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Study on Development Law and Yield Replacement Method in Sazhong Development Area

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Abstract

with the increasing time of water drive development in the Sazhong development zone, the oilfield has gradually entered the stage of high water cut stage or ultra-high water cut stage, and now it has entered the development stage of the high water cut period of the coexistence of the two drive. In order to extend the production life of the oilfield and plan the scale of production, based on the application of reservoir engineering method to calculate the natural decline rate and by grouping the Sa Pu oil layer and the Gaotaizi oil reservoir in the Sazhong oilfield, reducing the yield base of each year and re prediction of water drive production decline rule in Sazhong development area, which is concluded that the average decline rate is 7.46%. At the same time, the characteristics of tertiary oil recovery are analyzed, and the production replacement equation is established through the production demand under different production decline conditions. Based on the law of decreasing water drive and the change rule of chemical flooding production, the average chemical drive reserves in 12th Five-Year and the annual largest chemical drive reserves as tertiary oil recovery reserves, and the output forecast index of the sash development zone can be obtained.

Key words: Decline rate; Tertiary oil recovery; Yield replacement

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By the end of 2014, the comprehensive water cut of the Sazhong development zone was 94.92%, including water flooding comprehensive water cut 94.5%, tertiary oil recovery block comprehensive water cut 95.42%, now entered the two drive coexistence of the high water cut stage of the development stage (Liu, 2010). With the deepening of oilfield development, the object of water drive production is becoming worse and worse because of the factors such as plugging and utilizing of tertiary oil recovery (Li, 1997), the development target is changed from middle and low permeability layer to low permeability layer, and the development rule is different from the past. The tertiary oil recovery is an important means to make up the decline of production. Due to the different ways of displacement, the difference in the physical property of the oil layer and the way of adjustment, the development rules of each block are very different. At the same time, because of the ups and downs of tertiary oil recovery and reserve seal of primary layer, it has a great influence and risk on controlling the decline of oilfield in the later period. It is necessary to systematically study the characteristics of tertiary oil recovery and the effect of polymer flooding reserve storage on late production replacement capacity (Liu, 2008; Liu, 2007).

1. STUDY ON THE DECLINE LAW OF WATER DRIVE PRODUCTION IN THE SAZHONG DEVELOPMENT ZONE

The production decline law is controlled by the production system (Arps, 1945). Under the condition of liquid production, the change rule of the decline rate usually rises first and then decreases with the increase of recovery degree of recoverable reserves or the increase of water content. Under the condition of constant pressure production, the rate of decline always decreases with the increase of recovery degree of recoverable reserves or water content. In the calculation of the decline in the output of the Sazhong oil field, there are many factors that affect the decline of oil field production. The law of the decline in the water drive and predict production in Sazhong oil field cannot be accurately given by a comprehensive decline (Liu, et al., 2010; Liang, 2005; Liang, et al., 2008). Therefore, we need to calculate the natural decline rate of Sazhong oil field and study the change rule of production decline so as to predict the change of oilfield output.

1.1 Decrease Rate of Water Drive in Sazhong

The rate of decline is the rate of change in production per unit time (Wang, 2007). It can be expressed in the following form:

$$D = -\frac{1}{Q}\frac{dQ}{dt} \qquad (1)$$

The comprehensive decline rate refers to the ratio of the difference between the oil production of the upper stage and that of the current stage after deducting the production of new wells in oil production to the previous stage. The expression is:

$$D_R = \frac{Q_{i-1} - (Q_i - Q_{xji})}{Q_{i-1}} \times 100\% \qquad (2)$$

The natural decline rate reflects the true situation of oil field production decline, which is related to, such as reservoir type, reservoir physical property, crude oil property, water cut stage, oil production speed, oil production composition, production management and so on (Yu, 1995). Natural decline rate refers to the rate of decline in production without new well production and various production measures. that is, the difference between the oil production of the previous stage and that of the current stage after deducting the production of new wells and various stimulation measures, which accounts for the ratio of the oil production of the previous stage. The expression is:

$$D_N = \frac{Q_{i-1} - (Q_i - Q_{xji} - Q_{csi})}{Q_{i-1}} \times 100\% \qquad (3)$$

In the formula: D_N is natural decline rate,%; Q_{i-1} is the upper stage of oil recovery, $10^4 t$; Q_i is the oil production at this stage, $10^4 t$; Q_{csi} is the measure of oil production at this stage, $10^4 t$; Q_{xji} a is the production of new well at this stage, $10^4 t$.

