

Optimization Study on Fracture Morphology Based on Different Reservoir Types

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Abstract: The research on the optimization of hydraulic fracturing fracture morphology is an essential aspect of hydraulic fracturing design. However, suboptimal fracture morphology resulting in lower than expected production often occurs due to the mismatch between reservoir types and hydraulic fracturing operational parameters. Different geological sweet spot reservoirs require distinct optimal fracture morphologies. In this paper, we categorize reservoirs into types I, II, and III, considering them as preferred layers for hydraulic fracturing. Three geological models are established to investigate the impact of fracture length and fracture conductivity on post-fracturing productivity, aiming to determine the optimal fracture morphology. The findings of this research will provide a scientific basis for the development of tight sandstone gas reservoirs in the Ordos Basin.

Keywords: Reservoir classification, Fracture morphology, Fracture length, Conductivity.

1. Introduction

The favorable exploration area for onshore tight gas in China covers 32.46×10^4 km², with estimated reserves of 21.85×10^{12} m³, mainly distributed in basins such as the Ordos, Bohai Bay, and Sichuan. The Ordos Basin alone holds over 12×10^{12} m³ of tight sandstone gas resources, accounting for approximately 83% of the total natural gas resources in the basin, primarily concentrated in the Sulige area [1].

Horizontal wells serve as an effective method to enhance single-well production in tight sandstone gas reservoirs. The geological characteristics of the Ordos Basin's tight sandstone gas reservoirs show rapid lateral variations and vertical multi-layer development, posing challenges for the effective development of large-scale horizontal wells. In recent years, as the quality of the tight gas reservoirs in the basin has declined and reservoir conditions have become more complex, especially in regions like the northern part of the Sulige Gas Field, the demand for effective fracturing and fracture volume in horizontal sections has increased [2]. Currently, horizontal well production in target areas faces difficulties due to the mismatch between construction parameters and reservoir properties, hindering the potential production enhancement from fracturing. The suboptimal fracture morphology caused by the mismatch between reservoir types and hydraulic fracturing operational parameters often leads to lower than expected production. Therefore, optimizing hydraulic fracturing operational parameters to match geological characteristics holds significant practical significance for cost reduction and efficiency improvement.

Conventional fracture parameter optimization methods identify the most suitable and ideal fracture parameters for a specific block, but they fail to consider the actual geological characteristics, resulting in unsatisfactory reservoir modification effects. Hence, it is necessary to study the propagation patterns of hydraulic fracturing fractures in block horizontal wells to determine whether the fracture

morphology formed by fracturing is favorable for oil and gas exploitation. Due to the expensive cost of field experiments and the uncertainties in monitoring data interpretation, numerical simulation currently serves as the primary means to study this issue. By establishing a fluid-solid coupled numerical model for fracture propagation, parameter analysis can reveal the underlying physical mechanisms behind the competition process of multiple fractures' propagation. To seek favorable conditions for the uniform expansion of multiple fractures, this study conducts parameter optimization for different reservoir types based on the geological characteristics of the Sulige area. The goal is to optimize the fracture morphology parameters of hydraulic fracturing to achieve maximum production for different reservoirs, thereby improving the efficiency of hydraulic fracturing operations. The findings of this research will provide a scientific basis for the development of tight sandstone gas reservoirs in the Ordos Basin and also offer strong support and guidance for the development of China's tight gas resources. In the context of global energy transformation, this study will contribute to promoting China's energy structure adjustment and sustainable development, actively contributing to a green, low-carbon, and sustainable energy future[3].

2. Mechanism Model Establishment

Based on the K-means clustering algorithm, the reservoirs in the target block are classified, and three typical reservoir numerical simulation mechanism models are established. The study analyzes the impact of fracture length and fracture conductivity on post-fracturing productivity, aiming to find the optimal fracture morphology suitable for each reservoir type[4]. The parameter range values for this research are set based on previous hydraulic fracturing design and construction results. The study determines the range of semi-fracture length to be between 50 to 200 meters and the range of fracture conductivity to be between 18 to 200 microsquare centimeters.

