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Application of thin interbed fracturing technology in Hanggin Banner Block

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Abstract

The Hanggin Banner block is a low porosity, low permeability and tight reservoir. In order to improve the vertical productivity, the paper uses the logging curves and the indoor and field data to get the distribution characteristics of rock mechanics and in-situ stress, constructs the pseudo-three-dimensional model, simulates and analyzes the fracture height expansion law, and compiles the chart of fracture parameters, the design parameters are optimized, and good effect is achieved through field application.

Keywords

Hanggin Banner; Slot Height Expansion; quasi-three-dimensional model; Through-layer fracturing.

1. Preface

Located in the north of Ordos Basin, the Hanggin Banner block is a tight, low permeability and tight sandstone gas reservoir. The main layer is the 1st layer of xiashihezihe formation, and 1-3 sets of small layers are developed vertically, it shows the characteristics of multiple gas layers, thin interlayer and large variation of interlayer thickness in plane. In order to improve the vertical production rate, the fracture height expansion rule is studied in Hanggin Banner block, the main factors affecting fracture height are analyzed[1], and the fracture height monitoring results are combined with the fracture height monitoring results, the paper compiles the technical parameter chart of cross-layer fracturing, carries out the experimental evaluation of the conductivity of the inter-layer in the laboratory, demonstrates the reliability of the inter-layer, and forms the technical scheme of thin interlayer cross-layer fracturing by using numerical simulation, through-layer fracturing technology has realized effective through-layer, improved vertical productivity and single well production, and supported gas field productivity construction.

2. Distribution characteristics of reservoir and barrier

There are many sets of gas layers, many thin interlayers and various reservoir structures in He 1 gas layer of Jin 58 well area in Hanggin Banner area. Based on the analysis of straight well and horizontal well guide section data in the production area of Jin 58 horizontal well in the early stage, the distribution characteristics and thickness of single well reservoir and interval are statistically analyzed by using logging curves, and the main types of reservoir and interval in Jin 58 well area are defined.

On the whole, 1-3 sets of gas layers are developed vertically in He 1 formation, among which single set of gas layers accounts for 19.7% , two sets of gas layers accounts for 47.4% , three sets of gas layers accounts for 32.9% , and multiple sets of gas layers are relatively developed.

(1) A single gas reservoir is developed, with average sand body thickness of 21.8m, sand body thickness of 5.7-31.9m, mainly distributed over 20m, and interval thickness of 6-40m, average of 15m, mainly distributed over 10-20m;

(2) Two sets of gas layers are developed, with an average thickness of 12.7 m and a distribution of 3.0-23.3 m, a span of 15-40 m and a distribution of 10-20 m, and an average thickness of 1.6-7.1 m and an average of 4.1 m, respectively, most are less than 4 m;

(3) Three sets of gas layers are developed, with an average thickness of 14.7 M and a distribution of 6.7-21.8 m, a span of 35-50 m and a distribution of 10-20 m, and an average thickness of 0.8-6.4 m and a mean of 3.3 m, it was mainly distributed within 6m (92.4%) .

Through statistics, we can see that the thickness of HE1 reservoir is 3-32 m, mainly in 10-20 m, and the thickness of interval is 1-40 m, mainly in 4-12 M. For the development of multiple sets of gas layers, the interlayer is thin and less than 6M, which has favorable conditions for through-layer fracturing and is suitable for the application of through-layer fracturing technology.

3. Rock mechanics and in-situ stress characteristics

Through the fitting analysis of the block dipole acoustic logging curve, a more accurate shear-wave time difference formula is obtained (Fig. 1) . The dynamic rock mechanics parameters can be obtained by using logging curves, and the dynamic and static parameters can be corrected with the results of laboratory experiments. The average young's Modulus and Poisson's ratio are 21.8 GPA and 0.28, respectively, the average young's modulus is 28.3 GPA and Poisson's ratio is 0.25[2] .