The average decrease rate of natural decline rate of water flooding in sac oilfield is 7.70%. With the natural decline rate is compared with the comprehensive decline rate, the change of the decreasing curve indicates the effect of reducing the decline of water drive by the measure of increasing oil increase. The change trend is irregular and does not conform to the adjustment of oil field, and it has a great disturbance to the forecast of oil production in the future. Therefore, it is very important to find out the main factors affecting production decline and to reduce the true decline of water flooding under the condition of new wells and measures.

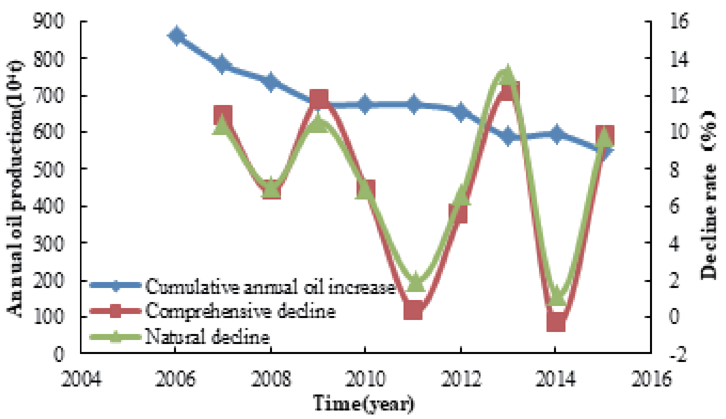


Figure 1
Comparison of comprehensive production decline and natural decline in water drive in Sazhong

1.2 Restore the Law of Decline After Real Water Flooding

The law of real production decline in the development zone of the SSA is restored, which lays the foundation for later prediction of production decline and rational planning of production (Gao & Wang, 1999). Formula for calculating natural decline rate is:

$$D_N = 100 - \frac{(Q_i - Q_{xji} - Q_{csi} - Q_{smji} + Q_{lyyxi} + Q_{zyxi} + Q_{fdyxi} + Q_{tqyxi} + Q_{zgyxi})}{Q_{i-1} - Q_{xji-1} - Q_{fdci} - Q_{zxi} - Q_{lyci} + Q_{zgyxi-1}} \times 100\% \qquad (4)$$

In the formula: D_N is natural decline rate,%; Q_{i-1} is the upper stage of oil recovery, 10^4t; Q_i is the oil production at this stage, 10^4t; Q_{xji} a is the production of new well at this stage, 10^4t; Q_{snxji} was the last year new well did not measure oil production, 10^4t; Q_{csi} is the measure of oil production at this stage, 10^4t; Q_{fdci} is the oil production capacity of last year, 10^4t; Q_{zzci} is oil production of conversion well in the previous year, 10^4t; Q_{yyxi} is the amount of oil produced by the use effect of this stage, 10^4t; Q_{lvci} is oil production used in the previous year, 10^4t; Q_{tsyxi} is the oil production effect by this stage damage , 10^4t; Q_{fdyxi} is the amount of oil produced by plugging in this stage, 10^4t; Q_{snxji} is the amount of oil produced by new well last year that did not take measures, 10^4t; Q_{zzyxi} is the amount of oil produced by the conversion in this stage, 10^4t; Q_{lyyxi} is the amount of oil produced by the use effect of this stage, 10^4t; Q_{zgyxi} is the oil producing quantity affected by drilling and closing in this stage, 10^4t.

