Application of comprehensive evaluation method of advantage channel in a block of Shengli Oilfield

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Abstract. Using geological factors, production dynamics, dynamic monitoring and other data, the fuzzy comprehensive evaluation method and the linear water-driven system modeling method based on fuzzy particle swarm optimization are used to comprehensively identify the dominant seepage channel in a block of Shengli Oilfield. An identification system for the advantage channel of the block is formed. Let \( V'(T) \) be the partial derivative of reservoir.

1. Introduction

According to estimates, with an average recovery factor of 35%, for every 1% increase in recovery rate in China's old oilfields, the recoverable reserves can be increased by \( 1 \times 10^8 \) t [1-3], equivalent to the discovery of an oil field with a reserve of \( 2.85 \times 10^8 \) t, and due to the ground foundation of the old oil fields. The facilities are relatively complete, and the economic benefits are better than the development of new oil fields. Therefore, tapping the remaining oil development potential has become the key to the extraction of old oil fields. The formation of the advantage channel leads to an increase in the ineffective water circulation between the oil and water wells, the water flooding efficiency is reduced, the contradiction between the reservoir development layers is aggravated, and the water flooding recovery is restricted. Therefore, it is of great significance to accurately identify the location of the advantage channel to improve water recovery and recovery potential of remaining oil. Another section of your paper.

2. Integrated identification method

2.1 Fuzzy comprehensive evaluation method

The fuzzy comprehensive evaluation method [4] has carried out research on reservoir geology and development. It first screens the main factors and indicators of the influence and marking of the dominant seepage channel and analyzes its related characteristics, then studies and determines the range of variation of each factor, the normalized evaluation index and the weight value. Finally, the fuzzy theory method is used to comprehensively process various static and dynamic factors such as permeability, porosity, permeability coefficient, apparent water absorption index, liquid sampling index and water content, and establish an expert system model for qualitative identification of dominant seepage channels. It then identifies the dominant seepage channels in the reservoir.
2.1 Classification and stratification of influence elements

Table 1. influencing factors

| Advantage channel comprehensive evaluation system (U) | Geological factors (U₁) | Coefficient of Permeability variation (U₁₁) |
|------------------------------------------------------|--------------------------|-----------------------------------------------|
|                                                      |                          | Permeability (U₁₂)                           |
|                                                      |                          | Porosity (U₁₃)                               |
| Development factor (U₂)                              |                          | apparent water injectivity index; (U₂₁)       |
|                                                      |                          | Produced liquid index (U₂₂)                   |
|                                                      |                          | Water percentage (U₂₃)                        |

2.1.2 Establishment of judgment matrix

In the hierarchical structure, the same level of factors subordinate to the upper level are compared in two ways to compare their importance to the criteria, and the judgment matrix is formed by quantifying them according to the scale specified in advance.

Table 2. Nine scale judgment matrix scale meaning

| Scale | Meaning                                      |
|-------|----------------------------------------------|
| 1     | Two factors are of equal importance          |
| 3     | One factor is slightly more important than the other |
| 5     | One factor is more important than the other  |
| 7     | One factor is much more important than the other |
| 9     | One factor is extreme more important than the other |
| 2, 4, 6, 8 | The median value of the above two adjacent factors |
| Reciprocal | If the judgment value of factor i compared with factor j is bᵢⱼ, then the judgment value of factor j compared with factor i is 1/bᵢⱼ |

2.1.3 Weight calculation of influencing factors

The root method is used to calculate the weight, and the number of influencing factors is set as n. The calculation steps are as follows:

A. Calculate the average value of all elements in each row of the judgment matrix;

\[ M = [m_1, m_2, ..., m_i, ..., m_n]^T \]

s.t.: \[ m_i = \sqrt[n]{\prod_{j=1}^{n} b_{ij}} \] (i=1,2,……, n)

B. Normalize the vector m to get the relative weight vector;

\[ \Omega = [\Omega_1, \Omega_2, ..., \Omega_i, ..., \Omega_n]^T \]

s.t.: \[ \Omega_i = \frac{m_i}{\sum_{j=1}^{n} m_j} \]

Table 3. Weight of influencing factors

| Index level | Factor set | Index name | Index weight |
|-------------|------------|------------|--------------|
| Target layer | U          | U₁         | 0.37         |
|              | U₂         | 0.63       |
| Criterion layer | U₁ | U₁₁ | 0.43         |
| Geological factors | U₂ | U₁₂ | 0.43         |
| Development factor | U₂ | U₁₃ | 0.14         |
|              | U₁₂        | 0.4        |
|              | U₂₁        | 0.4        |
|              | U₂₂        | 0.4        |
|              | U₂₃        | 0.2        |
2.2 Modeling method of linear hydrodynamic system based on Fuzzy-PSO
A hidden variable, water drive control between injection and production wells, is introduced to simulate the dynamic change of the reservoir, which changes with time and affects the production speed of production wells [5].

The control volume of water drive here refers to the fluid flowing from the injection well to the production well through this part of the control volume of water drive. However, the size of water drive control volume is related to the structural height, reservoir physical properties and other factors.

