

Study on macro prediction method of oil production in oil field with multiple development modes

Na Cha

Exploration and Development Research Institute of Daqing Oilfield Co Ltd. Daqing, China

chana@petrochina.com.cn

Abstract. With the large-scale popularization and application of new EOR technology, it is inevitable to face the problem of coexistence of multiple development methods, and the mechanism of new EOR technology is complex, there are many influencing factors, there is no mature prediction method, and the prediction of oil production is complex and heavy. How to use the simple, fast and small error method to calculate the oil production under the coexistence of multiple development modes has become an urgent problem. In this paper, the prediction method of oil production in different structure is established. By using the development indexes such as the macro oil production rate, the basic change trend of the development indexes under different development modes is studied and judged, so as to predict the annual oil production of the oilfield. Taking the EOR method of chemical flooding as an example, using the field practice of the block in which chemical flooding has been implemented for many years, the change trend of the macro oil recovery rate is predicted, and the oil production of the tertiary oil recovery of the oil field is determined according to the reserves of different scale. At the same time, the prediction results of the oil production of the whole oil field are obtained by combining the prediction results of the water drive oil production. It is verified by examples that the prediction accuracy can meet the needs of oilfield production, realize the rapid and accurate prediction of oil production in the field with multiple development modes, and solve the problem that there is no mature prediction method for new technology.

Keywords: Oil Production Rate; Tertiary recovery; Recovery Level; Layered Prediction.

1. Introduction

At present, most of the domestic oilfields are developed by water injection. With the gradual application of new EOR technology, it is inevitable that water drive reserves will be transferred to new EOR technology for development, especially the mechanism of EOR is not clear and there is no mature prediction method. How to use the simple, fast and accurate method to calculate the oil production under the coexistence of multiple development methods has become an urgent problem. At present, the prediction of oil production in oil field under the coexistence of multiple development modes is complicated and heavy. Taking chemical flooding tertiary oil production as an example, the annual oil production of tertiary oil production needs to predict the oil production in each block, so as to obtain the tertiary oil production of the whole oil field. There is no mature method for the prediction of oil production of some new EOR technology, so how to calculate the oil production under the coexistence of multiple development modes by using simple, fast and small error method becomes an urgent problem.

2. Macro production rate

With the extension of oilfield development time, the water cut is gradually increased, and the recovery degree of recoverable reserves is gradually increased. Through the analysis of the change rule of the oil recovery rate of the implemented EOR technology and the prediction of its macro rule, the change trend of the oil recovery rate of the EOR technology in the future is obtained.

2.1 Definition of production rate

Production rate refers to the ratio of annual oil production to geological reserves, expressed as percentage. If calculated according to the actual annual production, it is called the actual production

rate. It represents the percentage of actual oil production in geological reserves or recoverable reserves every year, and it is also an important indicator to measure the development speed of oil field.

Production rate of development mode A = annual oil production of development mode A / geological reserves of development mode A

2.2 Definition of production rate

The change law of oil production rate is complex, and the factors affecting oil production rate are mainly geological factors, development technology factors, economic factors, development life and so on. The complexity of structure, heterogeneity of reservoir, permeability difference, viscosity of crude oil, well pattern density and so on will affect the oil recovery rate. Although the numerical value of oil production rate is difficult to predict, the basic change trend of oil production rate can be studied and judged by using mathematical statistics method, and the change of oil production rate can be predicted, so that the influence of various single factors can be ignored, and the influence result of comprehensive factors can be obtained.

3. The prediction method of oil production in different structure

3.1 Establishment of hierarchical prediction model

Different development methods have different development laws, so it is necessary to use different development methods to describe the production rate. The change trend of oil recovery rate in water drive development area, the new technology EOR method uses its own change rule to predict. Different development methods predict according to their own rules, and finally synthesize the indicators of the whole reservoir. Therefore, the essence of layered prediction model is decomposition and synthesis.

3.2 Prediction model calculation steps

Calculate the production rate under different development modes. The oil production and reserves of oil field are classified according to different development modes, and the data of annual oil production and production reserves under different development modes are extracted to calculate the oil recovery rate under different development modes. The prediction method of water drive oil production is relatively mature, which can be predicted by oil production rate method or other methods.

Prediction of oil production rate under different development modes. By using the method of mathematical statistics to study and judge the basic change trend of oil production rate, the change of oil production rate under different development modes can be predicted.