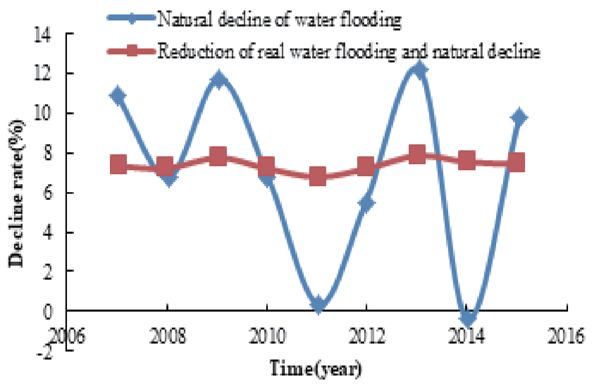


Figure 2
Comparison of natural decline restored in real water flooding and natural decline in water drive from Sazhong

2. STUDY ON THE CHARACTERISTICS AND LAWS OF THE TERTIARY OIL RECOVERY DEVELOPMENT

The tertiary oil recovery in the second type of reservoirs is an important replacement for production decline in the water flooding process, which is of great significance (Gao & Liu, 2002; Qi, 2017). In the actual production, polymer flooding and three element flooding are adopted. There are total of 13 tertiary oil recovery blocks in Sazhong, including 10 polymer flooding blocks and 3 blocks of three element composite flooding blocks. Production data of each block show that polymer flooding and three element flooding can achieve precipitation and oil increase. After high water cut stage, the water content of the polymer flooding or three element flooding decreased obviously, and the oil production increased. When the water content reaches the lowest point, it starts to pick up again. The recovery rate of polymer flooding is about 20%, and the three element flooding can reach about 25%.

2.1 Influence of the Amount of Polymer on the Recovery Degree

The amount of polymer used in each block is designed to study the effect of the amount of polymer used on the recovery degree. The scheme design and results are shown in the table below. The results showed that the recovery degree increased with the increase of polymer dosage, and the effect of polymer flooding in each block was obvious.

Table 1
The Amount and Recovery of Polymer in Polymer Flooding

Block	Average concentration of polymer injection mg/L	Polymer dosage at the end of polymer flooding mg/L.pv	Recovery degree at the end of polymer injection %
North first block second row west back block	1020	998.6	19.05
Block west east block	1210	1197.15	17.28
Middle block of South first block	1250	1820	17.78
Block east west block	1400	1534.08	19.07

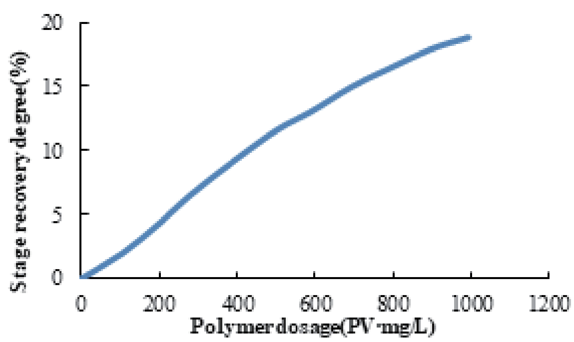


Figure 3
Relation between accumulation amount and recovery degree of north first block second row west back block

2.2 Influence of Injection of PV Number on Production Degree

The recovery degree corresponding to the cumulative pore volume multiplier. is calculated from the beginning of the injection to the subsequent stage of water flooding, and the recovery degree from the water flooding stage to the present stage. As shown in the following table. The results show that the recovery degree increases with the increase of the injected PV number, the overall stage recovery of Block west east block and middle block of south first block degree is low, and, the polymer flooding did not end In block west east block.

