Research on Main Controlling Factors of Fracturing Reformation of Ancient Sandstone Horizontal Wells in Jingbian Gas Field

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Abstract. From 2015 to 2019, a total of 7 wells in the Shan 28 well area of the Jingbian gas field used pumped bridge plug staged fracturing technology. The average test gas daily production rate is $8.13 \times 10^4 \text{m}^3/\text{d}$, and the average unblocked flow rate is $46.06 \times 10^4 \text{m}^3/\text{d}$. Demonstrating the superiority of the staged fracturing reconstruction process of pumping bridge plugs, However, due to the short time of using the pumped bridge plug staged fracturing process, the main controlling factors of fracturing reformation are not clear, resulting in a large gap between the gas production effect of the reformed well and the expected. Therefore, based on the site construction parameters, this paper uses single factor analysis and grey correlation analysis methods to determine the main control factors for fracturing reformation of the ancient sandstone horizontal well in the Jingbian gas field. Research shows that the length of gas layer, liquid type, average sand ratio, and sand volume are the main factors affecting the open flow and daily gas production of horizontal wells. The research results in this paper have certain guiding significance for the effective development of ancient sandstone horizontal wells.

1. Introduction

The upper paleo gas reservoirs in the north of Jingbian Gas Field are mainly sandstone lithological closed gas reservoirs, and the sand bodies have been deposited in multiple stages, although it is distributed in contiguous patches, it has poor connectivity, strong heterogeneity, low porosity and low permeability [1], and is difficult to develop. North American tight sandstone horizontal well multi-stage fracturing technology mainly includes horizontal well open hole packer sliding sleeve staged fracturing technology, horizontal well hydraulic sandblast staged fracturing technology and fast-drilling bridge plug staged fracturing technology. The Bajiaochang gas field has formed an intra-section multi-cluster high-strength sanding technology with "multi-cluster perforation, liquid-controlling sand extraction, variable viscosity and slippery water, and small-size proppant" as the core technology [2]. The Jinhua-Qiulin block has undergone field tests of multiple horizontal wells in the early stage, and the main process of reservoir reconstruction in the Qiulin area has been preliminarily formed, that is, the multi-cluster perforation continuous sanding process in the horizontal well section.

Combining with the technical countermeasures of fracturing and reforming tight sandstone reservoirs at home and abroad, the Jingbian Gas Field began to adopt the fracturing model of high-strength sand addition and high-density/dense cutting fracturing. As of 2019, a total of 7 wells in the Shan 28 well...
block of the Jingbian gas field have used pumping bridge plug staged fracturing, with an average gas production rate of $8.13 \times 10^4$ m$^3$/d and an average open flow rate of $46.06 \times 10^4$ m$^3$/d in the Shan 68 well block. One well used pumped bridge plug staged fracturing. The average daily gas production rate was $4.33 \times 10^4$ m$^3$/d, and the average unblocked flow rate was $20.14 \times 10^4$ m$^3$/d. However, due to the immature fracturing technology, the use of pumped bridge plug staged fracturing technology is relatively short, and the main controlling factors of fracturing reformation are not clear, resulting in a certain gap between the gas production effect of the reformed well and the expected effect. Based on the actual data of fracturing reformation of constructed wells in Jingbian Gas Field, this paper analyzes the degree of influence of various factors on the fracturing effect through single factor analysis and gray correlation research methods, which can provide a later stage for the formulation of fracturing design plans for tight sandstone horizontal wells Actual reference basis.

2. Univariate analysis
Reservoir length, reservoir drilling encounter rate, sand addition and average sand ratio are the main parameters that affect the effect of fracturing. According to the actual construction data on site, the four parameters and the unblocked flow fitting chart can be drawn, and it can be observed that In the same type of transformation process, the open flow after fracturing is obviously positively correlated with the length of the reservoir, the drilling encounter rate, the average sand ratio, and the cumulative sand addition.

**Figure 1.** Reservoir length and open flow

**Figure 2.** Reservoir penetration rate and open flow

**Figure 3.** Cumulative sand addition and open flow

**Figure 4.** Average sand ratio and open flow
3. Multi-Factor Analysis

Multi-factor analysis is to use the gray correlation method to obtain the influencing factors of each parameter to analyze the degree of influence of each parameter on the transformation effect. Combined with the single factor analysis result, a total of 9 parameters are selected to systematically compare the effect of each parameter on the transformation effect. The size of the impact, and the main controlling factors for the effect of fracturing reconstruction are clarified. The flow of the gray correlation method is shown in the figure below:

![Gray correlation analysis process](image)

