Application of Fuzzy Mathematics Evaluation Method in Prediction of Comprehensive Efficiency of Low Efficiency Oil Wells

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Abstract. In the process of oilfield development, due to long-term continuous mining and changes in geological conditions, oil-inefficient wells will be gradually produced. This phenomenon is unavoidable. How to optimize the low-efficiency oil wells with comprehensive mining potential according to the actual development situation, so as to achieve effective treatment of low-efficiency oil wells, this approach is of great significance to ensure and improve the overall economic benefits of the oilfield. In this paper, the fuzzy mathematics method and the statistical weighting theory are used for comprehensive analysis. The weight of the evaluation index is predicted by determining the comprehensive adjustment potential of the low-efficiency oil well, and then the low-efficiency oil well comprehensive adjustment potential prediction evaluation model and method are established, and then the practical application is carried out. The method can provide a basis for judging the comprehensive adjustment measures for the development of low-efficiency oil wells in oil fields.

Keywords. Fuzzy mathematics evaluation method, Low efficiency oil well, Comprehensive adjustment.

1. Introduction

T oilfield is a low-permeability complex fault block reservoir with complex geological conditions. Although it can obtain higher yield at the initial stage of production, due to the contradiction of water injection development, some oil wells begin to be inefficient or unproductive, and the T-field low-efficiency oil well has reached About 35.7%, this part of the well should be effectively integrated and developed as soon as possible to improve the overall development benefits of the oilfield [1-3]. Most of the potential evaluation methods are now qualitative descriptions, and the evaluation results depend to a large extent on the evaluator's work experience. In order to realize the quantitative evaluation of the development potential of low-efficiency oil well reuse, an evaluation index "inefficient oil well comprehensive adjustment potential index" was introduced to characterize the comprehensive adjustment potential of low-efficiency oil wells, and the comprehensive adjustment potential evaluation of low-efficiency oil wells was constructed. The indicator system determines the value of the potential index. One of the key technical challenges in the predictive evaluation of the adjustment potential of inefficient oil wells is the determination of the weight of the indicators. Since an indicator system...
contains multiple indicators, there are several times, and there are light and heavy. In order to ensure the accuracy of quantitative analysis and evaluation, it is necessary to assign corresponding weights to the indicators. The expert survey method is simple and easy to operate, and it is easy to operate, so it is widely used. However, this method is often unsatisfactory in terms of scientificity and credibility because it relies entirely on the subjective judgment of experts and has few strict mathematical treatments. The theory of solving matrix in fuzzy mathematics is a better method to solve statistical weighting [4-5].

2. Fuzzy mathematical methods and statistical empowerment

2.1. Indicator empowerment

Typically, an indicator system consists of multiple subsystems, each containing multiple specific metrics. Therefore, the framework of a multi-level indicator system is shown in Figure 1.

![Figure 1. Multi-level indicator system framework](image)

Statistical empowerment first empowers individual metrics within each subsystem and then empowers each subsystem within the large system.

The evaluation factor (indicator) is indicated by \( m_i \), \( m_i \in M_i \) \((i = 1, 2, L, n)\). First, consider comparing the indicators in the set, \( m_i \) and two, to determine the importance of each other. The importance of index comparison sets the closed interval \([1, 5]\) as a scale to reflect. If \( m_i \) is equivalent to \( m_j \), it is 1; if \( m_i \) is extremely important, it can be 5. Within 1 to 5, the larger the value, the higher the importance of one indicator than the other; the smaller the value, the lower the importance of one indicator than the other. This value can be called the judgment coefficient of the indicator.

![Figure 2. Inefficient oil well comprehensive adjustment measurement](image)
The specific indicators in the system are compared and fixed without exception, R and a judgment matrix composed of judgment coefficients can be obtained.

\[
R = \begin{bmatrix}
  m_{11} & m_{12} & L & m_{1n} \\
  m_{21} & m_{22} & L & m_{2n} \\
  L & L & L & L \\
m_{n1} & m_{n2} & L & m_{nn}
\end{bmatrix}
\] (1)

The middle \( m_{ij} \) represents the judgment coefficient of 111 compared with \( m_j \). If \( m_i \) is compared with \( m_{ji} = 1/m_{ij} \) is obtained.