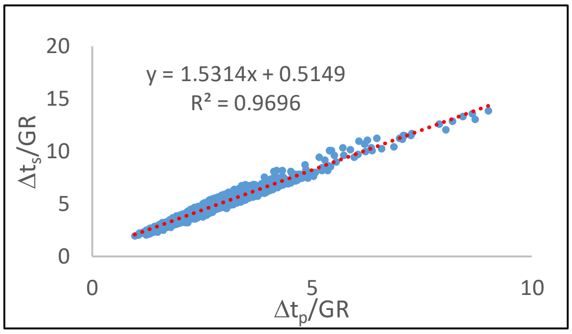

Fig. 1 Graph of P-WAVE and s-wave time difference (GR weighted linear fitting)

Correlation between static and Dynamic Poisson's ratios of rocks:

$$\mu_s = 0.6078\mu_d + 0.1354 \quad (1\text{-}1)$$

Among them, μ_s : Static Poisson's ratio of rock; μ_d : Dynamic Poisson ratio of rock.

Correlation between static and Dynamic Elastic Modulus of rock:

$$E_s = 4.0606E_d - 137215 \quad (1\text{-}2)$$

Among them, E_s : Static Modulus of Elasticity of rock, MPa; E_d : Dynamic Elastic Modulus of rock, MPa.

Based on the accurate parameters of rock mechanics and the formula of Horizontal Minimum Principal Stress, the stress distribution of reservoir and partition can be obtained.

$$\sigma_{\text{hmin}} = \frac{\mu}{1-\mu}\left(\sigma_{\text{v}} - \alpha p_p\right) + \alpha p_p$$

Among them σ_{hmin}: Minimum Horizontal Principal Stress, MPa; α: Effective Stress Coefficient; P_p: Pore pressure, MPa.

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The minimum principal stress gradient of reservoir is 0.0144 mpa/m, the minimum principal stress gradient of interlayer is 0.0165 mpa/m, and the minimum principal stress difference of reservoir and interlayer mainly distributes between 2 and 10 MPa, the average is 6.4 MPa.

4. Analysis of High Propagation Law of fracturing fracture

Based on rock mechanics and in situ stress parameters of He 1 layer in Jin58 well block, a pseudo-3d model of fracture propagation is established by using fracturing simulation software MFRAC[3]. On this basis, the actual operation curve and temperature logging curve are used to fit the fracture model, and the more accurate performance parameters of fracturing fluid are obtained. Through fitting, the error between simulated fracture height and temperature logging is 1.5% , less than 5% , which meets the requirement of engineering precision. It shows that the pseudo-3d fracture propagation model has high precision and can guide the analysis of fracture propagation law.

On this basis, the propagation of fracture under different parameters is simulated [4-6] ,the results show that[7] the fracture height decreases with the increase of the stress difference between the reservoir and the interval, and increases with the increase of the viscosity of the fracturing fluid, the displacement of the fracturing fluid and the amount of the in-situ fluid[8]. In order to accurately understand the influence of different factors on the fracture height and the primary and secondary relationship of the influence degree[9], on the basis of the single factor analysis of the fracture height, the orthogonal test design method was used to scientifically arrange the multi-factor test scheme, quantitative determination of the impact of various factors on the fracture height of the primary and secondary order and significance. Among the geological factors, the stress difference of the reservoir is the most important to the fracture height expansion, the next is the thickness of the interlayer, the next is the viscosity of the fracturing fluid, the next is the amount of fluid entering the ground, and the weakest is the construction displacement [10].

Table 1 The results of orthogonal experimental analysis

Factor	Stress Difference of reservoir and barrier MPa	Viscosity mPa.s	Interlayer thickness m	Liquid volume m3	Displacement m3/min	Thickness m
Extreme bad(m)	82.4	60.8	49.5	42.6	32.5	11.9

Based on the study of fracture height extension, two sets of geological models of gas reservoirs and three sets of geological models of gas reservoirs with different parameter combinations are established, simulation of fracture height extension under different displacement and in-situ fluid flow conditions, and the corresponding critical value of fracturing operation parameters, two sets of gas layers and three sets of gas layers series fracturing design chart are compiled.

For the two sets of plates of fracturing parameters for gas reservoirs, the plates are composed of "three lines and four zones" , and Area I is the fracture-controlling zone, where the fracture extends in the target zone and the fracture height is controlled in the interlayer, when the interlayer thickness is less than 4M, the area of this area is relatively small, and the fracture height is easy to break through the interlayer. When the interlayer thickness reaches 8M, the area of the controlled fracture area is larger, and the fracture height is not easy to break through the interlayer. Zone II is a cross-layer fracturing zone, which means that the fracture height extends in the adjacent gas layer after breaking through the barrier layer, and the upper boundary is the construction displacement and ground inflow when the fracture height reaches the boundary of the adjacent gas layer. With the increase of ground liquid, the seam height re-enters the interlayer, and the Zone III is the zone of overcrossing the interlayer, in which the seam height reaches the boundary of interlayer and extends in the interlayer again after breaking through the adjacent gas layer. Zone IV is sand plug zone, which indicates that sand plug is easy to occur in construction because of narrow seam width due to low displacement.

