Research on the calculation method of the horizontal well reserves in the A oil field

Zhang Mei *
Daqing Oilfield Co., Ltd. 8th Oil Production Plant, Heilongjiang Daqing 163514, China

*Corresponding author e-mail: zhangmei111@petrochina.com.cn

Abstract. The application of horizontal well development is one of the effective methods for the utilization of low permeability reservoir at present. The horizontal well development test in A oil field started from 2002, and it achieved better results. But it is one of the difficulties in the designs that how to find out the development about the horizontal wells. Volume method is the most suitable method for calculating reserves in Z oil field by studying in this paper, so the author prefers Delaunay triangular network method to calculate the single horizontal well control area at first, then considers the key points of reserve calculation, obtains the reserve results of A oil field by applying the reserve calculation software at last.

Keywords: horizontal wells; reserve calculations; volume method; Delaunay triangle network.

1. Introduction
P oil layer of A oil field is a low abundance and thin oil layer, so the efficiency is low by conventional straight well mining. Since 2002, horizontal well field test research has been implemented in Z oil field, and obtained better development results. As the development life increases, how to figure out the development of horizontal well reserves has become one of the difficulties in the conceptual designs. Therefore, it is necessary to carry out horizontal well utilization reserve calculation research for the joint development blocks for Straight Wells and Horizontal Wells in Z oil field, then we can understand the extent of horizontal well reserve producing.

2. Current reserve calculation methods
2.1. The characteristic curve method of waterflooding
At present, there are four types of waterflooding characteristic curves: A, B, C and D. The geological reserves are calculated by using the water flooding characteristic curve, which is mainly concentrated on the characteristic curve of waterflooding A. Because it is simple, convenient, and suitable for waterflooding oil deposits. However, it is not applicable when the oil development is in low-water-containing period and ultra-high water-containing period because it mainly affected by the water-containing stage, oil field development adjustment measures and production stability, so it only applicable to medium-high water-containing period and stable development period.
2.2. Volume Method
Using volume method to calculate the geological reserves of oil fields is very common. One method is to circle the oil area of the block first, and then according to the other parameters of the block to obtain geological reserves, which is the conventional method of calculating reserves. The other method is to circle the oil area of the block by the triangular mesh method, then obtains geological reserves with other parameters, so the sum of the reserves of each well is the block reserve. That's the triangle method. If we use volume method to calculate the reserve, the workload is large, and it is difficult to describe the impact of a new well when the well network density is relatively large. And it is also difficult to describe the impact on oil field mining when fracking, acidification and other measures are taken.

2.3. Production decreasing method
In 1945, Arps first summed up the laws of decreasing yield as three types, exponential decline, hyperbolic decline, harmonic decline, later they became the classical methods of production decline prediction. The main reason for the prediction of yield decline is to use different mathematical methods, first we use single-well production data to calculate the decreasing parameters, and next we obtain the prediction formula. Then we calculate the decreasing production. The method is intuitive and convenient, and the more points of continuous decline. The evaluation results is faster and more reliable, but there are still shortcomings, that is production decline cannot predict the production in the unstable flow state.

2.4. Numerical simulation method
Numerical simulation method calculates the produced reserves mainly based on the change of oil saturation, but it still has deficiencies, one is that the change of oil saturation has a great influence on the calculation results of the produced reserves, the second is that Historical fitting is difficult. And if there are many faults and many wells in the simulated block, it is difficult to achieve the appropriate fit accuracy.

3. The produced reserve calculation method of horizontal well and straight well

3.1. The optimal calculation method of Z oil field produced reserves
According to the actual development of Z oil field and the basic idea which is easy to program, we choose the volume method to realize the automatic calculation of oil field produced reserves. The parameters are valued as follows:

(1) The oil area is determined by the horizontal well virtual well points, faults and boundaries.

(2) The effective thickness of the straight well is determined according to the results of the log data, and the oil layer effective thickness is valued according to the interpretation result; the water layer effective thickness is zero; and the oil-water layer effective thickness is half discount. The effective thickness of the horizontal well key well point is measured according to the weighted average of the surrounding straight wells effective thickness.

