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Analysis of Factors Influencing the Capacity of Fractured Straight Wells in Tight Gas Reservoirs

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Abstract: *In response to the problems of non-production and low production from tight gas reservoirs, a study on the degree of influence of different parameters on the production capacity after fracturing of straight wells was carried out. Taking fractured wells in the Linxing block as the target, under the premise of relatively small and incomplete data, geological and engineering factors with gas wells in production were given priority, and the parameters affecting the production capacity of each well were calculated and analyzed by using the information quantity analysis method and gray correlation analysis method to determine the information quantity of each parameter and the correlation degree between each parameter. The analysis concluded that: permeability, shot hole thickness, water content saturation and porosity are the main factors affecting straight wells, and the secondary factors are seam length, formation pressure, and return discharge rate, respectively. Based on the high similarity of the analysis results of the above two methods, it is considered that the objective analysis method, gray correlation method, can compensate for the errors of the information quantity analysis method due to subjective factors. In the design of the Linxing gas reservoir development plan, the engineering factor among the main factors is used as the entry point, which can significantly improve the gas well capacity*

Keywords: *Tight gas, Fracturing straight wells, Degree of impact, Production capacity, Informativeness, correlation coefficient*

1. Introduction

Tight gas reservoirs have poor reservoir physical properties, high inhomogeneity, low recoverable reserves in single wells, and a decreasing trend year by year [1-2], China's tight gas reservoirs are very rich in prospective resources, but they must be transformed by reservoirs to obtain high quality recoverable volumes, and the extraction of tight gas fields is inseparable from hydraulic fracturing technology, which is essential for tight gas reservoir development [3]. In gas field development, the yield of gas wells after fracturing is affected by both geological and engineering factors, among which the factors affecting the yield of tight gas wells during construction are very complex [4-5], and each factor is difficult to be taken into account at the same time, so it is of great significance to reasonably determine the main control factors of production capacity and find out the degree of influence of each factor on production capacity to modify the scheme of field operations in tight gas reservoirs. At present, some scholars use hierarchical analysis [6], numerical simulation [7], entropy method [8], "Pearson-MIC" analysis [9], and orthogonal experimental analysis [10] to determine the priority of the factors influencing production capacity, which are good methods to analyze the degree of influence of some factors on production capacity. However, based on these methods, a large amount of data is required, which can produce large errors in analyzing some blocks with relatively little data.

In this paper, we use the information quantity analysis and gray correlation analysis to calculate and analyze the selected parameters that affect the capacity of straight wells in tight gas reservoirs. Firstly, we apply the subjective analysis method to derive the magnitude of information quantity of each parameter, and then apply the objective analysis method to derive the correlation degree of the correlation coefficient of each parameter. By comparing and analyzing the degree of influence of each parameter on the production capacity, the main and minor factors affecting the production capacity of straight wells are identified, which provides a strong basis for efficient and accurate adjustment of

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parameters in the field fracturing construction of tight gas reservoirs in the Linxing block, as well as a key basis for the overall production increase and development of tight gas fields in the Linxing block.

2. Information Volume Analysis Method

The principle of the information quantity analysis method [11] is to classify the analysis object into categories I and II using a certain numerical criterion, count the mapping frequencies of different parameter numerical intervals I and II, and compare the analysis frequencies to determine the degree of difference between the two categories (I and II) of the allocation, and the degree of difference is proportional to the relationship between the information quantity. Using this method, the amount of information of each factor affecting the capacity of fractured straight wells in tight gas reservoirs is analyzed, and the amount of information of each influencing factor indicates the degree of influence of that factor on the capacity, and the total amount of information is also proportional to the degree of difference [12].

The steps for calculating each information quantity are：

(1) Convert the frequency probabilities (in percent) of the projections on I and II $y_{\mathrm{I}\,\delta}$ and $y_{\mathrm{II}\,\delta}$, where δ is the interval ordinate.;

(2) Calculate the average probability frequency of each interval $\overline{y_{\mathrm{I}\,\delta}}$, calculated as;

$$\overline{y_\delta}=\frac{1}{10}\left(y_{\delta-2}+2y_{\delta-1}+4y_\delta+2y_{\delta+1}+y_{\delta+2}\right) \tag{1}$$

(3) Calculate the ratio of the mean frequencies as $\overline{y_{\mathrm{I}\,\delta}}/\overline{y_{\mathrm{II}\,\delta}}$;

(4) Calculate the diagnostic coefficient Z_δ formula is;

$$Z_\delta=10\lg\left(\overline{y_{\mathrm{I}\,\delta}}/\overline{y_{\mathrm{II}\,\delta}}\right) \tag{2}$$