Table 2
PV and Recovery Degree Injected at Each Stage

Block	Cumulative injection pore volume multiplier at the stage of polymer injection PV	Recovery degree of polymer injection stage %	Cumulative injection pore volume multiplier in subsequent water flooding stage PV	Recovery degree of follow-up water flooding stage %	General stage recovery degree %
North first block second row west back block	0.98	19.05	0.36	5.01	24.06
Block west east block	1.13	17.28	-	-	17.28
Middle block of South first block	1.18	19.85	0.83	4.6	24.45
Block east west block	1.126	17.78	0.27	1.8	18.56

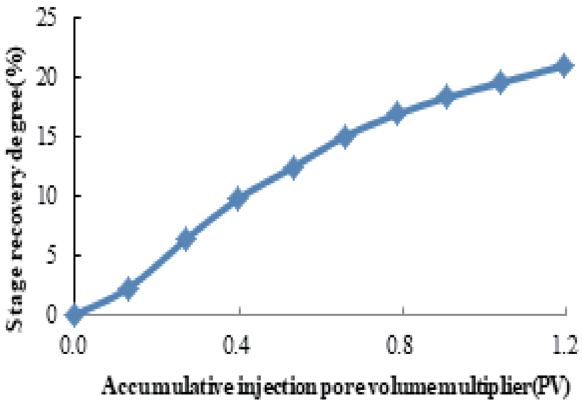


Figure 4
Relationship between pore volume multiplier and recovery degree in north first block second row west back block

3. STUDY ON THE REPLACEMENT METHOD OF TERTIARY OIL RECOVERY

3.1 The Establishment of a Mathematical Model for the Tertiary Oil Recovery of Yield Composition

The amount of oil produced by the new investment chemical drive in t year can be expressed as follows:

$$M_i = \sum_{i=1}^{i=n}(1-f_{wpi})\times v_i \times N_{n+1-i} \quad (5)$$

The oil production of plugging block in t year is as follows:

$$F_i = \sum_{i=1}^{i=n}(1-f_w)\times v_i \times N_{n+1-i}\times(1-D_i)^{i-1} \quad (6)$$

The annual oil production can be expressed as:

$$Q_t = S_t + H_t - F_t + M_t \quad (7)$$

Where, S_t-the annual oil production of water drive block; H_t-the annual oil production of chemical flooding has been put into production; a_i-annual oil recovery ratio; N_i-I year arrangement of geological reserves; V_i-liquid mining speed; D_i-I year decline rate.

3.2 Formulation and Solution of the Tertiary Oil Recovery Replacement Plan

3.2.1 Chemical Flooding Reserve Planning Based on Yield Replacement Planning Model

In order to make the production replacement decision more scientific, that is, to make up for the decline of production year by year with the smallest possible geological reserves, it is necessary to add the constraint conditions: the total input geological reserves of the new chemical flooding is the lowest. In order to calculate the reasonableness of the results, a mathematical optimization model for the composition of oil production is established by setting the constraints on the condition that the results of the yield composition and the target value of the oil production are floating 5%.

It is assumed that the annual production target of Sazhong oil field is stable than that of 2015, that is, the annual production target is $933.22\times10^4 t$. The above mathematical optimization models are implemented in mathematical language as follows:

The constraints are expressed as:

$$\min\left(\sum_{j=1}^{n} \mathrm{abs}((p[j]*a[j]-q[j]))\right) \quad (8)$$

The relationship between the composition of the oil production is expressed as:

$$\sum_{i=1}^{n}(a[i]*p[1+n-i]) - \sum_{i=1}^{n}(b[i]*p[1+n-i]) + S_i + H_i = Qi \quad (9)$$

Abs（Qi-933.22）/933.22<=5%　(10)