Imagine that if the coefficient in the estimate is correct, then there should be R.

\[
RW = \begin{bmatrix}
  m_{11} & m_{12} & L & m_{1n} \\
  m_{21} & m_{22} & L & m_{2n} \\
  L & L & L & L \\
m_{n1} & m_{n2} & L & m_{nn}
\end{bmatrix} \begin{bmatrix}
w_1 \\
w_2 \\
L \\
w_n
\end{bmatrix} = \lambda \begin{bmatrix}
w_1 \\
w_2 \\
L \\
w_n
\end{bmatrix}
\] (2)

That is, the feature vector of \( W = (w_1 \ w_2 \ L \ w_n)' \) is. Usually, each component of the feature vector \( W = \left( \sum_{i=1}^{n} w_i = 1 \right) \) corresponding to the largest feature root is taken as the weight of each index in the system. In practice, for the convenience of operation, the geometric mean method is commonly used to process the feature vector. The specific approach is R:

(1) The components will be multiplied by row, and the geometric mean is obtained to obtain an n-dimensional column vector \( \left( \overline{w_1}, \overline{w_2}, L, \overline{w_n} \right)' \).

\[
\overline{W_i} = \sqrt[n]{\prod_{j=1}^{n} m_{ij}}
\] (3)

(2) The weight vector is obtained by dividing each of the obtained n-dimensional vectors by the sum of the components.

In order to analyze the rationality and reliability of the weight distribution, fuzzy mathematics provides a method for consistency checking of R. The formula used is

\[
CR = CI / RI
\] (4)

\[
CI = (\lambda_{max} - n) / (n - 1)
\] (5)

Where CI is the general indicator of the judgment matrix R;

RI-the random consistency indicator of the judgment matrix R, which can be found by the RI value table
\[ \lambda_{\text{max}} = \frac{1}{n} \sum_{i=1}^{n} \left( RW \right)_i \] (6)

When CR is less than 0.1, R can be considered to have better consistency, indicating that the weighting is reasonable; otherwise, the judgment matrix needs to be adjusted until a satisfactory consistency index is obtained.

### 3. Subsystem empowerment

After assigning weights to specific indicators in the subsystem, each subsystem can be empowered under a large system. At this time, each subsystem as a project can be treated as a comprehensive indicator, and they are compared in pairs to determine the importance of each other, and a judgment matrix \( R' \) can also be constructed.

\[
R' = \begin{bmatrix}
p_{11} & p_{12} & L & p_{1n} \\
p_{21} & p_{22} & L & p_{2n} \\
L & L & L & L \\
p_{n1} & p_{n2} & L & p_{nn}
\end{bmatrix}
\] (7)

For \( R' \), the eigenvector can be obtained by the previous geometric averaging method, and the test index of the rationality is the same as described above.

The statistical empowerment of the indicator system first empowers the indicator and then empowers the subsystem. The weight of the indicator is for the subsystem and the weight of the subsystem is for the total system. If the weights of the indicators are multiplied by the weights of the corresponding subsystems, the weights of the indicators directly to the total system can be obtained. The sum of the weights of all indicators to the total system should be 1.

**Figure 3.** Low-efficiency oil well comprehensive adjustment potential prediction index system

### 4. The application of fuzzy mathematics method weighting

#### 4.1. Establishment of predictive indicator system for comprehensive adjustment potential of low-efficiency oil wells

Through detailed anatomy of the characteristics of 86 low-efficiency oil wells in 241 oil wells in T oilfield, a comprehensive evaluation index system for low-efficiency oil wells is constructed. The selection system consists of 5 subsystems with 7 indicators [6-10], as shown in picture 2.
5. **Determine the weight and value criteria of the evaluation indicators**

5.1. **Determination of weights within the indicator group**

Taking the second subsystem "oil layer condition potential indicator subsystem" as an example, the fuzzy mathematics principle is used to weight two of the indicators.

