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Research and Practice on Key Factors of Fracturing Technique in Changqing Zhenbei Tight Thick Layer

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Abstract:

Zhenbei Chang 8 layer is an important evaluation layer of Changqing oilfield. In view of questions as low early fracturing effort, which affects a further exploration and development. Combined with development of volume fracturing recent years. Analyzed the ability of fracturing of reservoir from the research of rock mechanics and optimized important parameters such as displacement of pump and fracturing liquid. Way of fracture distribution was changed and complicated fracture was formed finally. Production tested improved by 2.2 times. Production of single well improved by 1.6 times. Widen the exploration area, guide the development of block, and find an important way to improve production.

Key words: Zhenbei oilfield; Tight thick layer; Crushability; Complicate fracture

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INTRODUCTION

Thickness of Chang 8 layer of Zhenbei area is large, average thickness is 22.3 m, partly thickness is over 30 m, air permeability is less than 0.3 mD. For this kind of reservoir, separate layer fracturing, inner layer fracturing, multi-stage sand and oriented perforating was conducted. These technique get good effort in low permeability reservoir in Changqing oilfield. As sandbody of Chang 8 layer in Zhenbei area is boiled up and there is no obvious interbed, the main method is multi stage sand and oriented perforating[1-3], displacement of pump increased to 2.6 m^3/min, meanwhile in order to form a long fracture, volume of sand increased to 40 m^3, oil produced per day is 6.5 t/d, water produced per day is 3.7 m^3/d.

Study the reason of low production, introduce fracturing technique, study the ability of fracturing, change the way of fracture distribution and form a fracturing method of this area.

1. OPTIMIZATION AND STUDY THE WAY OF FRACTURE DISTRIBUTION

1.1 Test and Evaluate of Reservoir Fracturing

Evaluating reservoir fracturing is an important way of studying direction and form of hydraulic fracture. Friability index is an important target of evaluating reservoir fracturing. In this paper, combined with exploration well data, calculation way is mineral content. The calculation way is the following:

$Bi = C_{SiO_2} / (C_{SiO_2}+C_{clay}+C_{carbonate\ rock})$,

where：Bi—Friability index, %;

C_{SiO_2}—Mass fraction of SiO_2, %;

C_{clay}—Mass fraction of clay, %;

$C_{carbonate\ rock}$—Mass fraction of carbonate rock, %.

Study shows that when friability index of tight and thick layer is larger than 50%, complicate fracture can be formed[4]. Test result shows this area has the potential to form complicate fracture.

Table 1
Evaluate Result of Friability Mineral

Well number	Layer	Content%							Friability index
		Quartz	Plagioclase	Potassic feldspar	Calcite	Dolomite	Siderite	Clay	%
H305	Chang 8	38.7	21.58	10	3.03	3.93	1.73	21.05	52.96
H56	Chang 8	43.33	22.65	9.75	2.35	3.3	0.7	17.93	49.43
M30	Chang 8	29.08	13.83	5.35	10.38	6.53	4.55	30.3	35.09
M59	Chang 8	31.8	20.68	8.88	7.23	3.03	4.08	24.33	42.95
ZH176	Chang 8	29.85	19.85	7.63	16.95	4.33	0.2	21.2	38.1
Average		34.55	19.72	8.33	7.99	4.22	2.25	22.96	43.71

1.2 Analyze the Condition of Fracture Forming

1.2.1 Test and Evaluate of Horizontal Main Stress

The smaller difference between the two horizontal main stress, the easier to form complicate fracture.

Using the acoustic emission Kaiser effect method, test stress of different directions. The following is calculation way.

$$\sigma_V = \sigma_\perp + \xi P_p, \qquad (1)$$

$$\sigma_H = \frac{\sigma_{0^\circ} + \sigma_{90^\circ}}{2} + \frac{\sigma_{0^\circ} - \sigma_{90^\circ}}{2}\left(1 + tg^2 2\alpha\right)^{\frac{1}{2}} + \xi P_p, \qquad (2)$$

$$\sigma_h = \frac{\sigma_{0^\circ} + \sigma_{90^\circ}}{2} - \frac{\sigma_{0^\circ} - \sigma_{90^\circ}}{2}\left(1 + tg^2 2\alpha\right)^{\frac{1}{2}} + \xi P_p, \qquad (3)$$

$$\mathrm{tg}\,2\alpha = \frac{\sigma_{0^\circ} + \sigma_{90^\circ} - \sigma_{45^\circ}}{\sigma_{0^\circ} + \sigma_{90^\circ}}. \qquad (4)$$

Where: σ_v is overlying formation stress; σ_H, σ_h is maximum and minimum horizontal main stress; P_p is formation pore pressure; ξ is valid stress factor; $\sigma_\perp$ is vertical core Kaiser point stress; σ_{0°, σ_{45°, σ_{90° is 0°, 45°, 90° horizontal core Kaiser point stress.

Difference of horizontal stress of this area is small, 4.1-4.6 MPa, increase net pressure to 4.6 MPa can form a complicate fracture.

