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Evaluating Efficacy of the Separate Layer Water Injection of the Wells by Using Fuzzy Comprehensive Evaluation Method

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Abstract

It can directly reflect the effect of injection wells before and after the layering water injection by evaluating the layering water injection wells. In view of the uncertainties on the impact of various factors of injection well group, it can establish a series of quantitative method which is suitable for the evaluation of well group. Prior to the evaluation of water injection wells group, it is necessary to make evaluation of the existing wells. This study uses the fuzzy comprehensive evaluation method to calculate comprehensive evaluation coefficient of well group to judge the nature of each well group. According to the calculation of the comprehensive evaluation coefficient of E2 which is combined with the actual geological and development condition of Ba fault block 17, it can not only find the increasing relation between E2 values and water injection effect, but also evaluate the effect of water injection well group, which can determine whether symmetry layering water injection is reasonable or not.

Key words: Layering water injection; Quantitative methods; Evaluation; Nature factor; Fuzzy comprehensive evaluation

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INTRODUCTION

Presently, the development of Huabei oilfield has entered a stage of high water cut. The main problems in the development of the oilfield are as follows. The remained recoverable reserves are gradually decreased, and the rising velocity of oilfield water cut further accelerated, comprehensive management is more and more difficult, the implementation effect gradually worse. Therefore, in order to further improve the effect of water flooding, it must take effective measures to enhance oil recovery. Prior to the implementation of enhanced oil recovery measures, it needs to evaluate well conditions of each reservoir and adjust the subdivision of reservoir. Moreover, it is necessary to evaluate the layering water injection. As a result, it can indicate the direction for the next injection interval adjustment measures, provide a scientific basis for oilfield future planning, deployment and fine potential tapping, and guide the economic development of water flooding oilfield effectively.

1. AHP ANALYSIS TO DETERMINE THE EVALUATION INDEX-WEIGHT

Based on the oil increment of oil wells, water absorption ratio of injection well and producing degree of waterflood, it can be compared in pairs. So we could have the judgment matrix p:

$$p=\begin{bmatrix}1 & 0.5 & 0.333\\ 2 & 1 & 0.5\\ 3 & 2 & 1\end{bmatrix}. \tag{1}$$

We can determine the evaluation index-weight by using AHP weights. Then we get the weight value of the above factors is $W = [0.163, 0.297, 0.54]$[1].

2. THE FUZZY COMPREHENSIVE EVALUATION METHOD TO DETERMINE THE PROPERTIES OF WELL GROUP

After determining the weights of each factor, we can use the fuzzy comprehensive evaluation method to calculate comprehensive evaluation coefficient (E2) which can reflect the properties of each well group, and finally determine the properties of well group through suitability degree[2-4].

2.1 Fundamentals of Fuzzy Comprehensive Method

2.1.1 Establish the Factor Set

Factor set is a common collection of various factors affecting the judgment object. Usually it is shown by capital letters U which can be given by:

$$U = \{u_1, u_2, ..., u_n\}. \tag{2}$$

Annotation: the elements u_i (i=1,2,...,n) represent various factors and these factors have various degrees of ambiguity. When we evaluate the nature of small layer, the factor set includes oil increment of oil wells, water absorption ratio and producing degree of waterflood.

m samples need to be classified. It is given by:

$$u_i = (u_{i1}, u_{i2}, ..., u_{im}). \tag{3}$$

Thus, the sample set can be determined by a vague matrix which can describe the characteristics of things. It is denoted as:

$$U = (u_{ij})_{n\times m} \quad (i=1, 2..., n; j=1, 2,..., m). \tag{4}$$

2.1.2 Calculation of the Utility Function

The eigenvalue which describes others should be normalized by using the processing method of utility function. The processing methods are follows:

(a) The bigger he better index. And its calculation formula of the utility function is defined as:

$$b_{ij} = \frac{u_{ij}-(u_{ij})_{\min}}{(u_{ij})_{\max}-(u_{ij})_{\min}}. \tag{5}$$

(b) The smaller the better index. And its calculation formula of the utility function is defined as:

$$b_{ij} = 1- \frac{u_{ij}-(u_{ij})_{\min}}{(u_{ij})_{\max}-(u_{ij})_{\min}}. \tag{6}$$

$(u_{ij})_{\min}$ is the minimum of the i^{th} characteristic of the m sample. $(u_{ij})_{\max}$ is the maximum of the i^{th} characteristics of the m sample.