In the first step, the two indicators in the oil layer condition potential indicator subsystem are compared two-two, and the judgment coefficient matrix reflecting the importance degree is constructed as follows

\[
R = \begin{bmatrix}
1 & 1 \\
1 & 1 \\
\end{bmatrix}
\]  

(8)

In the second step, find the geometric mean of each row in R, and get a column of vectors as follows

\[
(1,1)'
\]  

(9)

In the third step, each component in the obtained column vector is divided by its total number, and the obtained index weight vector is as follows

\[
(0.5, 0.5)'
\]  

(10)

The fourth step is to verify the credibility of the weights.

\[
RW = \begin{bmatrix}
1 & 1 & 0.5 \\
1 & 1 & 0.5 \\
\end{bmatrix} = \begin{bmatrix}
1 \\
1 \\
\end{bmatrix}
\]  

(11)

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![Figure 4](image-url)
Then \( \lambda_{\text{max}} = \frac{1}{\sum_{i=1}^{n} \left( \frac{RW_i}{w_i} \right)} = \frac{1}{2 \left( \frac{1}{0.5} + \frac{1}{0.5} \right)} = 2 \) \hspace{1cm} (12)

\( CI = (\lambda_{\text{max}} - n) / (n - 1) = (2 - 2) / (2 - 1) = 0 \) \hspace{1cm} (13)

Looking up the table RI = 0, which indicates that the weight assigned to the oil layer condition potential indicator subsystem has a high degree of credibility and can be used in practice.

5.2. Determination of subsystem weight
In the first step, the five potential indicator subsystems in the evaluation system are compared two by two, and the judgment coefficient matrix reflecting the importance degree is constructed as follows

\[
R' = \begin{bmatrix}
1 & 4 & 2 & 2 & 4 \\
0.25 & 1 & 0.5 & 0.5 & 1 \\
0.5 & 2 & 1 & 1 & 2 \\
0.5 & 2 & 1 & 1 & 2 \\
0.25 & 1 & 0.5 & 0.5 & 1
\end{bmatrix}
\] \hspace{1cm} (14)

The second step is to find the geometric mean of each row, and get a column of vectors as follows

\[
(2.2974, 0.5743, 1.1487, 1.1487, 0.5743)'
\] \hspace{1cm} (15)

In the third step, each component in the obtained column vector is divided by its total number, and the obtained index weight vector is as follows

\[
(0.4, 0.1, 0.2, 0.2, 0.1)'
\] \hspace{1cm} (16)

The fourth step is to verify the credibility of the weights.

\[
RW = \begin{bmatrix}
1 & 4 & 2 & 2 & 4 & 0.4 \\
0.25 & 1 & 0.5 & 0.5 & 1 & 0.1 \\
0.5 & 2 & 1 & 1 & 2 & 0.2 \\
0.5 & 2 & 1 & 1 & 2 & 0.2 \\
0.25 & 1 & 0.5 & 0.5 & 1 & 0.1
\end{bmatrix}
\] \hspace{1cm} (17)

then \( \lambda_{\text{max}} = \frac{1}{\sum_{i=1}^{n} \left( \frac{RW_i}{w_i} \right)} = \frac{1}{5 \left( \frac{2}{0.4} + \frac{0.5}{0.1} + \frac{1}{0.2} + \frac{1}{0.2} + \frac{0.5}{0.1} \right)} = 5 \) \hspace{1cm} (18)

\( CI = (\lambda_{\text{max}} - n) / (n - 1) = (5 - 5) / (5 - 1) = 0 \) \hspace{1cm} (19)

Look up the table, RI=1.12, then CR=CI/RI=0<0.1, which indicates that the weight assigned to the subsystem group weight has higher credibility and can be used in practice.
By multiplying the weights in the indicator group by the weights of the corresponding subsystems, the comprehensive weights of the indicators directly to the total system can be obtained. For example, the comprehensive weight of the total effective thickness without dimension is 0.5*0.1=0.05. As shown in the above method, the comprehensive weights and index values of each indicator in the low-efficiency oil well comprehensive adjustment potential evaluation index system are given, as shown in Table 1.

**Table 1.** Weights and value criteria for evaluation index of comprehensive adjustment potential of low-efficiency oil wells

| Grouping | Group weight | Evaluation index | Group weight | Comprehensive weight | Evaluation method |
|----------|--------------|------------------|--------------|----------------------|-------------------|
| A₁       | 0.4          | A₁₁              | 1            | 0.4                  | $A_{11} = \frac{R_M}{R_Q}$ |
|          |              | A₂₁              | 0.5          | 0.05                 | $A_{21} = \frac{H_M}{H_Q}$ |
| A₂       | 0.1          | A₂₂              | 0.5          | 0.05                 | $A_{22} = \frac{h_M}{h_Q}$ |
| A₃       | 0.2          | A₃₁              | 1            | 0.2                  | $A_{31} = \frac{E_M}{E_Q}$ |
| A₄       | 0.2          | A₄₁              | 1            | 0.2                  | $A_{41} = \frac{J_M}{J_Q}$ |
| A₅       | 0.1          | A₅₁              | 0.3          | 0.03                 | $A_{51}=0$ when there is damage to the facility caused by accidents such as falling accidents and no damage or repair A₅₁=1 When the above measures are not used, A₅₂=0 |
|          |              | A₅₂              | 0.7          | 0.07                 | $A_{52}=0$ when there is damage to the facility caused by accidents such as falling accidents and no damage or repair A₅₂=0 |

