Application and Discussion of Reserve-production Balance Coefficient in Oilfield

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Abstract. The reserve-production balance coefficient is the ratio of the annual increase in recoverable reserves to the annual oil production, also known as production reserve replacement ratio. What is the relationship between the index and the stable production of oilfield? How to use the index to predict the stable production ability of oilfield? When the annual increase in recoverable reserves is greater than the annual oil production, it can only mean that the resource base is further strengthened, but whether the annual oil production in the following year can be kept stable or increased, it also depends on the ability of new recoverable reserves to be converted into annual oil production and the magnitude of the decline rate of the previous year's annual oil production. Based on the analysis of the critical value of stable production of the reserve-production Balance Coefficient, this paper discusses how to apply the reserve-production Balance Coefficient in oilfield development, and when the reserve-production Balance Coefficient reaches what critical value, the annual oil production of an oilfield can be stabilized or increased in the next year.

Keywords: Reserve-production Balance Coefficient; production; rate of decline; critical value of stable production; productivity rate; fulfillment rate of production capacity.

1. Statement of problem
The reserve-production Balance Coefficient is the ratio of annual increase in recoverable reserves to annual oil production, also known as the production reserve replacement ratio. People who are engaged in the research of oilfield development often need to calculate the index of reserve-production Balance Coefficient, so how to apply this index in Oilfield Development? Some people think that if the reserve-production Balance Coefficient reaches 1, the oil field should be able to achieve stable production next year, in fact, this is not accurate. When the annual increase in recoverable reserves is greater than the annual oil production, it can only mean that the resource base is further strengthened, but whether the annual oil production in the following year can be kept stable or increased, it also depends on the ability of new recoverable reserves to be converted into annual oil production and the magnitude of the decline rate of the previous year's annual oil production. So how to use reserve-production Balance Coefficient to predict the stable production capacity of oilfield? The concept of stable production critical value of reserve production balance Coefficient is introduced to analyze the relationship between reserve production balance Coefficient and stable production.
2. Determination method of stable production critical value of reserve-production balance coefficient

2.1. Determination of reserve-production Balance Coefficient
The reserve-production Balance Coefficient is the ratio of the new recoverable reserves in the current year to the annual oil production. The new recoverable reserves in the current year include two parts, one part is the recoverable reserves increased by the annual production of geological reserves in the new area, the other part is the annual increase in recoverable reserves in the old area by EOR.

2.2. Determination of stable production critical value of reserve-production balance coefficient
According to the method of production composition in annual production allocation, the annual oil production is composed of three parts, one is pure old well oil production (including measures) \( Q_1 \), which can be determined by the old well oil production \( Q \) and the old well comprehensive decline rate \( DC \), the other is the production of wells put into production last year \( Q_2 \), it can be determined by the newly built production capacity that increased the recoverable reserves in the previous year and fulfillment rate of production capacity- \( G \). The third is the oil production from new wells that year \( Q_3 \), which can be determined by the new production capacity plan and production contribution rate of the year. The expressions for \( Q_1 \) and \( Q_2 \) in annual oil production are:

\[
Q_1 = Q(1 - D_C) \\
Q_2 = \frac{\Delta N_R}{E_R} V_N G 
\]

In the formula: \( Q_1 \) is the annual oil production of the previous year after the decline of the next year, \( 10^4 t \); \( Q \) is the old well production of the previous year, \( 10^4 t \); \( D_C \) is the comprehensive decline rate of the old well, \( \% \); \( Q_2 \) is the annual oil production from the new production capacity built to increase recoverable reserves in the following year in accordance with the previous year, \( 10^4 t \); \( \Delta N_R \) is an increase in recoverable reserves in the previous year, \( 10^4 t \); \( E_R \) is the recovery factor, \( \% \); \( V_N \) is the planned production speed, \( \% \); \( G \) is the fulfillment rate of production capacity, \( \% \).