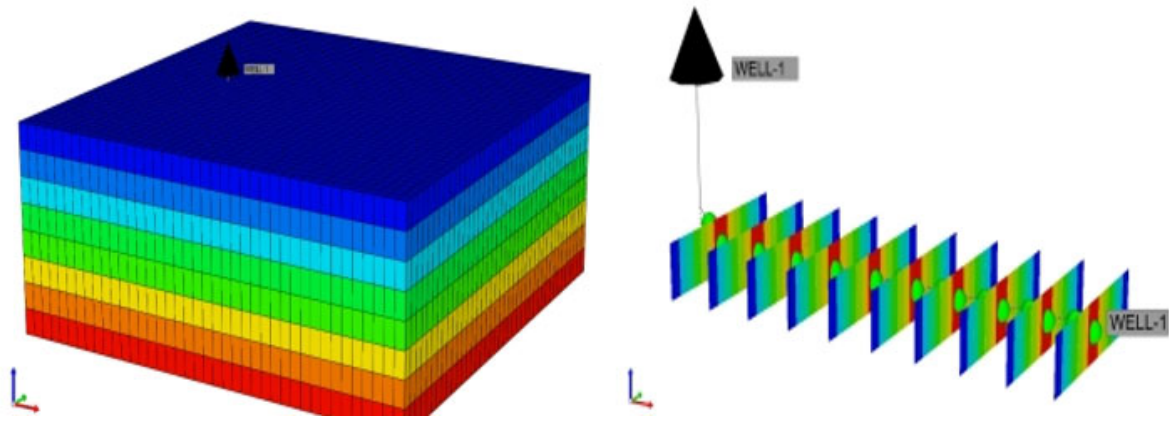


Figure 1. Mechanism Model and Fracture Distribution Diagram of Hydraulic Fracturing Horizontal Wells.

Table 1. Basic Parameters of Numerical Simulation Mechanism Models.

Model Parameters:	Parameter Values		Model Parameters	Parameter Values	
Numerical Simulation Grid	50*50*10		Horizontal Well Length (m)	1000	
Depth (m)	3300		Original Formation Pressure (MPa)	29.6	
Water Saturation (%)	I	53.14	Mud Content (%)	I	11.86
	II	65.4		II	14.3
	III	75.88		III	15.59
Reservoir Permeability (mD)	I	1.22	Reservoir Porosity (%)	I	9.94
	II	0.85		II	8.82
	III	0.59		III	7.87
Fracture Conductivity ($\mu\text{m}^2 \cdot \text{cm}$)	18~200		Number of Fracturing Stages	5~10	
			Fracture Half-Length (m)	50~200	

3. Production Capacity Impact Study

3.1. Impact of Fracture Half-Length

During the construction of horizontal wells, the fracture half-length is a critical factor that directly affects the dynamic productivity of the hydraulic fracturing wells. The fracture half-length is influenced by the distribution of in-situ stresses along the wellbore, the constraints of the fracturing method, and the presence of natural fracture zones. As a result, the lengths of the fractured pathways will vary. To gain a better understanding of this issue, it is essential to conduct an in-depth analysis of the impact of fracture half-length on the productivity of hydraulic fracturing wells[5-6].

For this study, numerical simulations were conducted with different fracture half-lengths of 50m, 75m, 100m, 125m, 150m, 175m, and 200m, considering a fracture conductivity of $70\mu\text{m}^2 \cdot \text{cm}$, to investigate the productivity of hydraulic fracturing horizontal wells. The simulation results are presented in Figure 2.

Increasing the fracture half-length and improving the fracture conductivity can significantly enhance the gas well productivity. However, from the perspective of the cost of the fracturing process, longer fractures are not always better. For the S block, the optimal fracture lengths for different reservoir

types are as follows:

Type I reservoir: recommended fracture half-length of 125-150m.

Type II reservoir: recommended fracture half-length of 150-175m.

Type III reservoir: recommended fracture half-length of 175-200m.

3.2. Impact of Fracture Conductivity

The productivity of hydraulic fracturing horizontal wells is influenced by various factors, with fracture conductivity being one of the most sensitive factors. Fracture conductivity refers to the product of fracture width and permeability. With the continuous development of fracturing technology, the fracture conductivity provided by fracturing processes has also increased. Particularly for low-permeability oil and gas reservoirs, increasing fracture conductivity can significantly enhance the productivity of hydraulic fracturing horizontal wells[7-8]. Numerical simulations were conducted to analyze the impact of fracture conductivity on gas production in hydraulic fracturing horizontal wells. The simulations considered a fracture half-length of 200m and fracture conductivities ranging from $20\mu\text{m}^2 \cdot \text{cm}$ to $160\mu\text{m}^2 \cdot \text{cm}$. The results are presented in Figure 3.