(5) Calculate the amount of information in each interval of variation of each parameter by the formula;

$$\mathrm{I}_\delta=\frac{1}{2}Z_\delta\left(\overline{y_{\mathrm{I}\,\delta}}/\overline{y_{\mathrm{II}\,\delta}}\right) \tag{3}$$

(6) Calculate the total amount of information I;

$$\mathrm{I}_{总}=\sum \mathrm{I}_\delta \tag{4}$$

Table 1: Fracturing straight well parameters in the Linxing block

Well number	permeability/md	porosity/%	stratigraphic pressure/Mpa	Water content saturation/%	Shot thickness/m	return rate/%	Seam length/m	production capacities×104 /(m3/d)
LX-26-2D	0.6	8.9	18	41	3	83.41	267.7	6.81
LX1-35-4D	3.62	25.3	13.5	44.6	4	40.95	242.5	29.65
LX-41-3D	0.54	9.6	16.93	62.6	6	42	252.4	7.32
LX-5-2D	0.83	10.7	13	59	3.7	66.8	118.7	6.15
LX-159-2D	0.15	6.7	17	45	3.4	93.02	153.6	8.50
LX-33-1D	0.54	10	13.2	52.1	9	48.93	245.8	30.23
LX-58-3D	1.64	13	13.4	39.5	3	38.93	212.5	25.11
LX-160	1.66	12.5	12.4	44.6	3.6	48.8	336.6	16.10
LX-160-2D	2.31	13.6	12.29	40.8	4	54.83	274.3	6.80
LX-57-2D	2.63	14.4	14.2	45.6	5	24.48	236.8	11.16

Taking LX-26-2D, LX1-35-4D, LX-41-3D, LX-5-2D, LX-159-2D, LX-33-1D, LX-58-3D, LX-160, LX-160-2D, LX-57-2D in the Linxing block as an example, the data of each parameter are shown in

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Table 1. Taking the production capacity as the analysis object, according to the fractured.

Table 2: Fracture stage information calculation results

Serial number	Penetration interval (MD)	Component shot frequency		Probability frequency		Average probability frequency		Average probability ratio	Diagnostic coefficient	volume of information
		A	B	yA δ	yB δ	\`yA δ	\`yB δ	\`yA δ /\`yB δ		
1	0-0.7	3	1	60	20	28	12	2.33	0.37	29.44
2	0.7-1.4	1	0	20	0	22	14	1.57	0.20	7.85
3	1.4-2.1	0	2	0	40	14	22	0.64	-0.20	7.85
4	2.1-2.8	1	1	20	20	10	18	0.56	-0.26	10.21
5	2.8-3.5	0	0	0	0	4	12	0.33	-0.48	19.08
6	3.5-4.2	0	1	0	20	2	10	0.20	-0.70	27.96
total		5	5	100	100	80	88	5.63	-1.06	102.40

Horizontal well production capacity of 10.5×104m3/d as the numerical criterion, less than 10.5×104m3/d is classified as group I, and large and 10.5×104m3/d is classified as group II, and the parameters that need to be calculated informatively (permeability, porosity, water content saturation, formation pressure, shot thickness, seam length, rejection rate) are counted separately in their different The frequency of their shot hitting Group I and Group II in different variation intervals is further calculated to determine the degree of difference between the assignments belonging to the two classes (Group I and Group II), and the greater the degree of difference, the greater the amount of information.

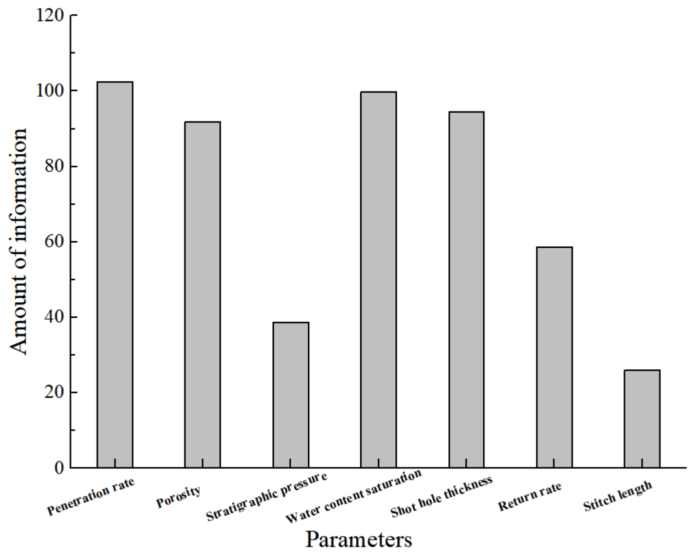

Figure 1: Comparison of the amount of information on each parameter

According to the above calculation steps and parameter data, the calculation process is illustrated with permeability as an example, and the total information amount is calculated as 102.4, as shown in Table 2. The total information quantity calculation results of the remaining six parameters are shown in Figure1, and according to the information quantity ranking of each parameter, it can be seen that among these factors, the information quantity of permeability, shot hole thickness, porosity, water content saturation, dominates and is the main factor affecting the straight well; followed by seam length, formation pressure, and return discharge rate belong to the secondary factors.

