A method for predicting fracturing productivity

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Abstract. With the development of oil field, it enters the period of super high water cut and measuring well selection is becoming more and more difficult. In order to forecast well productivity more scientific and reasonable after fracturing, this paper presents a method of predicting production after fracturing (factor analysis-formula deduction-instance validation). Its basic idea is that, firstly analysing all factors affecting fracturing productivity, and then using the orthogonal design method to quantify the main factors according to the influence weight, again fitting production forecasting out formulas after fracturing according to the score situation by a statistical principle, finally production forecasting formulas for instance analysis to verify its rationality. The results of the research results show that the prediction method can basically accurately predict the productivity after fracturing and can effectively meet the needs of oilfield development, and provide a reliable theoretical basis for well selection and formation selection in fracturing plan.

1. Introduction
With the development of oil field, it enters an ultra-high water cut period and it is becoming more and more difficult to select wells with measures. In order to predict the productivity of wells after fracturing more scientifically and more reasonably, this paper puts forward a method to predict the productivity after fracturing, which provides a technical reference for well selection after fracturing.

2. Analysis the influencing factors of fracturing effect
The affects to the fracturing effect of oil wells geological factors, we consider the sandstone thickness of fracturing layer, moisture content, permeability, production pressure difference, surface factor, and analyze vaguely. Quantitative limits of various influence factors are given under the condition that oil well is suitable for fracturing. According to the results of the analysis, we determine the effects on the fracturing effect of several factors, and study the factors affecting the evaluation of this relative importance and the corresponding optimal value range using the orthogonal design method[1].

2.1. Single factor analysis
Considering the special position of water cut in oilfield development, we first analyze the influence of water on the fracturing effect. The results and proportions of water cut before fracturing and oil increase in the early stage after fracturing were statistically analyzed in 281 fractured wells in the past years.

The water cut evaluation matrix was obtained by statistical analysis.
According to the experience, the weight distribution matrix under different oil increment conditions is:

\[ A = \begin{bmatrix} 0.8 & 0.5 & 0.2 \end{bmatrix} \]

According to the weighted average method, \( B \) values in different water content ranges can be obtained. When \( B \) is the maximum, it is the most appropriate water cut of fracturing formation. \( B \) represents the comprehensive evaluation result of the influence of water cut in fracturing layer on the initial oil increase effect[2].

\[
B' = A \times R
\]

(2)

\[
B_i = B' / \sum_{j=1}^{3} r_{ji}
\]

(3)

Table 1. Water content classification table

| Rate of water (%) | \(<=85\%\) | 85~90% | 90~95% | \(>=95\%\) |
|------------------|-----------|-------|-------|----------|
| Bi               | B1        | B2    | B3    | B4       |
| Values           | 0.546     | 0.507 | 0.416 | 0.365    |

From Table 1 we can see, it is the maximum when \( B_1 \) is 0.546. It is concluded that the best range of water content is less than 85%. The values of \( B \) fluctuate obviously in the different water content range, therefore, it can be considered that water content has a great influence on the fracturing effect.

The same method is used for fuzzy analysis of sandstone thickness, permeability and production pressure difference. The analysis results show that four factors, such as water cut, sandstone thickness, permeability and production pressure difference, have great influence on fracturing effect of oil well[3].

2.2. Multiple factors analysis

In order to further study the relative importance of each influencing factor of fracturing effect, we use the orthogonal design method to carry out the multi-factor synthesis analysis. Considering a total of four factors have a greater impact on the fracturing effect, we choose \( L_{25} \left( 5^4 \right) \) orthogonal table to arrange the experiment. According to the analysis above, we consider that the following table can be used as the level number of each factor in the orthogonal test[4].

Table 2. \( L_{25} \left( 5^4 \right) \) factor and corresponding level number

| Rate of water % | 80.8 | 84.3 | 89.3 | 92.1 | 96.4 |
|----------------|------|------|------|------|------|
| Sandstone thickness m | 8.4  | 11.5 | 13.8 | 16.6 | 21.5 |
| Production pressure differential Mpa | 4.06 | 5.93 | 6.82 | 7.44 | 8.95 |
| Permeability \( \mu \text{m}^2 \) | 0.094 | 0.166 | 0.223 | 0.307 | 0.475 |

Thus the orthogonal test is arranged, we can see the test results and the corresponding range analysis results from Table 3.

