Study on determination method of economic limit water cut of water drive oilfield in ultra-high water cut stage

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Abstract. According to the waterflooding characteristics in extra-high water cut stage of oilfield, a calculation model which is based on profit and loss balance principle has been created. This model can be used to identify the economic limit water cut of producers with different cost component. With the use of this model, the economic limit water cut in a development block of Daqing Oilfield with different oil prices has been calculated, and according to the economic benefit, producers have been classified into different group. This model is a significant basis of well shut-in and oil-field development.

Keywords: waterflooding, economic benefit, breakeven, water cut.

1. Introduction
At present, Daqing LaSaXing oilfield has entered into the period of ultra-high water cut. With the increasing water cut of the oilfield, the development investment and production cost are also increasing. In order to maximize the development benefits of the oilfield, the production wells without economic benefits should be shut down in time, so it is necessary to determine the shut in limit. It is generally believed that when the water cut of oil well reaches 98%, there will be no economic benefit, which is just a general concept. The economic limit water cut of oil field should be determined according to the specific production, investment and operation environment of the oil field. Different oil fields have different economic limit water cut in different periods.

According to the principle of profit and loss balance, this paper establishes the calculation model of economic limit water cut of oil wells with different cost composition, which provides important decision basis for determining the well shut in limit and guiding the economic and effective development of oil fields [1-4]

2. Establish economic limit water cut model
The so-called economic limit water cut refers to that when the water cut of an oil well reaches a certain value at a certain stage, the input and output are equal. As the water cut continues to rise, the production of an oil field is not only unprofitable, but also loss. At this time, the water cut of oil well is called economic limit water cut [5-8].
2.1. Fundamentals

According to the principle of economic profit and loss balance, the profit and loss balance point can be determined through profit and loss analysis. For an oil field or block, the profit and loss balance point can be reflected by determining the economic limit water cut of the oil well. The economic limit water cut is the water cut of the oil well when the income is equal to the investment [9-13].

The revenue of the oilfield is the after tax revenue of crude oil sales:

\[ R = P \cdot Q \cdot (1 - f_w) \cdot (P - R) \]  

In formula (1): 
- \( s \)-sales revenue, yuan;
- \( \alpha \)- commodity rate of crude oil, \( \% \);
- \( \tau \)- well opening rate, decimal;
- \( Q_L \)- daily liquid production;
- \( f_w \)- moisture content, \( \% \);
- \( P \)- sales price of crude oil, yuan /t;
- \( R \)-ton oil tax, yuan /t.

Profits of the field:

\[ I = S - C \]  

In formula (2):
- \( I \)-oilfield profit, yuan;
- \( C \)-oilfield cost, yuan.

When the operation of the oil field reaches the balance of profit and loss, the profit of the oil field is 0. At this time:

\[ S = C \]  

2.2. Model building

In the actual production of oil field, it is customary to divide the cost into total cost, production cost and operation cost[14-16]. The total cost refers to the total cost of oil and gas production during the operation period of the oil and gas development and construction project, which consists of production cost and period cost, including oil and gas operation cost and depreciation depletion. Operation cost refers to the expenses incurred in the operation and maintenance of oil and water wells and the production and operation of relevant equipment and facilities, including the direct material cost, well logging and testing cost, direct personnel cost, maintenance and repair cost, factory and mine management cost and the direct fuel cost, direct power cost, oil displacement material injection cost, downhole operation cost, oil and gas treatment cost and natural gas purification cost Fees and transportation fees. Depreciation and depletion expense is the compensation expense withdrawn to compensate the value loss of oil and gas assets in the production process. Period expenses include management expenses, financial expenses, operating expenses and exploration expenses.