(3) Other parameters are the actual values of Z oil field, the effective porosity is 19%, the oil saturation is 65%, the ground crude oil density is 867t/m3, and the crude oil volume coefficient is 1.089.

3.2. The single well control area calculation method
When we use volume method to calculate a single well produced reserve, the control area of a single well is a top priority. At present, there are three calculation methods, the traditional method, the traditional triangular network method and the Delaunay triangular network method.

The single-well Delaunay triangular grid can make full use of the original well point data to obtain the most accurate geological reserves. Therefore, this study uses the Delaunay triangular network method to calculate the control area of a single well.
Table 1. Comparison of single well control area calculation methods

|                                | Traditional Method                                      | Traditional triangular network method                  | Delaunay triangular network method                  |
|--------------------------------|--------------------------------------------------------|-------------------------------------------------------|-----------------------------------------------------|
| Single well control area       | The total area of the block/the well number of the block| The half of the well distance is produced as the control radius of a single well | The Delaunay triangle boundary serves as a single well control boundary |
| Effective thickness and single storage coefficient | Average.                                               | The well point value                                   | Each well is weighed against the surrounding well, weighted average |
| Advantages and disadvantages   | The precision of blocks with relatively dense well points and large sand body development scale is high, and the regional precision is low with less wells and smaller sand. | The calculated single well control area is not accurate enough. | The quality of single well Delaunay triangular grid is high, because it can make maximum use of the original well data |

The step of the Delaunay triangle network method (Lawson): at first we find the largest triangle in all points, the largest triangle contains all the points inside, in the second we insert all the scatter points, in the third we remove the common edges that affect the triangle in the block, at last we connect the triangle vertices which are inserted into the scatter. That is the process of inserting the scatter points into the Delaunay triangle chain table.

According to the actual oil and water well position in Z oil field, the oil area of the straight well is the area of the triangle mid-point in the triangle network. It can be regarded as the area of the surrounding four-way shape, and its calculation method is:

\[
S_i = \sqrt{(p - a)(p - b)(p - c)(p - d) - abcd\cos^2\alpha} \quad (1)
\]

Parameters: \(\alpha = \frac{1}{2}(\angle A + \angle C) = \frac{1}{2}(\angle B + \angle D)\).  

Then we get the oil area of the straight well:

\[
S = \sum_{i=1}^{n} S_i
\]

Parameters: \(S\) is the oil area of the straight well, \(n\) is the number of triangles around the straight well.

3.3. The produced reserve calculation method of single well

3.3.1. The impact of well types on the produced reserves for a single well. When we calculate the reserves by using volume method, the control oil area of each well can be determined according to the distance between two wells, and then the geological reserves can be calculated. The control oil area of horizontal well is determined by weighing the area method for the well point, according to the virtual well point position of the horizontal well, we circle the control oil area of each virtual well point, and then obtain the geological reserves of each virtual well point, and the sum is the geological reserve of each horizontal well.

3.3.2. The impact of boundaries and faults on the produced reserves for a single well. If there is no fault and well area boundary around the well, the straight well uses the Delaunay triangle mid-hanging line as the boundary of the single well control oil area, and limits the maximum distance between the well
point and the surrounding triangular center in 150m. In the case of faults and well area boundaries around wells, if the well distance from the fault or the boundary is less than 150m, the fault and the boundary is used as a single well control oil area boundary. Extra pushes as a control oil boundary if the distance is longer than 150m.

3.3.3. The principle of reserve division between oil and water wells. The division of reserves between oil and water wells is mainly affected by the connection and the distance between wells. First of all, we judge the oil well connectivity, if the oil well layer is connected with the close water well. If the oil well layer is connected, then the reserves of the water well in that layer split into the oil well should be smaller than the produced reserves of the oil well layer.