Thus, the utility function matrix B can be given by:

$$B = [b_{ij}]_{n\times m}. \tag{7}$$

2.2 The Establishment of the Fuzzy Decision Model

According to the index-weight W=[W_1, W_2,..., W_n] and each index of the utility function matrix B which can be got by analytic hierarchy process (AHP). So the comprehensive evaluation coefficient of each sample value follows:

$$E = \sum_{j=1}^{n} W_j b_{ij} \; . \tag{8}$$

In the process of judging the effect of water injection well group, the bigger the comprehensive evaluation coefficient of E2 is, the better the affection water injection well group which indicates that the effect of layered water injection is effective, the smaller the E2 value is, the worse the effect of water injection which shows it needs to be modified the measures to improve the effect of water injection.

2.3 Case Analysis

Taking the Ba fault block 17 as an example, we will analyze the properties of each well array. And then, explaining the application of the fuzzy mathematics comprehensive evaluation method in sublayer predication and the subdivision adjustment.

First, the factors set is established, it includes three factors that are oil increment, water absorption ratio, exploitation degree of water drive, and influence factors of each well array data is showed in Table 1. According to above factors, the membership value of the different influence factors can be obtained through the utility function Formulas (5), (6). By analytic hierarchy process, we can get weights W = [0.163, 0.297, 0.54]. According to fuzzy comprehensive evaluation, the fuzzy transformation is done with weight and membership degree, then we get the comprehensive evaluation coefficient Table 2 through programming. After calculating the comprehensive evaluation coefficient E2 of each sublayer, we put E2 values as abscissa, oil increment of wells as the ordinate and map the trend line which shows the drift of the well changed with the E2 values (Figure 1)[5].

Table 1
Various Influence Factors Data of Each Injection Well Group

Well number	Oil increment of well group after zonal injection (m^3/d)	Water absorption ratio (%)	Producing degree of water flood (%)	Well number	Oil increment of well group after zonal injection (m^3/d)	Water absorption ratio (%)	Producing degree of waterflood (%)
Ba18-2	22.63	0.02265	0.43839	Ba 18-19	19.84	0.00542	0.46527
Ba18-4	19.28	0.0505	0.44053	Ba 18-21	24.85	0.0142	0.46437
Ba18-8	18.18	0.05243	0.41644	Ba 18-23	28.82	0.02474	0.45117
Ba18-11	21.21	0.02739	0.44543	Ba 18-25	17.97	0.06597	0.44998
Ba18-118	18.23	0.13394	0.46161	Ba 18-45	19.61	0.03098	0.45856
Ba 18-126	10.92	0.04309	0.4459	Ba 18-62	24.88	0.01935	0.43587

To be continued

Continued

Well number	Oil increment of well group after zonal injection (m^3/d)	Water absorption ratio (%)	Producing degree of water flood (%)	Well number	Oil increment of well group after zonal injection (m^3/d)	Water absorption ratio (%)	Producing degree of waterflood (%)
Ba 18-133	19.6	0.08733	0.44804	Ba 18-64	21.92	0.03147	0.44913
Ba 18-135	12.97	0.1387	0.44317	Ba 19-6	13.85	0.02403	0.45331
Ba 18-142X	11.7	0.0466	0.45493	Ba 19-30	13.92	0.00243	0.46139
Ba 18-143	17.38	0.07558	0.45564	Ba 19-42	14.89	0.09239	0.45583
Ba 18-155X	17.38	0.06516	0.45674	Ba 20-3	3.07	0.02107	0.45515
Ba 18-16	9.57	0.06674	0.445	Ba 20-5	14.31	0.08965	0.45845
Ba 18-164	22.02	0.22222	0.47107				

Table 2
Comprehensive Evaluation Coefficient of Each Well Group of Ba Fault Block 17