3. Grey Correlation Analysis Method

The grey correlation analysis method [11] can be used to process the data of the factors studied with relatively little information, and a method to measure the degree of correlation between factors based on the similarity or dissimilarity of the development trends among the factors. Since this method can reduce information asymmetry to a large extent and has low data requirements, it can be used to analyze the factors influencing the production capacity of straight wells in the Linxing block, The basic concept is as follows.

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(1) Collecting and organizing data and determining the series to be analyzed;

(2) Determine the reference series Y and the comparison series X_1, $X_2, \cdots\cdots, X_i$, according to the purpose of the analysis and list the following matrix (equation 5). (The reference column is a sequence of results reflecting the characteristics of the system, and the comparison column is a sequence of data consisting of several factors affecting the results of the system);

$$C = \begin{pmatrix} x_1(1) & x_2(1) & \cdots & x_i(1) & Y_1 \\ x_1(2) & x_2(2) & \cdots & x_i(2) & Y_2 \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ x_1(n) & x_2(n) & \cdots & x_i(n) & Y_n \end{pmatrix} \tag{5}$$

(3) Normalization of each data. Commonly used normalization indicator interval normalization;

$$X_i'(k) = \frac{X_i(1) - \min_i X_i(\mathrm{k})}{\max_i X_i(\mathrm{k}) - \min_i X_i(\mathrm{k})} \tag{6}$$

where, $m = 1, 2, \cdots\cdots, i; k = 1, 2, \cdots\cdots, n$.

(4) Calculate the absolute value of the difference $\left|Y_k - X_m(k)\right|$ between each comparative series and the reference series.

Table 3: Correlation coefficients for output impact parameters

Permeability /md	Porosity /%	stratigraphic pressure/Mpa	Water content saturation/%	return rate/%	seam length/m	Shot thickness/m
0.826	0.842	0.333	0.962	0.369	0.425	0.947
0.953	0.953	0.389	0.387	0.398	0.544	0.375
0.884	0.819	0.389	0.338	0.701	0.462	0.518
0.713	0.693	0.796	0.366	0.441	1.000	0.807
0.833	0.833	0.401	0.795	0.350	0.886	0.940
0.354	0.372	0.367	0.512	0.431	0.539	1.000
0.576	0.520	0.451	0.376	0.458	0.577	0.382
0.957	0.827	0.552	0.700	0.892	0.453	0.608
0.450	0.586	0.948	0.979	0.539	0.414	0.777
0.490	0.703	0.794	0.922	0.700	0.593	0.795

(5) Determine the number of correlation coefficients corresponding to each comparison series ε $\min_{m=1}^{i}\min_{k=1}^{n}\left|Y_k - X_m(k)\right|$ with $\max_{m=1}^{i}\max_{k=1}^{n}\left|Y_k - X_m(k)\right|$, from equation (7).

$$\varepsilon_m(k) = \frac{\min_m\min_k\left|Y_k - X_m(k)\right| + \rho\cdot\max_m\max_k\left|Y_k - X_m(k)\right|}{\left|Y_k - X_m(k)\right| + \rho\cdot\max_m\max_k\left|Y_k - X_m(k)\right|} \tag{7}$$

The ρ smaller the coefficient ρ ,0< ρ <1, the greater the difference between the correlation coefficients and the stronger the discrimination ability. Usually ρ take 0.5.

Calculate the correlation (correlation order): $R = \frac{1}{n}\sum_{k=1}^{n}\varepsilon_m(k)$, the larger the R value, the higher the correlation between the comparison series and the reference series is proved.