Calculation of oil production in the whole oil field. On the basis of predicting the oil production rate of different development modes, and multiplying the production reserves of different development modes, the annual oil production of different development modes can be calculated, and the annual oil production of the whole oilfield can be obtained.

$$Q = \sum_{i=1}^n v \cdot D$$

Where: Q is the annual oil production, 10000 tons; v is the oil production rate, percentage; D is the geological reserves implemented by different development methods, 10000 tons.

4. Prediction of oil recovery rate by EOR technology

There are many methods to predict oil production of water drive, and the methods are mature. More complex is the prediction of oil recovery rate of EOR technology. The following is an example

of chemical flooding EOR technology to illustrate the whole process of oil recovery rate prediction. Other EOR methods can be adjusted according to their own development methods.

4.1 Production rate of chemical flooding

With the injection of chemical agent, the viscosity of water phase is increased, the fluidity ratio of water and oil is reduced, the water cut is reduced, and the oil production is greatly improved compared with that of water drive. In the early stage of chemical flooding into the main slug, the water content of produced fluid begins to decline, the oil production increases, and the oil production speed gradually increases. At the peak of effectiveness, the oil production speed reaches the highest, then the water content rises, the oil production speed gradually decreases, and the oil production begins to decline. The effective period of chemical flooding is shorter than that of water flooding, generally 2-5 years. Daqing Oilfield began to inject tertiary oil recovery in 1996. From the primary oil layer to the current secondary oil layer, the reservoir conditions became worse, the oil production of a single well decreased, and the effect of various factors superimposed showed the phased decline law of tertiary oil recovery rate.

4.2 Prediction of oil production rate

Select the tertiary oil production rate of oilfield a over the years, and there is a good decreasing trend from the change trend of the tertiary oil production rate, and also a good trend from the fitting trend of index and log curve (as shown in Figure 1). Therefore, it has a good reference for the prediction of oil production rate in the later stage. Comprehensive use of index, logarithm, time series and other forecasting methods to predict the oil production rate, use a variety of methods to predict the oil production rate under different development modes, and optimize the appropriate methods. A single method can be used or multiple methods can be used to weight the prediction to meet the prediction accuracy.

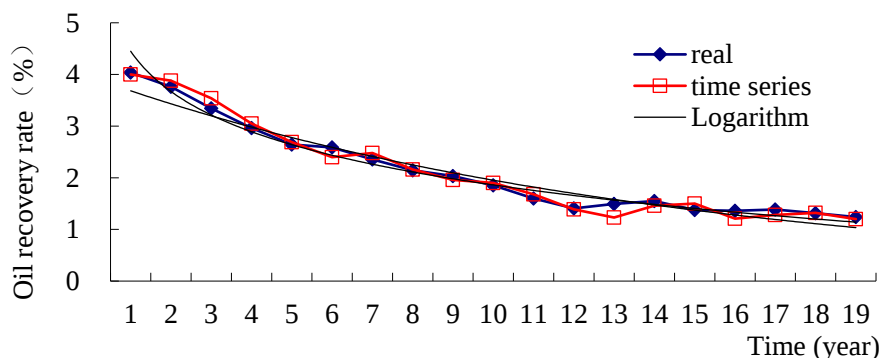


Fig. 1 Prediction of oil recovery rate of EOR

In the production practice of Daqing Oilfield, the development method of layer by layer upward return is adopted. Every time the upward return is carried out, the well pattern of the original layer system should be used by the next layer system. Therefore, the geological reserves of the third production of the original layer system have been used, but the oil production is zero because there is no well to exploit it. Therefore, when calculating the oil recovery rate of the tertiary oil recovery and development mode, the geological reserves produced by the tertiary oil recovery and development mode should be deducted from the geological reserves without oil production, otherwise, with the increase of the upper return block and the increase of production stop reserves, the calculation results will be greatly affected. Table 2 lists the change of oil production rate of tertiary oil production and development technology in Oilfield a. the first 18 data are sample data and the last 3 are forecast data.

From the perspective of prediction results, the logarithmic prediction results are relatively high, the early stage of time series prediction is high and the later stage is low, and the index prediction results are in the middle. From the perspective of the three prediction results, the average value of the index and logarithmic prediction results is close to the real value, so the index and logarithmic

prediction results are recommended as the prediction results. The forecast results are shown in Table 1.

Table 1. The prediction table of oil production of EOR in A field.