Because the production of new well in that year is affected by the adjustment of plan and the progress of drilling, there are many uncertain factors, and the production of new well is considered separately. If the annual oil production of old wells achieves stable or increased production, then

\[
Q_1 + Q_2 \geq Q 
\]

The formula (1) and (2) are substituted by the formula (3), which can be derived

\[
\frac{\Delta N_R}{Q} \geq \frac{E_R D_C}{V_N G} 
\]

The left side of the formula (4) is approximately equal to the reserve-production Balance Coefficient of the previous year, and the right side of the formula (4) is the reserve-production Balance Coefficient stable production critical value, that is, the lower limit of reserve-production Balance Coefficient when the old well achieves stable production.

2.3. Influencing factors of stable production critical value of reserve-production balance coefficient
The stable production critical value of the reserve-production Balance Coefficient can be obtained from the formula, the critical value of stable production is affected by four factors: the parameter \( E_R \) which reflects the reserve quality, the parameter \( D_C \) which reflects the comprehensive decline state of the old well, the parameter \( V_N \) which reflects the production state of the scheme and the parameter \( G \) which reflects the fulfillment rate of production capacity. These four parameters determine the critical value of stable production of reserve-production Balance Coefficient in different development stages of different oilfields.
3. Prediction and application of stable production critical value of reserve-production Balance Coefficient in an oilfield

3.1. Determination of four parameters of stable production critical value of reserve-production balance coefficient

ER (oil recovery rate): adopting 24.0% according to the demarcated oil recovery rate.

Dc (Comprehensive decline rate of old well): adopting 11.0% according to the comprehensive decline of old wells in recent years.

VR (productivity rate): according to the definition of productivity rate, the formula of productivity rate is deduced as follows:

\[ V_N = \frac{\text{well pattern density} \times \text{oil–water well ratio} \times \text{oil recovery intensity} \times 0.03}{\text{single storage factor} \times (\text{oil–water well ratio} + 1)} \]

The productivity rate is 1.8% when the density of well pattern is 8.5, the ratio of oil wells to water wells is 2.4:1, the production intensity is 1.0 t/d.m and the unit reserve factor is 10.

G (fulfillment rate of production capacity): the productivity arrival rate has changed greatly in recent years and this template calculates the productivity arrival rate of 50%-100% under different circumstances.

According to the above analysis, among the four parameters of the stable production critical value of the reserve-production balance coefficient, the three parameters of ER, DC and VN are relatively stable, and the fulfillment rate of production capacity varies greatly.

3.2. Prediction of stable production critical value of reserve-production Balance Coefficient in an oilfield

The formula of stable production critical value of reserve-production Balance Coefficient is

\[ GV = \frac{E_R \cdot D_C}{V_N \cdot G} \]

Substituting four parameters into the formula can obtain that the stable production critical value of the reserve-production Balance Coefficient is from 1.47 to 2.93, which shows a wide range of variation (table 1). The critical value of stable production of reserve-production Balance Coefficient is 1.73 when the productivity rate is 85%, and 2.10 when the productivity rate is 70%. Therefore the stable oil production can be achieved in the next year, not only when the reserve-production Balance Coefficient reaches 1, but also when the reserve-production Balance Coefficient reaches the critical value. Due to the different parameters of different oil fields, the critical value of stable production of the storage-production balance coefficient is also different.

3.3. Application of stable production critical value of reserve-production balance coefficient

Table 1. Stable production critical value of reserve-production balance coefficient under different deliverability rate

| stable production critical value of reserve-production balance coefficient and its parameters | 1.47 | 1.54 | 1.63 | 1.73 | 1.83 | 1.96 | 2.1 | 2.26 | 2.44 | 2.67 | 2.93 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| stable production critical value of reserve-production balance coefficient | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 |
| ER | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 |
| DC | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 |
| VN | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 |
| G | 100 | 95 | 90 | 85 | 80 | 75 | 70 | 65 | 60 | 55 | 50 |
From the derivation of equation (4), it can be known that when the reserve-production Balance Coefficient of the previous year is much higher than the calculated stable production critical value, the oil production of the next year's old well will be in a fast rising stage; When the reserve-production Balance Coefficient of the previous year is close to the critical value of stable production, the oil production of old wells in the next year is basically stable; when the Balance Coefficient of reserves and production in the previous year is less than the critical value of stable production, the oil production of the old well in the next year will decline or become more difficult to keep stable production.