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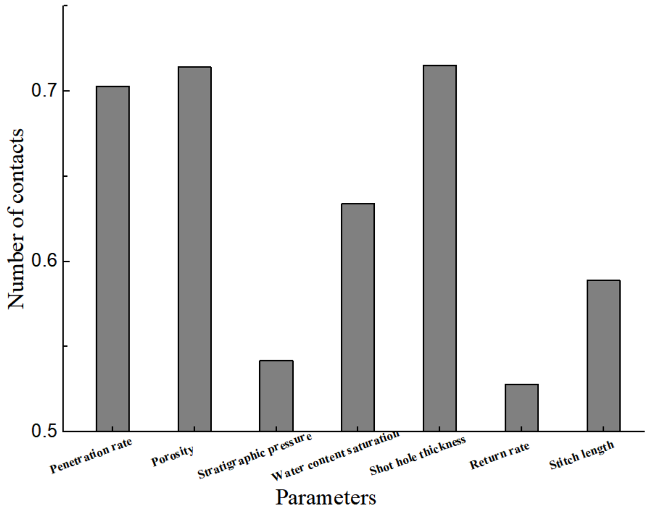

Figure 2: Grey correlation ranking of each parameter

The grey correlation analysis was carried out with 10 straight wells in the Linxing block as an example. Firstly, Table 1 is normalized, and then according to the normalized data, the capacity data is used as the reference series and the remaining 7 parameters are used as the comparison series to get the correlation coefficient of each parameter, and the calculated correlation coefficient is shown in Table 3. The correlation degree of each parameter can be obtained from the correlation formula, and the ranking according to the correlation degree of each parameter is shown in Figure 2. It is easy to see that the correlations of four factors, namely permeability, shot hole thickness, porosity and water saturation, are ranked at the top, while the correlations of rejection rate, seam length and formation pressure are ranked at the bottom.

4. Comparative Analysis of Results

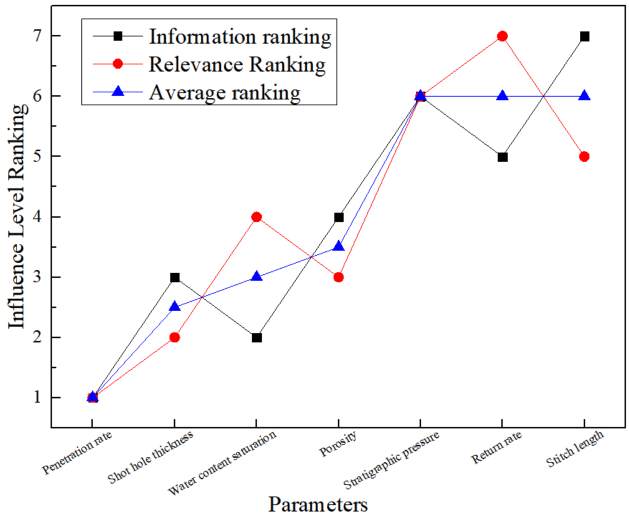

Figure 3: Combined ranking of the degree of influence of each factor

The results of the information content analysis method and the gray correlation method showed that the similarity of the calculation results of the two methods was extremely high, and the information content and correlation degree of each parameter were ranked consistently from an overall perspective. By comprehensively ranking the degree of influence of each factor (as shown in Figure 3), it is obvious that permeability and shot hole thickness are the most important factors affecting the production capacity of straight wells in the Linxing tight gas field, porosity and water saturation are the main influencing factors, and rejection rate, seam length, and formation pressure are secondary factors. According to the results of the comparative analysis, the ranking of the factors influencing the production capacity of Linxing tight gas field is permeability, shot hole thickness, water content

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saturation, porosity, formation pressure, rejection rate, and seam length. In the specific calculation process, because the information quantity analysis will have subjective level influence on the parameter interval grading, it is necessary to use the objective analysis method gray correlation method to eliminate the error caused by less data, and the combination of two methods achieves the inner unity of subjective and objective, which makes the analysis results more realistic and reliable.

5. Conclusion

(1) The degree of influence of fractured straight well capacity in the Linxing tight gas reservoir was analyzed and calculated by combining the information quantity analysis method and gray correlation analysis, and the analysis results concluded that permeability, shot hole thickness, and water saturation are the main factors affecting the capacity of fractured straight wells in the Linxing tight gas reservoir.

(2) The results of the analysis of the factors influencing production capacity by applying the grey correlation analysis method and the information quantity analysis method have a high similarity, and both methods are effective methods for analyzing the primary and secondary relationships of the production capacity of fractured direct wells in tight gas reservoirs. Combining subjective and objective mathematical analysis methods can achieve the inner unity of subjectivity and objectivity and make the analysis results more realistic and reliable.

(3) For the Linxing block gas formation, geological and engineering factors together determine whether a gas well can achieve high production. Selecting a high-quality reservoir is the foundation and applying advanced technology is the guarantee, and the top-ranked controllable factors can be given priority in actual production operations to increase the production capacity of straight wells in tight gas reservoirs.

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