Time (year)	Logarithm (%)	Index (%)	Time series analysis (%)	True value (%)	Average of the three (%)	Average of logarithm and index (%)
1997	4.35	3.55	4.00	4.04	3.97	3.95
1998	3.60	3.33	3.88	3.76	3.61	3.47
1999	3.17	3.13	3.54	3.35	3.28	3.15
2000	2.86	2.93	3.05	2.96	2.95	2.90
2001	2.62	2.75	2.69	2.64	2.69	2.69
2002	2.43	2.58	2.40	2.59	2.47	2.50
2003	2.26	2.42	2.48	2.36	2.39	2.34
2004	2.12	2.27	2.16	2.14	2.18	2.20
2005	1.99	2.13	1.96	2.03	2.03	2.06
2006	1.88	2.00	1.90	1.85	1.93	1.94
2007	1.78	1.87	1.68	1.60	1.78	1.83
2008	1.69	1.76	1.39	1.41	1.61	1.72
2009	1.60	1.65	1.23	1.50	1.49	1.62
2010	1.52	1.55	1.46	1.55	1.51	1.53
2011	1.45	1.45	1.50	1.38	1.47	1.45
2012	1.38	1.36	1.21	1.36	1.32	1.37
2013	1.31	1.28	1.28	1.39	1.29	1.30
2014	1.25	1.20	1.32	1.31	1.26	1.23
2015	1.20	1.12	1.20	1.21	1.17	1.16
2016	1.14	1.05	1.06	1.15	1.08	1.10
2017	1.09	0.99	0.93	1.02	1.00	1.04

5. Application of instances

Table 2. An oilfield development data sheet

Time (year)	Annual oil production (104tons)	Geological reserves of oil field (104tons)	Recovery degree of oil field (%)	New annual water drive reserves (104tons)	Annual production reserves of tertiary oil recovery (104tons)	Accumulated produced reserves of the third mining (104tons)	Geological reserves shut down in the third mining year (104tons)	Annual oil production of third production (104tons)
1996	336.1	28004.3	30.23		702.6			17.7
1997	336.1	28004.6	31.28		127.8	830.4		33.5
1998	334.2	28324.0	32.24		472.9	1303.3		49.0
1999	327.0	29460.5	33.16		180.3	1483.5		49.6
2000	318.0	28649.1	34.06		419.5	1903.0		56.4
2001	309.0	28879.5	34.98	230.4	260.3	2163.3		57.2
2002	300.8	28921.8	35.69	42.3	468.6	2631.9		68.1
2003	290.4	29040.2	36.48	118.4	629.5	3261.4	114.8	74.1
2004	278.4	29305.5	37.25	265.2	191.6	3453.0	113.0	71.6
2005	269.7	29638.0	37.94	332.5	249.3	3702.4	125.8	72.7
2006	260.4	29934.6	38.23	296.6	214.0	3916.4	125.0	70.2
2007	250.2	30143.4	38.73	208.8	523.6	4440.0	132.4	68.9
2008	241.2	30745.6	38.79	602.2	382.2	4822.2	131.2	66.0
2009	240.0	31100.0	38.95	354.5	196.5	5018.7	143.3	72.9
2010	240.0	31579.2	39.13	479.2	308.6	5327.3	304.3	77.9
2011	240.0	32000.3	39.38	421.1	740.1	6067.4	307.9	79.2
2012	240.0	32432.7	39.81	432.4	397.8	6465.1	436.0	82.0
2013	240.0	32720.8	40.27	288.1	204.1	6669.2	587.5	84.2
2014	240.0	33088.5	40.46	367.7	447.0	7116.2	650.6	84.9
2015	230.3	33348.9	40.83	260.3	388.6	7458.9	795.5	80.5
2016	219.4	33650.3	41.12	301.4	245.8	7679.3	976.4	76.9
2017	204.0	33950.3	41.36	300.0	360.0	8039.3	1126.4	70.2

Take an oilfield a that has implemented tertiary oil recovery and development as an example. Since 1965, the oilfield has been put into development, with the first step of self injection production and then water injection development. Since 1996, it has been put into tertiary oil recovery development. The basic data of oilfield development are as follows.