Therefore, considering different cost components, different economic limit water cut can be obtained. When only the operation cost is considered, the economic limit water cut model 1 is obtained as follows:

\[ f_{wa} = 1 - \frac{C_C}{365 \cdot \alpha \cdot \tau \cdot Q_L \cdot (P - R)} \]  

In formula (4):
- \( f_{wa} \)-Considering the economic limit water content under the operating cost, decimal;
- \( C_C \)-Operating cost, yuan.

When considering the production cost, the economic limit water cut model 2 is obtained as follows:

\[ f_{wb} = 1 - \frac{C_C + C_Z}{365 \cdot \alpha \cdot \tau \cdot Q_L \cdot (P - R)} \]  

In formula (5):
- \( f_{wb} \)- economic limit water content under production cost, decimal;
- \( C_Z \)-depreciation depletion, yuan.
Considering the total cost, the economic limit water cut model 3 is obtained as follows:

$$f_{wc} = 1 - \frac{C_c + C_L + C_f}{365 \cdot \alpha \cdot \sigma \cdot Q_c \cdot (P - R)}$$  \hspace{1cm} (6)

In equation (6):
- \(f_{wa}\)- the economic limit water content under the total cost is considered, decimal;
- \(C_f\) - period expense, yuan.

3. Example calculation

Taking a block in Daqing as an example, the economic limit water cut of different cost components under different oil prices in 2010 is calculated. Relevant parameters of the block include: operating cost per ton of liquid 31.1 yuan / T, liquid production 71.12t/d, commodity rate of crude oil 98.23%, well opening rate 0.78, actual sales price of crude oil 3180 yuan / T, tax per ton of oil 123.35 yuan / T, depreciation loss 332000 yuan / well, period expense 275000 yuan / well.

There is a certain functional relationship between the operating cost per ton of liquid and the daily liquid production of a single well. The functional relationship between the operating cost per ton of liquid and the daily liquid production of a single well is obtained by fitting the actual data of the oilfield, as shown in Figure 1. Through calculation, the change of economic limit water content with liquid production under different cost components under different oil prices is obtained, as shown in figure 2-figure 4.

![Figure 1. Relation curve between liquid production and operating cost per ton of liquid](image1)

![Figure 2. Relation curve between liquid production and economic limit water content of model 1](image2)
It can be seen that with the increase of daily liquid production and oil price of a single well, the economic limit water cut is also gradually increased. Considering the operating cost, the economic limit water cut is 99.94%, considering the production cost, the economic limit water cut is 99.39%, considering the total cost, the economic limit water cut is 98.94%.

According to the relationship between income and different costs, the economic benefits of production wells can be reflected: after tax income total cost > 0 is benefit class I well; after tax income production cost > 0 is benefit class II well; after tax income operation cost > 0 is benefit class III well; after tax income operation cost ≤ 0 is non benefit class well. Therefore, the classification of production wells can be determined by the water cut of production wells. See Table 1 for the classification of production wells in this block.

**Table 1. Classification of oil well economic benefits**

| Benefit Category         | Number of wells | Annual oil production |
|--------------------------|-----------------|-----------------------|
|                          |                 | Kou                   | Proportion (%) | 10,000 tons | Proportion (%) |
| Benefit class I          | 296             | 75.51                 | 39.32          | 96.92       |
| Benefit class II         | 10              | 2.55                  | 0.25           | 0.62        |
| Three types of benefits  | 44              | 11.22                 | 0.73           | 1.8         |
| No benefit               | 42              | 10.72                 | 0.27           | 0.66        |
| total                    | 392             | 100                   | 40.57          | 100         |
4. Conclusion

(1) The economic limit water content changes with the change of oil price and liquid production. The higher the oil price, the higher the economic limit water content, the higher the liquid production, the higher the economic limit water content.

(2) The economic limit water cut of oil wells is a dynamic index. It should be adjusted in time according to the production, investment and operation environment, take measures to increase the economic limit water cut of oil wells, actively formulate specific control measures for all kinds of invalid wells, reduce the number of invalid wells and improve the economic benefits of oil field development.

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