Table 3. Test results

| Test plan | Rate of water(%) | Sandstone thickness (m) | Production pressure differential (MPa) | Permeability \( (\mu \text{m}^2) \) | Increases in oil per well(t/d) |
|-----------|------------------|-------------------------|---------------------------------------|----------------------------------|-------------------------------|
| 1         | 80.8             | 8.4                     | 4.06                                  | 0.094                            | 4.56                          |
| 2         | 80.8             | 11.5                    | 5.93                                  | 0.166                            | 5.01                          |
In the table 3, $M_{ij} = \text{The sum of the column } j \text{ level of No. } i \text{ increases in oil per well, } i=1,2,3,4,5; j=1,2,3,4.$

$$m_{ij} = M_{ij} / 5$$ \hfill (4)

$$R_j = \max \{m_{ij}\} - \min \{m_{ij}\}$$ \hfill (5)

$$W_j = \frac{R_j}{\sum_{i=1}^{5} R_j}$$ \hfill (6)

Through the multi-factor range analysis, combined with the results of the single factor analysis, the following understanding is finally obtained: To achieve better fracturing effect, the relative weight and optimal value range of the four main factors affecting fracturing effect are:

**Table 4. Reasonable value range and weight table of factors affecting fracturing effect**

| classification | Rate of water (%) | Sandstone thickness (m) | Production pressure differential (Mpa) | Permeability ($\mu$m²) |
|----------------|------------------|-------------------------|----------------------------------------|------------------------|
| Optimum range  | <80.8            | >21.5                   | >6.95                                  | 0.15 – 0.3             |
| Relative weights % | 26.95        | 29.34                   | 23.48                                  | 20.23                  |

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3. The derivation of single well fracturing effect prediction formula

Using a dimensionless function value (taking the factors affecting the fracturing effect as independent variables) to evaluate the ideal degree of the fracturing effect of a single well. As long as the corresponding parameter value is given, we can judge whether the well has fracturing value through calculation. Based on the above ideas, we made the following analysis:

Considering that we have known the relative weight of the four factors affecting fracturing effect and the corresponding optimal value range of each factor, and the value of each factor has little influence on the change of other factors, the four factors can be considered as irrelevant factors. In other words, when the optimal values of all four factors are achieved at the same time, the well can achieve the optimal fracturing results. If the fracturing parameter variable of a single well is compared with the optimal value, the comprehensive evaluation value of fracturing effect of each well can be obtained[5].

Based on the above considerations, we can come to the conclusion:

\[
E_j = \frac{Y_u - Y_1}{Y_1} \times X_1 + \frac{Y_2 - Y_2}{Y_2} \times X_2 + \frac{Y_3 - Y_3}{Y_3} \times X_3 + \frac{Y_4 - Y_4}{Y_4} \times X_4
\]  

(7)

The formula above is the comprehensive evaluation formula of single well fracturing effect, Combined with the fracturing parameter data provided in Table 4, the constants in Equation (1) can be obtained in table 5.

| X1=26.95 | X2=29.34 | X3=23.48 | X4=20.23 |
|----------|----------|----------|----------|
| Y1=80.8  | Y2=21.5  | Y3=6.95  | Y4=0.22  |

4. Examples analysis

In order to fully test the accuracy of the prediction formula, we substituted all four fracturing parameters of 47 fractured wells in the block into formula (2) to obtain the predicted fracturing effect E value of each well, and then compared the relationship between E value and oil increase.

As can be seen from the result, 80% of the fractured wells were in line with the trend of increasing oil production with the increase of E value. Therefore, it can be concluded that the lower E value is, the more conducive to achieving ideal fracturing effect.

The comprehensive evaluation formula for expected fracturing effect is verified, and the results show that the formula can basically accurately predict the fracturing effect of producing wells, and can meet the requirements of fracturing well selection and formation selection in the ultra-high water cut period, which provides reliable data support for judging whether the producing wells have the conditions for fracturing production.

According to the application of the conclusions above to the principle of well selection of fractured wells in 2020, 15 wells are selected as the optimal measures, 13 of which have been implemented so far, with a daily fluid increase of 422t and oil increase of 63.1t. The comprehensive water cut has decreased by 5.97 percentage points, and the cumulative oil increase of 6892t has reached a good level.

5. Conclusion

(1) It is scientific and reasonable to use the combination of fuzzy comprehensive evaluation and orthogonal design test to comprehensively analyze the influencing factors of fracturing effect.

(2) The method of "factor analysis-formula deduction-instance validation" described in this paper can predict the fracturing productivity of a single well relatively accurately.
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