For the three sets of gas reservoirs, the plates are composed of "five lines and four zones" , which are also composed of fracture-controlled fracturing zones, through-layer fracturing zones, excessive through-layer zones and sand plug zones. For the three sets of gas reservoirs, a set of gas reservoirs is developed at the top and bottom of the target formation. As the upper seam height is easy to expand compared with the lower seam height, the seam height first breaks through the upper barrier to reach the first boundary, and then breaks through the lower barrier to reach the second boundary with the increase of the injected liquid, the upper boundary of gas layer is reached first, then the lower boundary of gas layer is reached, and finally the zone of overcrossing layer is entered. From the chart of fracturing parameters, it can be seen that the critical penetration fluid volume decreases with the increase of displacement.

According to the parameter chart, the design parameters can be optimized, and the optimum fracturing design parameters can be determined according to the Field Operation Ability, fracture profile and economy.

5. Evaluation of interlayer conductivity

The influence of proppant imbedding on the conductivity of interbed is the key to evaluate the effectiveness of cross-layer fracturing. If the conductivity of interbed can not satisfy the flow passage of oil and gas in upper and lower reservoirs, cross-layer fracturing would then become meaningless, so in the Hanggin Banner block, measurements of the conductivity of the interlayer under different sand-laying concentrations were carried out to determine the appropriate sand-laying concentration for the design.

According to the calculation, with the increase of the closing stress, the conductivity of the interlayer decreases gradually, and the lower the sand concentration, the smaller the conductivity. When the closing stress is more than 20 MPa, there is a decreasing trend of flow conductivity.

After fracturing through the Interlayer, the conductivity must be more than $20\mu m^2\cdot cm$ to meet the effective flow of reservoir fluid. According to the formation closing stress 45 MPa, the conductivity is more than $20\mu m^2\cdot cm$, it is determined that the sand concentration of the interlayer must be greater than 5 kg/m^2 after the thin interlayer is fractured.

6. Applications in the Field

On the basis of obtaining the technical parameters of thin interbed fracturing, the test and verification are carried out in a vertical well at first. Taking well J58-1 as an example, the thickness of sand body of He2 layer is 15m, the thickness of upper interval is 4m, and the stress difference of reservoir interval is 4 MPa. According to the chart of fracturing technical parameters, the construction displacement is $3.5m^3/min$, the ground inflow volume is $300m^3$, and the sand addition volume is $50m^3$ according to the sand concentration.

In this well, the height of fracture can be judged by the difference of anisotropy through two times of dipole acoustic logging before and after pressure. The results show that the measured fracture height is 24.5 m, which penetrates through the interlayer and reaches the top box 3 layers.

On the basis of determining the feasibility of reservoir fracturing technology, Hanggin Banner block has been popularized and applied in a large scale in horizontal wells, with 58 wells being applied. The average gas production after fracturing is 3.59×10^4 m^3, which is 47.1% higher than that of conventional technology,the vertical production rate is increased by more than 30%, which further validates the reliability of the fracturing technology.

7. Conclusion

(1)The average young's modulus is 21.8 GPA, the poisson's ratio is 0.28, the average young's Modulus is 28.3 GPA, the Poisson's ratio is 0.25, and the minimum principal stress gradient is 0.0144 MPa/M, the minimum principal stress gradient of interlayer is 0.0165 MPa/M, and the minimum principal stress difference of reservoir and interlayer mainly distributes between 2 and 10 MPa, with an average of 6.4 MPa.

(2)Among the geological factors, the stress difference of the reservoir is the most important, the next is the thickness of the interlayer, the next is the viscosity of the fracturing fluid, the next is the amount of fluid entering the ground, and the weakest is the construction displacement.

(3)Based on the results of numerical simulation and fracture height monitoring, two sets of fracturing design charts for gas reservoirs and three sets of fracturing design charts for gas reservoirs are compiled.

(4)Fracture height monitoring results and field tests in Hanggin Banner block have confirmed the reliability of the fracturing technology.

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