P reservoir in the Z oil field is poor, not continuous, many sand bodies are stripes. According to the above-mentioned reserves split method, in case of the poor sand body or fault blocking, the oil and water wells will be unconnected, if we directly according to the triangle to divide the area, the divided reserves will be small. The solution is to split half of the uncombed reserves of the wells.

3.3.4. The impact of the production method on the produced reserves for a single well. If the horizontal well is perforated, the main factors are the position and length of the perforation segment. The reserves of the perforated horizontal section are produced, the reserves of the unperforated horizontal segment cannot be produced, so the produced reserves of the perforated horizontal wells are less than their geological reserves.

If the horizontal well is cracked, the main factors are fracking positions and fracking layers. Because the single well drilling sandstone thickness in P oil layer is less than 1-14m, the average single well drilling sandstone thickness is 6.0m, the cracked seam height is generally higher than 10m, so all layers are cracked and all layers are produced. When we calculate the produced reserves of the cracked horizontal wells, their produced reserves are close to their geological reserves.

4. The results of the single wells and the blocks

4.1. The software computing ideas

The reserve calculation software is compiled by the C++, and it can calculate the single-well produced reserve, the single-well geological reserve and single-well water flooding controlled reserve automatically. The program can import the single well position, fault, horizontal well and straight well data, its file format is compatible with oil field database files, and it can check the data integrity and rationality to ensure the efficiency and accuracy of software applications.

4.2. The produced reserves calculations of the blocks and single well

The calculation results of geological reserves, production reserves and water flooding control reserves of 88 horizontal wells are given by using the software of single well production reserves calculation. So do the calculation results of 794 single well reserves in Z oilfield. Then the geological reserves, produced reserves and water flooding control reserves of the joint development block of the Z oil field are obtained.

|                     | Geological reserves (10^4t) | Produced reserves (10^4t) | Water flooding controlled reserves (10^4t) | Level of Reserves utilization (%) | Level of Water flooding controlled reserves (%) |
|---------------------|----------------------------|--------------------------|------------------------------------------|----------------------------------|-----------------------------------------------|
| Straight wells      | 827.26                     | 819.02                   | 691.22                                   | 99.00                            | 83.56                                         |
| Horizontal wells    | 876.49                     | 736.83                   | 630.31                                   | 84.07                            | 71.91                                         |
| All                 | 1703.75                    | 1555.85                  | 1321.53                                  | 91.32                            | 77.57                                         |

Table 2. The results of the calculation
5. Conclusion

(1) Z oil field is a continuous development oilfield, so it is not appropriate to use water flooding characteristic curve method. The parameters required for numerical simulation method are uncertain and the historical fit has multiple solutions, so it is not applicable, too. And the production reduction method is applicable to oil and gas fields that have entered the decreasing stage and have a long decreasing history, so it is not applicable to the research blocks. Therefore, the volume method is preferred to calculate the produced reserves.

(2) When using volume method for reserve calculation, we should consider the effect of well types, boundaries and faults and production method on the calculation of produced reserves for a single well.

(3) In the case of poor sand bodies or faults resulting in unconnected between oil wells and water wells, one half of the reserves of the water wells that have not been properly split shall be divided into the oil wells which are connected.

References

[1] Geng Na, Miu feifei, Liu Xiaohong, etc. Study on the calculation method of water flooding reserve utilization [J]. Broken oil and gas fields. 2014, 4.

[2] Chang Liyan, Li Yaqiong. The calculation method and software design of the recoverable reserves of the reservoir [J]. Broken oil and gas fields. 2015. 2.

[3] Chen Yuanqian. Methods for calculating the recoverable reserves of oil fields. Xinjiang petroleum geology [J]. 2000, 2.

[4] Yu Runtao, Liu Jiyu, Liang Donghe. Calculation of Oil and Gas Reserves by Triangle Network [J]. Journal of Daqing Petroleum Institute. 2004, 10.

[5] Tang Rui, Li Juhua, Tao Shizeng, etc. Analysis of several common methods of production decline in oil and gas wells [J]. Guangdong Chemical. 2013, 11.