$R_M$ in the table-the remaining geological reserves of the target well, t;  
$R_Q$-the largest single well residual geological reserve of the fault block of the target well being evaluated, t;  
$H_M$-total effective thickness of oil-bearing sandstone of the target well, m;  
$H_Q$-the total effective thickness of the largest single well oil-bearing sandstone in the fault block where the target well is located, m;  
$h_M$-the average single layer effective thickness of the target well, m;  
$h_Q$-the maximum effective average thickness of a single well in the fault block where the target well is located, m.  
$E_M$-the degree of water drive control of the target well, %;  
$E_Q$-the maximum degree of water flood control in the fault block where the target well is located, %.  
$J_M$-the specific production index of the target well;  
$J_Q$-The maximum single well specific oil production index of the fault block where the target well is located.
5.3. Characterization of the comprehensive adjustment potential index of low-efficiency oil wells

Using the actual data of the T oilfield, refer to the standard of Table 1 for the value, and calculate a value that reflects the comprehensive adjustment potential of the inefficient well, based on the cumulative, which is the low-efficiency well comprehensive adjustment potential index QL.

\[ QL = w_{11}A_{11} + w_{21}A_{21} + w_{22}A_{22} + w_{31}A_{31} + w_{41}A_{41} + w_{51}A_{51} + w_{52}A_{52} \]  (20)

In the formula \( A_{11}, A_{21}, A_{22}, A_{31}, A_{41}, A_{51}, A_{52} \) - respectively for each evaluation index \( w_{11}, w_{21}, w_{22}, w_{31}, w_{41}, w_{51}, w_{52} \) - Comprehensive weight.

The comprehensive adjustment potential of low-efficiency oil wells ranges from 0 to 1. The larger the value, the greater the development and adjustment potential of the target wells being evaluated.

5.4. Evaluation results of comprehensive adjustment potential of low-efficiency oil wells

As of December 2018, T oilfield has 89 low-efficiency oil wells. The low-efficiency oil well comprehensive adjustment potential prediction model established above is used to calculate the oilfield, and the low-efficiency oil well with comprehensive adjustment potential is selected.

According to the prediction results of low-efficiency oil wells in T oilfield and combined with field experience, the comprehensive adjustment potential of low-efficiency oil wells in the oilfield is determined: \( QL \geq 0.75 \), which is classified as Class I potential wells, and its comprehensive adjustment potential is large; \( 0.5 \leq QL < 0.75 \), For Class II potential wells, its comprehensive adjustment potential is relatively large; \( QL < 0.5 \) is a Class III well with a small comprehensive adjustment potential. Based on the above principles and the analysis of the comprehensive adjustment potential index of each low-efficiency oil well, it is estimated that there are 19 Class I wells, 17 Class II wells and 53 Class III wells. It provides a certain selection basis for inefficient oil well treatment and comprehensive adjustment measures.

Considering the impact of oil price and related measures cost and other factors of comprehensive adjustment potential of low-efficiency oil wells, it is preferred to have 17 low-efficiency oil wells with the most comprehensive adjustment potential in T井 in 2019. So far, 10 of them have taken corresponding measures. Governance, the average daily oil increase was 2.15t, and the input-output ratio reached 1:5, which achieved good economic benefits.

6. Conclusion

(1) Applying fuzzy mathematics method and statistical weighting theory, comprehensively considering the multi-factors such as geology, development and ground engineering, the comprehensive potential prediction and evaluation model of low-efficiency oil wells is realized, and the quantitative prediction and evaluation of the comprehensive adjustment potential of low-efficiency oil wells is realized.

(2) The calculation by examples shows that the method has high practicability and can provide decision-making basis for oilfield development adjustment and management.

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