It is estimated that the critical value of stable production is between 1.27 and 1.96, and the Balance Coefficient of reserves and production is greater than the critical value of stable production in the year of 2007-2010, the annual oil production increased from 1.341 million tons in 2007 to 1.616 million tons in 2010, and the Balance Coefficient of reserves and production approached the critical value of stable production in the previous year from 2011 to 2013. In 2014, the reserve-production Balance Coefficient of 1.85 was higher than the stable production critical value of 1.27, and the annual oil production of the oilfield increased greatly again. In 2017, the Balance Coefficient of reserves and production was much lower than the critical value of stable production, which made it more difficult for oilfield to maintain stable production. It is predicted that the critical value of the reserve-production balance coefficient for stable production in 2018 will increase with the reduction of oil increase measures, and the fulfillment rate of production capacity will drop to about 70%, and the critical value of the reserve-production balance coefficient for stable production will increase to 2.19 (see table 2).

| Year | ER | DC | VN | G | stable production critical value of reserve-production balance coefficient | Balance Coefficient of reserves and production in previous year | Annual oil production (10^4t) | Annual production of old wells (10^4t) |
|------|----|----|----|---|---------------------------------|---------------------------------|--------------------------|-------------------------------|
| 2007 | 24 | 17.68 | 2.4 | 118.3 | 1.51 | 2.35 | 134.19 | 120.42 |
| 2008 | 24 | 17.19 | 2.2 | 106.4 | 1.73 | 3.18 | 148.02 | 136.01 |
| 2009 | 24 | 16.48 | 2.3 | 102.8 | 1.64 | 1.81 | 154.01 | 146.19 |
| 2010 | 24 | 14.64 | 2.4 | 75.4 | 1.96 | 2.08 | 161.61 | 158.62 |
| 2011 | 24 | 14.19 | 2.4 | 94.1 | 1.54 | 1.57 | 163 | 155.23 |
| 2012 | 24 | 12.35 | 2 | 83.1 | 1.79 | 1.58 | 164.1 | 158.9 |
| 2013 | 24 | 11.89 | 2.1 | 80.5 | 1.73 | 1.5 | 166.48 | 158.55 |
| 2014 | 24 | 10.42 | 2.1 | 93.9 | 1.27 | 1.85 | 176.7 | 165.59 |
| 2015 | 24 | 11.31 | 2.1 | 93.5 | 1.39 | 1.25 | 180.34 | 172.13 |
| 2016 | 24 | 10.19 | 2.1 | 83.3 | 1.38 | 1.64 | 180 | 172 |
| 2017 | 24 | 10.23 | 2 | 66.7 | 1.85 | 1.01 | 186 | 170 |
| 2018 | 24 | 11.44 | 1.8 | 70.7 | 2.19 | 2.23 | 184.5 | 178.5 |

4. Conclusion and understanding
(1) The stable production critical value of reserve-production Balance Coefficient is affected by four factors: the parameter ER which reflects the reserve quality, the parameter DC which reflects the comprehensive decline state of the old well, the parameter VN which reflects the production state of the scheme and the parameter G which reflects the fulfillment rate of production capacity.

(2) When the reserve-production Balance Coefficient Reaches 1, it does not mean that the oil production of the oilfield will be stable in the next year.

(3) The critical value of stable production is different in different stages of development in different oilfields.
(4) The stable production critical value of the reserve-production Balance Coefficient is 1.73 when the fulfillment rate of production capacity reaches 85%, and rises to 2.10 when the deliverability reaches 70%.

(5) When the reserve-production Balance Coefficient of the previous year is much higher than the calculated stable production critical value, the oil production of the next year’s old well will be in a fast rising stage; when the reserve-production Balance Coefficient of the previous year is close to the stable production critical value, in the next year, the oil production of the old well is basically stable; when the Balance Coefficient of reserves and production in the previous year is less than the critical value of stable production, the oil production of the old well in the next year will decline or become more difficult to keep stable production.

(6) The critical value of stable production of reserve-production Balance Coefficient will increase due to the deterioration of quality of new capacity blocks and the decrease of the rate of deliverability in place.

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