FRACTURE SIMULATION AND PARAMETER OPTIMIZATION OF HYDRAULIC FRACTURING ON GUANDONG SHALE OIL IN DAGANG OILFIELD

by

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The Dagang Oilfield has developed a multi-layered 3-D technology for terrestrial shale oil, but challenges such as multiple faults, vertical bedding, superimposed oil-bearing layers, and limited vertical modification lead to inconsistent effectiveness. To address this, this study establishes a 3-D geological model of the Guandong shale oil (GY) block, integrating fracture parameter inversion from construction pressure and logging data, calibrated through historical matching. It examines fracture morphology, well spacing, horizontal section length, and fracture parameters, optimizing well patterns and fracturing parameters using an orthogonal experimental method. Additionally, an evaluation system combining the analytic hierarchy process and fuzzy comprehensive evaluation provides guidance for efficient shale oil reservoir development.

Key words: *Dagang oilfield, shale oil, 3-D geological model, historical matching, analytic hierarchy process*

Introduction

Located in Huanghua Depression, Dagang Oilfield (17664 km²) contains three key shale strata: Kong-2, Sha1, and Sha3. Cangdong Depression's Kong-2 Section (400 m thick, 260 km² area) features micropores/fractures and 45°-60° NE stress alignment. The GY5 Block's four horizontal wells show varied production due to strata and parameter differences [1, 2].

Establishment and calibration of the 3-D geological model

The 3-D geological model

Block GY5's structural model utilized vertical wells (GD6X1, GD4, GD12, GD13, and GD15) and horizontal wells for sub-layer division, with 10 m × 10 m planar grids and three vertical layers. Cangdong faults aligned to maximum horizontal stress.

Property model

Combining structural models and well data (vertical GD6X1/GD4/GD12, horizontal wells) minimized interpolation randomness. Arithmetic/harmonic means discretized porosity,

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oil saturation, pressure, and permeability. Sequential Gaussian simulation generated porosity (0.45%-9.2%), permeability (0.0213-0.3004 mD), and oil saturation (0-0.45) models, see figs. 1(a)-1(c) [3, 4].

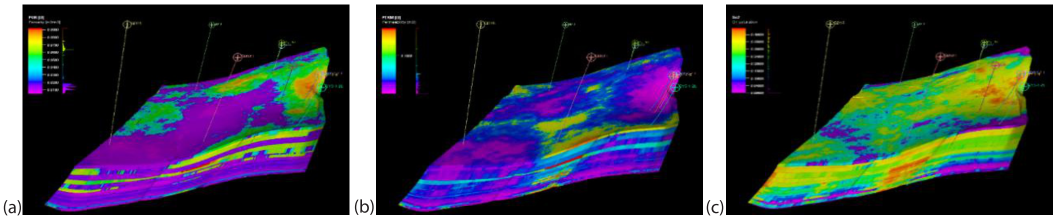

Figure 1. Porosity, permeability and oil saturation model of GY5 block; (a) porosity, (b) permeability, and (c) oil saturation

History matching

The 3-D model's accuracy, based on inter-well interpolation, was validated through historical matching, confirming alignment with actual reservoir characteristics. The GY5-1-9H and GY5-3-1H fitting results demonstrate reliable stratigraphic representation, tab. 1.

Table 1. Production of horizontal wells in block GY5

Well name	Production time	Cumulative oil production [m^3]	Cumulative water production [m^3]	Cumulative liquid production [m^3]
GY5-1-9H	2020.12.28-2022.4.29	11415.67	5259.98	16675.65
GY5-3-1H	2021.3.9-2022.4.29	11102.97	3792.81	14895.78

Numerical simulation for fracture optimization

Three new C3 horizontal wells (GY5-3-6H/7H/8H) on GY5 platform underwent simulation-based optimization. A 200×200×1 grid (10m spacing) black oil model with local refinement and equivalent fracture conductivity was developed using Guandong data, see tab. 2) [5-7].