Table 3. Prediction table of oil production

Time (year)	Predicted value					actual value					Prediction error		
	Water drive production rate (%)	Tertiary recovery rate (%)	Oil production of water drive (104tons)	Tertiary oil production (104tons)	Total annual oil production (104tons)	Water drive production rate (%)	Tertiary recovery rate (%)	Oil production of water drive (104tons)	Tertiary oil production (104tons)	Total annual oil production (104tons)	Oil production of water drive (%)	Tertiary oil production (1%)	Total annual oil production (%)
2015	0.56	1.16	146.26	77.23	223.49	0.58	1.21	149.82	80.50	230.32	-2.37	-4.06	-2.96
2016	0.55	1.10	142.64	73.46	216.10	0.55	1.15	142.43	76.93	219.36	0.15	-4.51	-1.48
2017	0.53	1.04	136.59	71.76	208.34	0.52	1.02	133.83	70.17	204.00	2.06	2.25	2.13

Using the prediction results of oil production rate in Table 2, take the data before 2014 as the sample to predict the oil production rate results in 2015-2017. According to the data of actual tertiary oil production reserves, production stoppage and new geological reserves of water drive in 2015-2017, the oil production of this oil field is predicted as shown in Table 3. From the prediction results, the error is within 3%, which can meet the actual production requirements.

6. Conclusion

1). It is simple and quick to use the prediction method of component oil recovery rate to predict the change trend of oil recovery rate. It avoids the complicated technical principle of EOR technology and meets the needs of oil field production from the mathematical statistics.

2). This method is suitable for a period of time when the new technology has been implemented. If the production time is short, the annual data can be refined to the monthly data, so as to increase the data items and improve the prediction accuracy.

3). This method is suitable for the macro research of oil production forecast in the medium and long term, and is not suitable for the calculation of annual production planning, because the time of injecting reserves (put into development in the first few months of each year) is not considered, which has a great impact on the current year's production.

Acknowledgment

This work was financially by National Science and Technology Major Special Project "EOR demonstration project of Daqing Chang yuan extra high water cut oilfield" (Number 2016zx05054).

References

- [1] Jiang Feng guang, Wang Xiao lin. Research on influence factors and theoretical value on recovery rate [J]. Journal of Southwest Petroleum University, 2013, 6(5): 104-108.
- [2] Xue Wei. SPSS application and analysis statistic [M]. Beijing: Publishing House of Electronics Industry, 2004: 242-243.
- [3] Tang Zi chang, Cheng Lin song, Li Chun lan. Application of partial correlation analysis to oil recovery rate influencing factor analysis [J]. Xinjiang Petroleum Geology, 2010, 31(4): 423-425.

- [4] Jiang Han qiao, Yao Jun, Jiang Rui zhong. The fundament and practice of reservoir engineering [M]. Dong ying, Shandong: China Petroleum University Press,2006:236.
- [5] Wang Peng. Research on reasonable production rate of low permeability injection reservoir [J]. Inner Mongolia Petrochemical Industry,2012,6(3):139-141.
- [6] Yu Qi tai, Li Wen xing. Production stabilizing pattern for waterflooding reservoir [J]. Petroleum Geology & Oilfield Development in Daqing,1998,17(1):20-25.
- [7] 1CHEN Yuan qian, ZOU Cun you. Model's typical curve and its application for forecasting production and recoverable reserves of oilfields
- [8] WANG Xiao lin, CHANG Yu wen, DOU Hong en. The experiences from east Texas oilfield being of great significance for the large oilfield development in China [J]. Foreign Oilfield Engineering, 2010, 26(9): 15-19.
- [9] SUN Long de,WU Xiao lin,ZHOU Wan fu,et al. Technologies of enhancing oil recovery by chemical flooding in Daqing oilfield,NE China[J]. Petroleum Exploration and Development, 2018, 45 (4) :636-645.
- [10] ZHOU Yun, ZHOU Fu jian, FENG Lian yong. A new model for predicting oil and gas production [J]. Petroleum Geology and Oilfield Development in Daqing,2018,37(5):76-80.
- [11] WANG Mei shi, CHEN Xiang guang, LI Yu feng. Multivariate linear regression and automatic regression models applied to output prediction of oilfield [J]. Petroleum Planning & Engineering, 2005, 16(3):19-21.
- [12] LIU Haohan. Probability theory and mathematical statistics [M]. Beijing: Higher Education Press, 2015: 113-115
- [13] WANG Jiqiang, SHI Chengfang, JI Shuhong, et al. New water drive characteristic curves at ultra-high water cut stage[J]. Petroleum Exploration and Development, 2017, 44(6): 955-960.
- [14] WANG Fang, HE Songbiao, GUO Ye. Improvement on the study of output optimization model of oilfields[J]. Oil-Gasfield Surface Engineering, 2006, 25(11): 1-2.
- [15] YIN Aizhen, ZHANG Zaixu, HUANG Changsheng, et al. A goal programming model for optimizing output of an oilfield[J]. Journal of China University of Petroleum (Edition of Natural Science), 2003, 27(5): 119-121.