Table 2
Formation Stress of Chang 8 Layer of Zhenbei Area

Well number	Layer	Core depth	Max horizontal stress	Max horizontal stress gradient	Min horizontal stress	Min horizontal stress gradient	Difference of horizontal stress	Vertical stress	Vertical stress gradient
		m	MPa	MPa/m	MPa	MPa/m	MPa	MPa	MPa/m
H305	Chang 8	2,450.6	41.7	0.017	37.2	0.0152	4.5	48.2	0.02341
H56	Chang 8	2,584.3	43.9	0.017	39.5	0.0153	4.4	58.5	0.02245
M30	Chang 8	2,653.5	44.2	0.0167	40.1	0.0151	4.1	61.6	0.02303
M59	Chang 8	2,589.2	43.3	0.0167	38.7	0.0129	4.6	58.4	0.02244
ZH176	Chang 8	1,949.5	32.8	0.0168	28.5	0.0146	4.3	45.1	0.02312
Average		2,445.4	41.2	0.01684	36.8	0.01502	4.4	54.3	0.02292

1.2.2 Calculation and Evaluation Conditions for Opening the Natural Fracture

A CT scan[5] is usually adopted to observe the natural fracture, the CT was carried out on the Zhenbei Chang 8 reservoir natural core 3D scanning and found that the reservoir exists natural micro fracture to a certain extent.

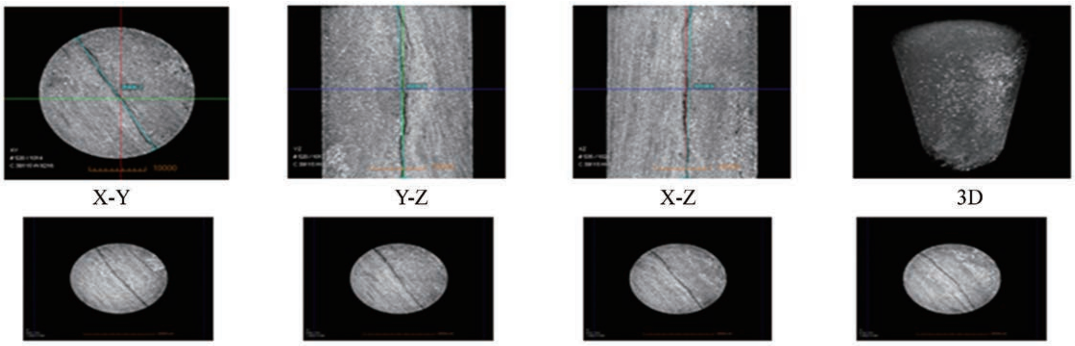

Figure 1
CT Scanning Picture of Zhenbei Area z308 Well

Open the natural fracture and forming cracks are favorable conditions to form complex fracture, according to the failure criterion of Warpinski and Teufel, when natural fracture extensional fracture occurs, the net pressure inside seam required is[6-8].

$$P_{\text{net}} > \frac{\sigma_H - \sigma_h}{2}(1-\cos 2\theta). \tag{5}$$

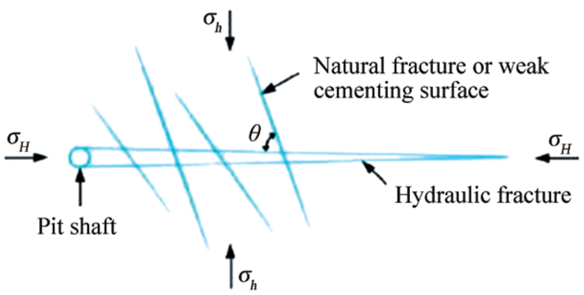

Figure 2
Chart of the Opening of Natural Fracture

Where:
P_{net}: Net pressure;
σ_H: Maximum horizontal main stress;
σ_h: Minimum horizontal main stress;
θ: Angle between natural and horizontal fracture.

When θ=90°, the P_{net} obtain maximum-σ_H-σ_h. Horizontal stress difference of Zhenbei Chang 8 levels have been measured, stress difference is 4.1-4.6 MPa, the maximum net pressure need to open the natural fractures is 4.1-4.6 MPa.

To form teams make the cracks in the rock burst of ontology, according to the theory of rock mechanics, the net pressure inside the crack in numerical level should be at least more than two to the differential stress and tensile strength of rock, the sum has been measured rock tensile strength is 2.6 MPa, the town of north long form complex crack the net value of 5.7-5.7 MPa pressure.

Therefore, calculated by the above, realize that through engineering method, improved a net seam pressure up to 5.7-7.2 MPa, a complex fracture can be formed. The original fracture distribution way of multi-stage sand directional perforation can be changed into a relatively complex volume fracture.

2. PARAMETER OPTIMIZATION OF FRACTURING PROCESS

2.1 Volume Fracturing Process of Mixed Water

The process aims to form the maximum contact area with the reservoir, slippery liquid water, the linear glue and crosslinking liquid of different combination is selected to form the mixed water fracturing fluid system, 100 mesh, 40/70 mesh, 30/50 mesh and 20/40 mesh of different particle sizes of quartz sand and ceramsite as proppant, using injection way of large amount of fluid, large displacement volume and low sand ratio[9-10].