Table 2. Model parameter table of C3 layer

Argument		Symbol	Unit	Average value
Formation physical property	Porosity	φ	[%]	6.01
	Oil saturation	So	[%]	39
Fluid property	Crude-oil viscosity (50 ℃)	μ	[mPa·s]	110
	Crude specific gravity	ρ	[g/m3]	0.90
In-situ stress	Initial formation pressure	σ_h	[MPa]	41
Horizontal well parameter	Well spacing	S	[m]	300
	Horizontal well length	L	[m]	1809-1920

Optimization of fracture distribution method

A Discrete fracture network (DFN) model simulated multi-stage hydraulic fracturing in the C3 layer, considering stress shadowing. Staggered fracturing outperformed aligned fracturing, achieving larger stimulated reservoir volume (SRV) and higher oil production, making it the preferred strategy for enhancing reservoir stimulation efficiency, figs. 2-4, [8].

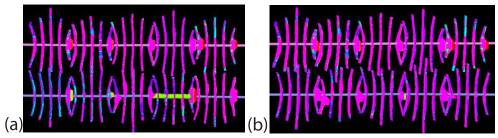

Figure 2. Fracture morphology of different Sewing method; (a) orthogonal fracture and (b) staggered fracture

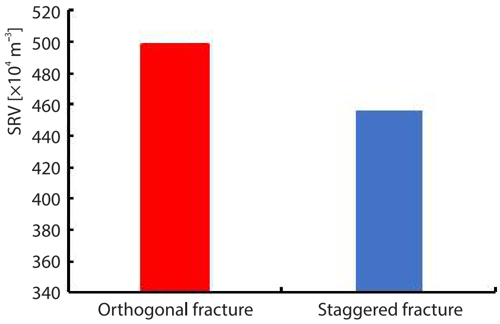

Figure 3. The SRV comparison diagram

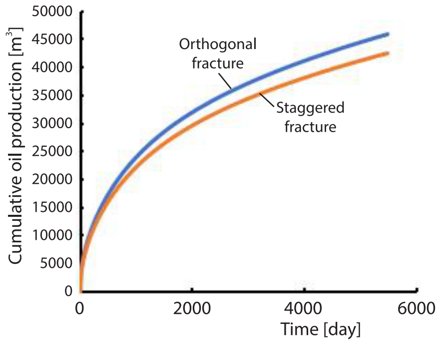

Figure 4. Oil production comparison chart

Fracturing technique optimization

Simulations comparing synchronous and zipper fracturing show zipper fracturing achieves 1.06 times the production enhancement of aligned fracturing and slightly higher cumulative production, figs. 5-7. As staggered fracturing modifies lateral regions effectively, zipper fracturing is preferred for enhancing far-end wellbore stimulation [9].

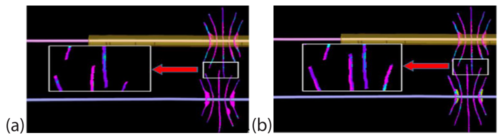

Figure 5. Fracture morphology of different fracturing techniques; (a) synchronous fracturing and (b) zipper fracturing