Well number	E2 value	Well number	E2 value
Ba 18-2	0.7424	Ba 18-19	0.78713
Ba 18-4	0.6413	Ba 18-21	0.87777
Ba 18-8	0.5438	Ba 18-23	0.90756
Ba 18-11	0.72729	Ba 18-25	0.62136
Ba 18-118	0.57065	Ba 18-45	0.72813
Ba 18-126	0.49192	Ba 18-62	0.78649
Ba 18-133	0.6212	Ba 18-64	0.74777
Ba 18-135	0.39898	Ba 19-6	0.60096
Ba 18-142X	0.53053	Ba 19-30	0.65539
Ba 18-143	0.61304	Ba 19-42	0.53891
Ba 18-155X	0.63023	Ba 20-3	0.38431
Ba 8-16	0.4293	Ba 20-5	0.53823
Ba 18-164	0.5604		

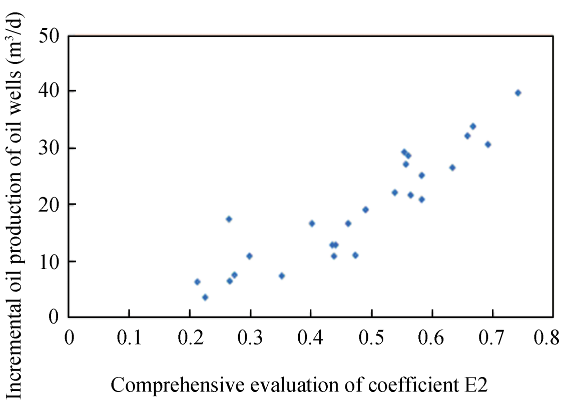

Figure 1
The Relationship Between Comprehensive Evaluation of Coefficient of the Wells Groups E2 and the Incremental Oil Production of Oil Wells

As you can see from Figure 1, with the increasing of E2, there is a growing trend when taking the various influence factors of well group together. We can also consider that the more the factors of each well group were influenced, the better the using condition of small layers, which means the value of E2 is bigger. The E2 values calculated by the fuzzy comprehensive evaluation method can reflect the effect of the separate layer water injection of well groups[6].

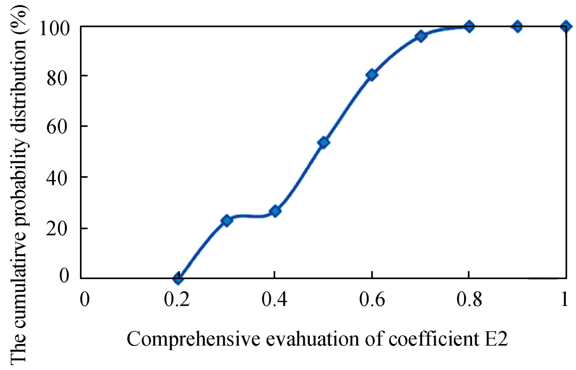

Figure 2
The Cumulative Probability Distribution Curve of Comprehensive Evaluation Coefficient E2

As shown in the image above, when the thickness of the cumulative distribution frequency of comprehensive evaluation coefficient E2 less than 25%, the maximum of Comprehensive evaluation coefficient is around 0.29564, then the well group whose E2 is less than it will be tentatively for water injection effect is poor, and it needs to take measures to improve the affection of water injection, when the cumulative distribution frequency is more than 75%, the minimum of Comprehensive evaluation coefficient is around 0.57827, and then the well group whose E2 is more than it will be tentatively for water injection affection is great, and should keep going[7]. We tentatively define that before the 25% of the thickness of the cumulative distribution frequency is good, behind the 25% of the thickness of the cumulative distribution frequency is bad, we can take appropriate measures to improve the effect of water injection for which the effect of water injection of well group is poor[8-10].

CONCLUSION

(a) We can get the properties of the various water wells by analyzing incremental oil production of oil wells, the absorption ratio of water wells, producing degree of water flooding of water injection effect in water injection wells through this research.

(b) This paper uses the analytic hierarchy process (AHP) to determine evaluation index weights, which means the importance of the various factors influence on water injection. Fuzzy comprehensive evaluation method is used to determine the symmetry properties, and take the E2 values, find the incremental relationship between the E2 value with the injection effect, and evaluate the advantages and disadvantages of the effect of water injection of well groups through comprehensive evaluation E2.

(c) We can improve the water injection of well groups by Putting forward the proposals like acidification, fracturing for the poorly injection well groups.

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