2.2 Optimization of Fracturing Liquid Displacement Volume

It has already proved that the net pressure value needs to form complex fracture is 5.7-7.2 MPa from item 2.2. At the same time, in order to avoid invalid fracturing, still need to determine the upper limit of the ascension net pressure. Interpretation the in-situ stress profile using ROCK system in combination with core experimental results, the reservoir interlayer stress difference calculated is 7.6 MPa. The net pressure control in 7.2-7.6 MPa is relatively reasonable, according to the theory calculation of indoor, the relationship between displacement volume and net pressure chart the is obtained, optimization construction displacement volume is 6-8 m^3/min by chart.

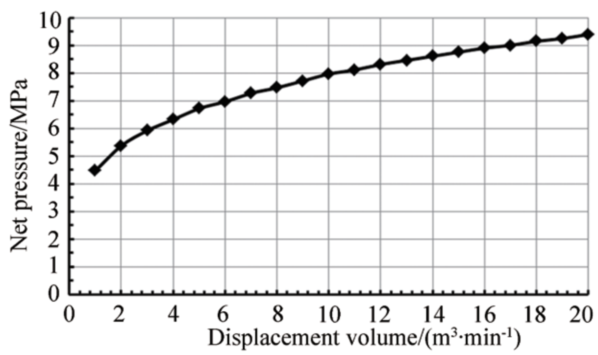

Figure 3
Relationship Between Displacement Volume and Net Pressure

2.3 Optimization of Proppant

Table 3
Static State Rock Mechanics Parameters of Zhengbei Chang 8 Layer

Well number	Layer	Depth	Density	Confinement pressure	Compressive resistance	Elastic modulus	Poisson's ratio	Resistance to tension
		m	g/cm^3		MPa	×10^4 MPa		MPa
H305	Chang 8	2,450.6	2.477	25	181.565	2.348	0.223	5.77
H56	Chang 8	2,584.3	2.425	25	164.336	2.283	0.225	7.21
M30	Chang 8	2,653.5	2.616	25	198.704	2.847	0.205	8.5
M59	Chang 8	2,589.2	2.491	25	166.785	2.558	0.242	6.07
ZH176	Chang 8	1,949.5	2.559	20	217.511	3.11	0.277	9.91
Average		2,445.4	2.514	24	185.78	2.629	0.234	7.49

3. ON SPOT APPLICATION EFFECT

Mixed water volume fracturing was applied on 52 wells, oil production increased from 6.5 t/d to 21.2 t/d.Net pressure improved 5-8 MPa, G function curve shows fracture open character is obvious.

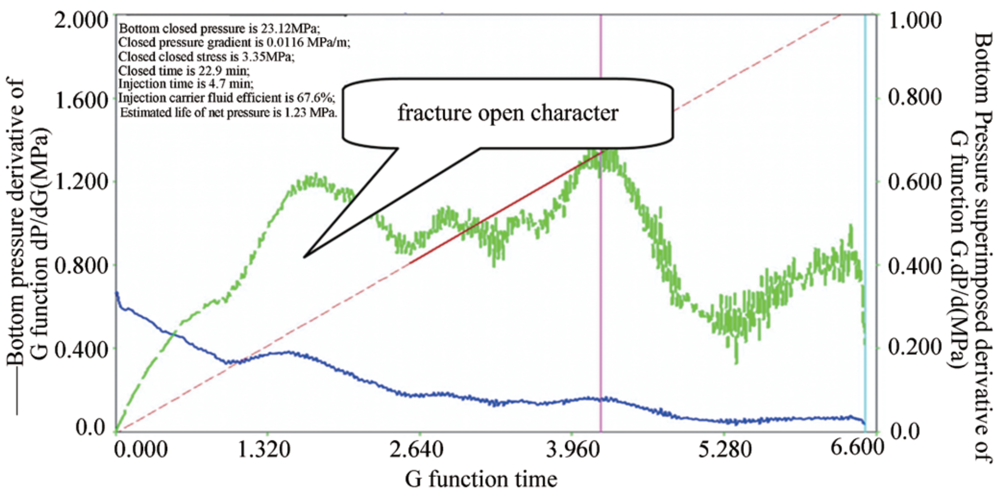

Figure 4
G Function Curve of ZH452 Well Fracturing Test

Meanwhile, this technique guide the production of this area. Average production is 800 t. This is 2.6 times of the fixed spot perforation using the same sand.

SUMMARY

(a) Zhenbei area of Changqing oilfield, Chang 8 reservoir is thickness and poor physical property, using the mixed water volume fracturing, increasing the contact surface area with the reservoir, get good reservoir modification effect.

(b) Laboratory rock mechanics parameters, reservoir interlayer stress difference and analysis the ability of fracturing, is an effective method for analysis of fracture morphology and distribution.

(c) By the method of engineering, combined with the feature of reservoir stress profile, analysis of natural micro cracks open conditions, reasonable increase of net pressure is an important way to form a complex fracture.

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