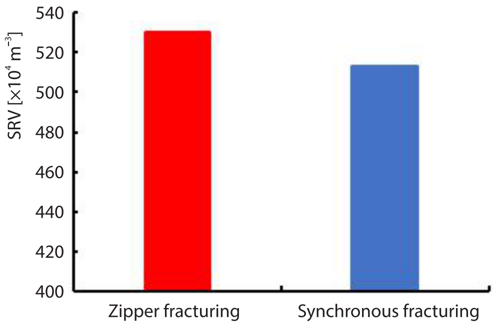

Figure 6. The SRV comparison diagram

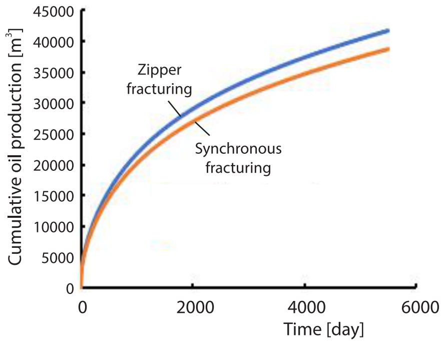

Figure 7. Oil production comparison chart

Well spacing optimization

Simulations evaluated cumulative production with varying well spacing, a 10 m fracture spacing, 6 D·cm fracture conductivity, and 160 m fracture half-length. Results show optimal well spacing is 350-400 m, balancing resource utilization and avoiding issues like fracture channeling or insufficient inter-well stimulation, fig. 8, [10].

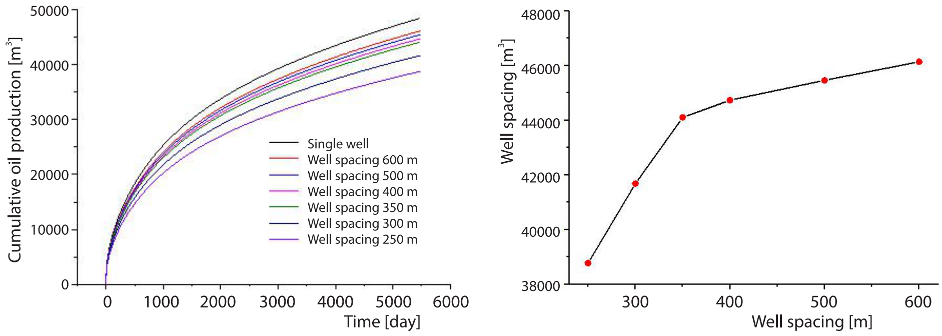

Figure 8. Change of cumulative oil production with time in different well spacing

Horizontal section length optimization

Horizontal section lengths ranging from 1200-2200 m were simulated. Production increased with length but plateaued after 1800 m, making it the optimal horizontal section length for balancing production and cost, fig. 9. [11].

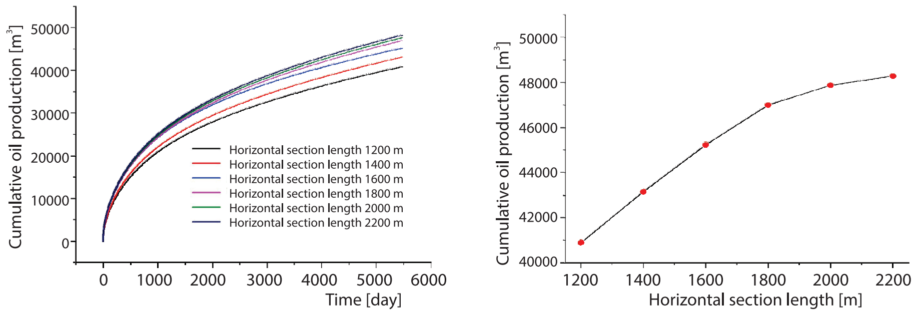

Figure 9. Variation of oil production in different horizontal stages

Fracture parameter optimization

Fracture half-length

Simulations evaluating fracture half-length (100-180 m) under fixed parameters (1800 m lateral, 20 D·cm conductivity, 10 m clusters) showed longer fractures boosted output but risked overlap at 300 m spacing; 140 m optimal, fig. 10.