![Figure 1. Schematic diagram of dynamic system waterflooding model](image)

In the process of waterflooding, the reservoir can be regarded as a system, in which the injection velocity of injection well is regarded as a continuous time pulse and the production velocity of production well is regarded as a response. For one injection one production system, according to the material balance equation, we can get:

\[ C_V \frac{dp}{dt} = i(t) - q(t) \]  \hspace{1cm} (2-1)

CT-- total compression coefficient;
VP--pore volume of reservoir, m3;
\[ \frac{dp}{dt} \] --Average change rate of reservoir pore pressure, MPa/d;
i(t)--Total injection rate of injection well at time t, m3/d;
q(t)--Total production speed of production well at time t, m3/d;

In the model established this time, the production index J is not set as constant or the relationship between reservoir pressure and production rate q(t) is linear. On the contrary, the reservoir pressure is regarded as a general function of time and location, without specific form, which is defined as follows:

\[ \frac{dp}{dt} = f(\hat{x}, t) \]  \hspace{1cm} (2-2)

The water drive model of power system is established by combining material balance equation (2-1) and (2-2). Formula (2-2) is assumed below.

Let formula \( V'(T) \) be the partial derivative of reservoir pore volume to time T, from the differential point of view, it represents the change of reservoir pore volume in a small time DT. From formula (2-2), it can be concluded that it is a function of time and location. Then material balance equation (2-1) can be written as:

\[ V'(t) = i(t) - q(t) \]  \hspace{1cm} (2-3)

The model established in this paper depends on the concept of water drive control volume, as shown in Figure 2-1. Here, water drive control volume refers to the volume from a specific injection well to a production well through which fluid flows from the vicinity of the injection well to the
production well. For example, Vij represents the water drive control volume between the injection well I and the production well J. However, the size of water drive control volume is related to structural height, reservoir physical properties, injection production distance and other factors.

Similar to equation (2-3), establish a material balance equation between any one of the injection/production wells (i, j):

$$V_j(t) = i_j(t) - q_j(t)$$

(2-4)

For a given production well j, taking into account the different impacts of the injection wells at different locations on the production well, add the appropriate weighting factor to the material balance equation of any one of the injection and production systems (i, j), so equation (2-4) Can be written as:

$$a^T V_j(t) = \beta^T i_j(t) - q_j(t)$$

(2-5)

It is assumed that the volume change rate of the water flooding is affected by the previous water flood volume change rate and the injection well injection rate. Let $V_j(t) + \Delta t$ represent the water volume control volume change rate at time t+\Delta t, and get:

$$\dot{V}_j(t + \Delta t) = f(\dot{V}_j(t), i_j(t)) + \varepsilon(t)$$

(2-6)

For the follow-up study, change equation (2-6) to discrete time step form:

$$\dot{V}_j(n + 1) = f(\dot{V}_j(n), i_j(n)) + \varepsilon(n)$$

(2-7)

For production well j, its water drive volume change rate at n+1 time is taken as a linear recursive function of water drive volume change rate and injection speed at time n:

$$\dot{V}_j(n + 1) = AV_j(n) + B i(n) + \varepsilon(n)$$

(2-8)

And for the material balance equation (2-5), change it to discrete form, add the error term $\gamma$, there are:

$$q_j(n) = \alpha^T \dot{V}_j(n) + \beta^T i(n) + \gamma(n)$$

(2-9)

In summary, for each production well j, the basic expression of the power system water drive model is:

$$\dot{V}_j(n + 1) = AV_j(n) + B i(n) + \varepsilon(n)$$

(2-10a)

$$q_j(n) = \alpha^T \dot{V}_j(n) + \beta^T i(n) + \gamma(n)$$

(2-10b)

It can be seen from equation (2-10) that the volume change rate of water flood control for time step n depends on the volume change rate of water drive control at n-1 and the injection speed at time n-1, and the control volume at time n. The rate of change and the injection rate simultaneously determine the production speed at time n, so the volume change rate of the water drive can be used to identify whether the formation has an advantage channel.

2.3 Comparison of recognition results
Comparing the recognition results of the two methods with those of the tracer, the most suitable recognition method is obtained.

| Well | Inj | Pro | Tracer | LHS | FCE |
|------|-----|-----|--------|-----|-----|
| Well1 | 1   | √   | √      | √   |     |
|       | 2   | √   | √      | √   |     |
| Well2 | 3   |     |        |     |     |
|       | 4   |     |        |     |     |
|       | 5   |     |        |     |     |
| Well7 | 17  |     |        |     |     |
|       | 18  |     |        |     |     |
| Well8 | 19  |     |        |     |     |
|       | 20  |     |        |     |     |
| Well9 | 22  |     |        |     |     |

Table 4. Comparison between the results of two methods and tracer
| Well | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 |
|------|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Well3 | | | ✓ | | | | ✓ | | | | | | | | | | | | | | | |
| Well4 | | | | | | | | | | | | | | | | | | | | | | | |
| Well5 | | | | | | | | | | | | | | | | | | | | | | | |
| Well6 | | | | | | | | | | | | | | | | | | | | | | | |

3. conclusion
By comparing with the results of tracer, we can see that FCE is more suitable for the selected block.

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