effect of different polymer flooding stages (Table 4), the oil increase amount and the effective period of the oil well which is in the stage of water content descending or lower water content is larger and longer than the oil well which is in water content recovery period [5].

Table 4 numerical simulation results of fracturing

scheme number	content	fracturing horizon	cumulative oil increment (t)	oil increment via fracturing (104t)	recovery efficiency increase via fracturing (%)
based scheme	don't take fracturing measures	the whole well	4532	N/A	N/A
scheme 1#	fracturing the main reservoir and the thin and poor reservoir in the water content descent period	main layer	4727	0.195	0.96
		thin and poor reservoir	4598	0.067	0.33
scheme 2#	fracturing the main and thin and poor reservoirs in the low water content stage	main layer	4723	0.191	0.94
		thin and poor reservoir	4610	0.079	0.39
scheme 3#	fracturing the main and thin and poor reservoirs in the recovery period of water content	main layer	4551	0.018	0.09
		thin and poor reservoir	4652	0.115	0.57
scheme 4#	fracturing the main oil layer in the water content descent period, fracturing the thin and poor oil layers in the recovery period of water content	main layer + thin and poor reservoir	4799	0.267	1.32
scheme 5#	fracturing the main oil layer in low water content stage, fracturing the thin and poor oil layers in the recovery period of water content	main layer + Thin and poor reservoir	4787	0.262	1.29

Conclusion

The increase of fluid volume is proportional to the permeability of geological factors, fracturing thickness, the sand content and sand liquid ratio, and it is inversely proportional to the fluid viscosity. For production wells with same geological condition and process condition, there is no significant difference in fluid increment after fracturing. The oil content increment after fracturing depends on the water content and oil saturation.

References

[1] Gui Dongxu.Analysis of fracturing effect of polymer recovery wells[J]. Inner Mongolia Petrochemical Industry, 2009(24): 202-203.

[2] Tong Shengqiang.Determination of fracturing timing of polymer flooding in bad oil layer [J].Petroleum Geology and development of Daqing, 2011,30(4): 131-134.

[3] Bi Yanchang, Su Yanchang, Li Yanxing .Application of hydraulic fracturing technology to improve the effect of polymer flooding [J]. Petroleum Geology and development of Daqing, 1999,18(3): 40-41.

[4] Zhai Yunfnag. Seepage Mechanics[M]. Petroleum Industry Press, 2009(7):13-23.

[5] Chne Taoping, Hu Jingbang[M]. Petroleum Industry Press, 2000(2):376-393.