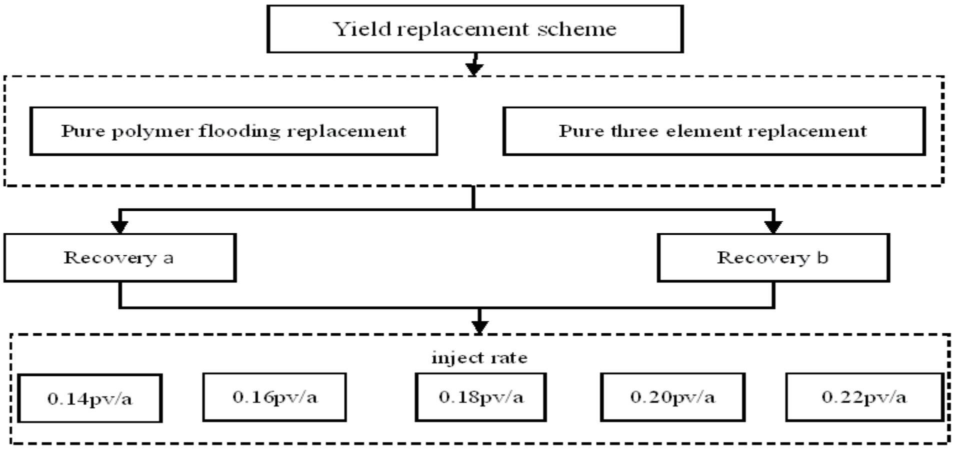
The implementation process in the optimization software 1stOpt is as follows:

MinFunction Sum(j=1:5)(abs((p[j]*a[j]-q[j])))
(11)

For(i=1:5)(1.05*q[i]>(Sum(i1=1:i)(a[i1]*p[1+i-i1])-Sum(i1=1:i)(b[i1]*p[1+i-i]))>0.95*q[i])
(12)

On the basis of the tertiary oil recovery rules, tertiary oil recovery plans for oil production replacement arrangements have been worked out.

The tertiary oil recovery schemes in the Sazhong development zone are mainly divided into two major categories: polymer flooding and three element flooding. Considering the injection speed factors in the tertiary oil recovery, after the recovery of the tertiary oil recovery is finished, the tertiary replacement scheme, which takes into account the inject rate and displacement type is given. The replacement scheme is divided into pure polymer flooding replacement and pure three element flooding. The injection rate is 0.14pv/a, 0.16 pv/a, 0.18 pv/a, 0.20pv/a and 0.22pv/a respectively, and the extraction degree of each stage is obtained. The succession plan structure diagram is shown as follows.



According to the above tertiary oil recovery scheme, the simulation injection speed 0.2PV/a is calculated by 1stOpt optimization software, and predicted that the geological reserves of the new production block on tertiary oil recovery succession plan of oil production in different injection stages are used to compensate for the decline of water flooding production.

3.2.2 Planning Reserves of Chemical Flooding Reserves According to "12th Five-Year" Period

The geological reserves of chemical flooding in the period of "12th Five-Year" were calculated, and the annual maximum and annual average value of tertiary oil recovery geological reserves were put into production during the period of "12th Five-Year", which was used to make up for the reserves of new tertiary oil recovery per year in the decline of water drive. On this basis, taking 15% extraction degrees in tertiary oil recovery stages as an example, the annual oil recovery is calculated by considering different injection speed, well spacing conditions and displacement types.

On the basis of 15% recovery in injection-polymer stage, production is carried out according to the average geological reserves of chemical flooding during the 12th Five-Year Plan. The annual oil production and the composition of annual oil production are calculated with considering factors such as injection rate, well spacing and displacement type. Finally, we predicted the output of successive production plans during the "13th Five-Year" period.

CONCLUSION

• Based on the calculation of natural decline rate in reservoir engineering method and combining the development characteristics of the Sazhong Development Zone, reducing the yield base of each year and the law of water drive decline is summarized again.It's concluded that the current average decline rate is 7.46%.

• According to the mining characteristics of the second types of oil reservoirs, it is clear that the law of the tertiary oil recovery development can accurately arrange the output structure, rationally deploy tertiary oil recovery and slow down the production decline of the oil field. It provides a theoretical basis and data basis for the exploitation of tertiary oil recovery block, the storage of polymer flooding reserves and the rational arrangement of oil production structure planning.

• Based on the law of decreasing water drive and the change rule of chemical flooding production, the average chemical drive reserves and the annual largest chemical drive reserves in the year of "12th Five-Year" are used as the tertiary new oil recovery reserves The output of the western part of the middle area can be obtained by considering the water content, the speed of the mining liquid, the decline output rate t of the stored block before the three oil recovery and the recovery degree in the three oil recovery stage.

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