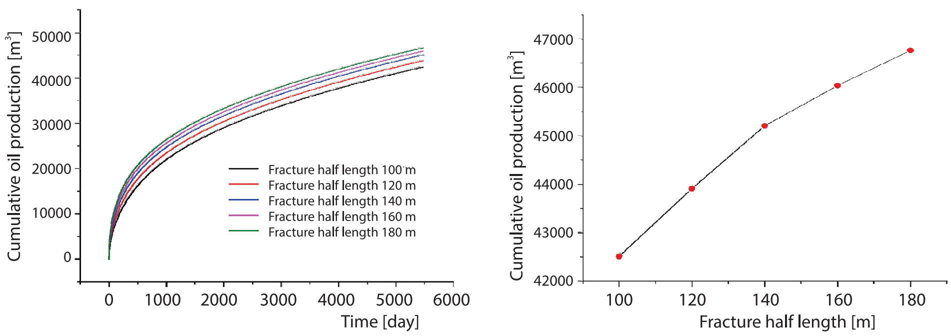

Figure 10. Variation of oil production in different fracture half-length

Cluster spacing

Simulations with cluster spacings of 5-20 m show smaller spacings boost initial and cumulative oil production, with diminishing returns. Significant gains occur between 10-20 m. Considering production and costs, 10 m cluster spacing is recommended for the GY5 block, fig. 11.

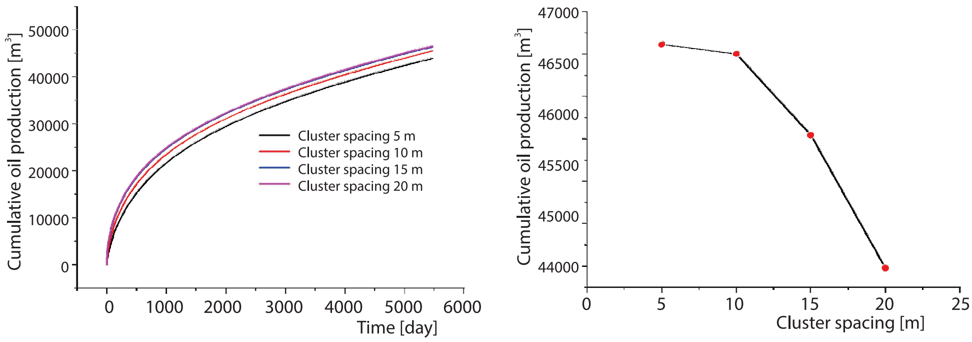

Figure 11. The effect of cluster spacing on pressure

Optimization of hydraulic fracturing parameters based on orthogonal analysis

Sixteen experimental schemes combining well spacing, horizontal section length, fracture half-length, and cluster spacing were analyzed, tabs. 3-4. Horizontal section length and fracture half-length most affected production, while well spacing influenced inter-well interference. Scheme 9 achieved optimal production with minimal interference, identifying the best parameter combination.

Table 3. Visual table of range analysis

	Argument	Well spacing	Length of horizontal section	Fracture half-length	Cluster spacing
Cumulative production	M1	45056	44269	44149	46498
	M2	46863	44833	46740	46389
	M3	45568	47067	46782	45145
	M4	45441	47659	46857	44496
	R1	1807	3390	2708	2002
Interference rate between productive wells	M1	0.226	0.127	0.124	0.144
	M2	0.156	0.17	0.155	0.157
	M3	0.1	0.147	0.185	0.108
	M4	0.095	0.135	0.192	0.079
	R2	0.131	0.043	0.068	0.065

Table 4. Best parameter combination

Well spacing [m]	Length of horizontal section [m]	Fracture Half-length [m]
350-400	1800	140
Cluster spacing [m]	Fracturing technology	Horizontal bearing [°]
10	Staggered distribution and zipper fracturing	0

Conclusion

This study optimized shale oil development in the C3 layer through geological modelling validated by historical matching. Production-pressure interference analysis and orthogonal tests identified optimal parameters: 350-400 m well spacing, 1800 m lateral length, 140 m fracture half-length, and 10 m cluster spacing. The zipper fracturing with the staggered spacing has enhanced the reservoir stimulation by 23%. The mitigating stresses the interference. These solutions significantly improve horizontal well performance, offering practical guidance for analogous shale reservoirs.

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