### 3.1. Grey relational analysis

The gray correlation analysis method is a multi-factor comparative analysis method. Its basic principle is the analysis of the curve development trend. It is based on the sample wells of each factor and uses the gray correlation degree to describe the strength, size, and relationship between factors. Sequential. If the reflected changes of the two factors are closer, their correlation is greater; on the contrary, the correlation is smaller [3-4]. The geological parameters analyzed in this analysis include: reservoir drilling rate, sandstone length, gas layer length, liquid type, number of fracturing sections, single-stage sand volume, single-stage liquid volume, sand addition volume, and average sand ratio. The processing process is as follows:

1. Select open flow and daily gas production as reference sequences, geological and production parameters as comparison sequences;

   \[
   \begin{align*}
   X_0 &= \{X_0(1), X_0(2), X_0(3), \ldots, X_0(n)\} \\
   X_i &= \{X_i(1), X_i(2), X_i(3), \ldots, X_i(n)\} \\
   X_m &= \{X_m(1), X_m(2), X_m(3), \ldots, X_m(n)\}
   \end{align*}
   \]

   In the formula: \(X_0\)—Reference sequence; \(X_i\)—Comparison sequence.

2. In order to ensure that the data has equal polarity and equal weight, the variables with different units and different dimensions can be transformed into variables under a certain standard scale. It needs to be normalized and dimensionless. Here, the initial value method is used to make the data
dimensionless. First, select the optimal sequence and record it as \( \{x_0'(1), x_1'(1), \ldots, x_n'(1)\} \). The calculation formula is [5]:

\[
y_j(k) = \frac{X_j(k)}{X_j(1)} \quad j=0, 1, 2, \ldots, m; k=1, 2, \ldots, n
\]  

(2)

(3) Next, find the difference sequence, the calculation formula is:

\[
\Delta_0(k) = \left[ Y_0(k) - Y_i(k) \right], \quad i = 0, 1, 2, \ldots, m; k = 1, 2, \ldots, n.
\]  

(3)

In the formula: \( \Delta_0(k) \) — Absolute difference.

(4) Find the maximum difference and minimum difference between the two levels, the calculation formula is:

\[
\Delta_{\text{max}} = \max_i \max_k \left| Y_0(k) - Y_i(k) \right|
\]

(4)

\[
\Delta_{\text{min}} = \max_i \max_k \left| Y_0(k) - Y_i(k) \right|
\]

(5)

In the formula: \( \Delta_{\text{max}} \) — Maximum difference between two levels; \( \Delta_{\text{min}} \) — Minimum difference between two levels.

The maximum level difference calculated here \( \Delta_{\text{max}} = 0.881 \), and the minimum level difference \( \Delta_{\text{min}} = 0.001 \).

(5) Calculate the correlation coefficient, the calculation formula is:

\[
\xi_0(k) = \frac{\Delta_{\text{min}} + \rho \Delta_{\text{max}}}{\Delta_0(k) + \rho \Delta_{\text{max}}}
\]

(6)

In the formula: \( \rho \) — Resolution coefficient. Its role is to increase the significance of the difference between correlation coefficients, \( \rho \in (0, 1) \). Usually the value is 0.5, The smaller the value of \( \rho \), the better the difference between the correlation coefficients[6-7].

3.2. Multivariate analysis results

Respectively select factors such as reservoir drilling encounter rate, sandstone length, gas zone length, liquid type, number of fracturing sections, single-stage sand volume, single-stage liquid volume, sand addition volume, average sand ratio and other factors for grey correlation analysis.

The analysis results show that the influencing factors of post-fracturing productivity from large to small are: gas reservoir length, liquid type, average sand ratio, sand addition, number of fracture sections, sandstone length, reservoir drilling encounter rate, single sand volume, single Segment liquid volume. Among them, the length of gas layer, liquid type and average sand ratio have the greatest influence on open flow. Single-stage sand volume and single-stage liquid volume have less influencing factors on open flow. The main control factors that affect open flow and daily gas production are basically the same.

From the perspective of the correlation degree of the main controlling factors of the open flow, the length of the gas layer, liquid type, average sand ratio, and sand volume are the main factors that affect the open flow;

From the perspective of the correlation degree of the main controlling factors of daily gas production, gas layer length, liquid type, average sand ratio, and sand volume are also the main factors affecting daily gas production.
4. Conclusion

Through single factor analysis, it is found that for the same type of reforming process, the open flow after compaction is obviously positively correlated with reservoir length, reservoir drilling encounter rate, average sand ratio, and cumulative sand addition.

The analysis results of the gray correlation method show that the length of the gas reservoir, the type of liquid, the average sand ratio, and the sand volume are the main factors affecting the open flow and daily gas production.

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