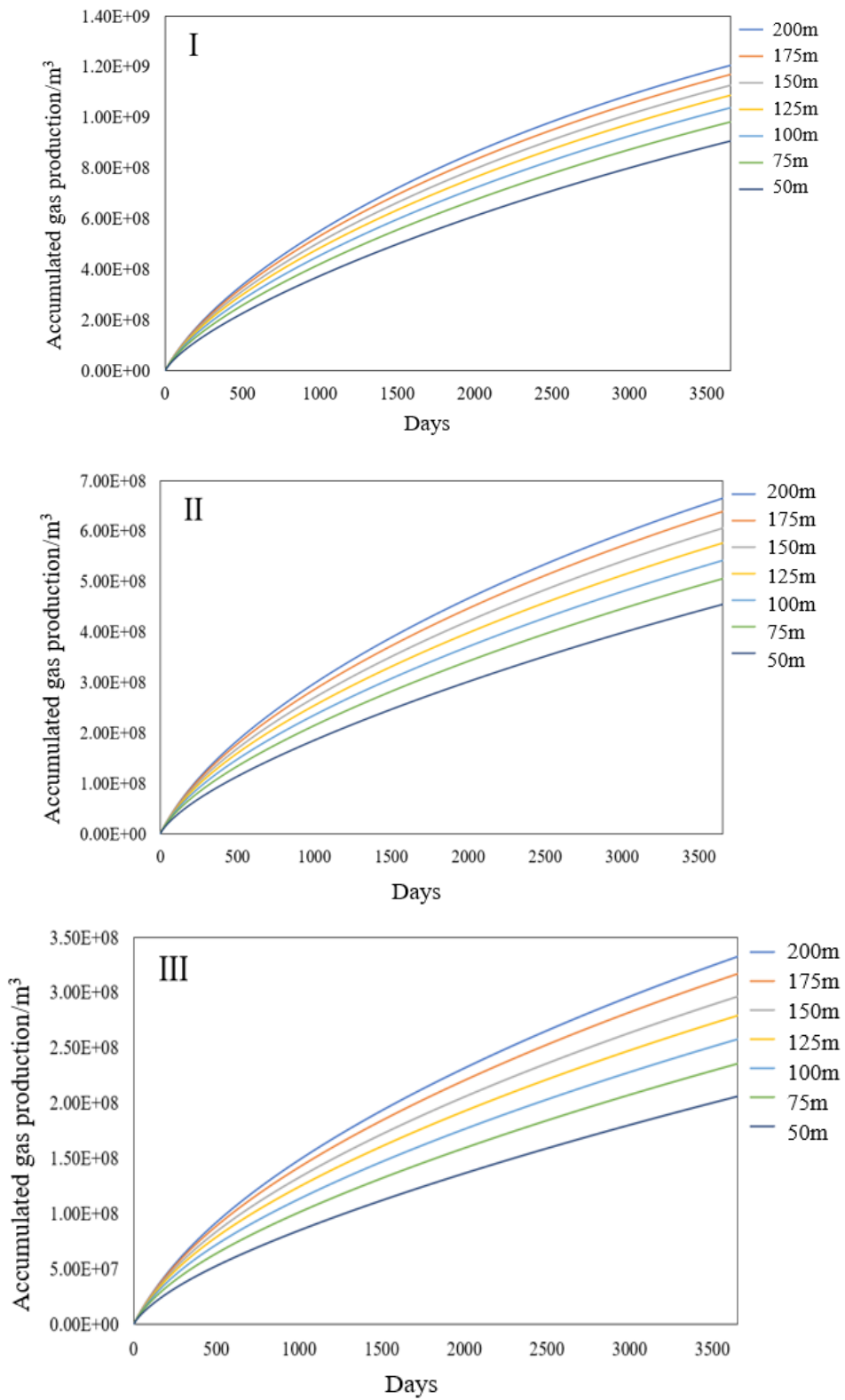


Figure 2. Impact of Different Reservoir Types' Fracture Half-Length on 10-Year Cumulative Gas Production.

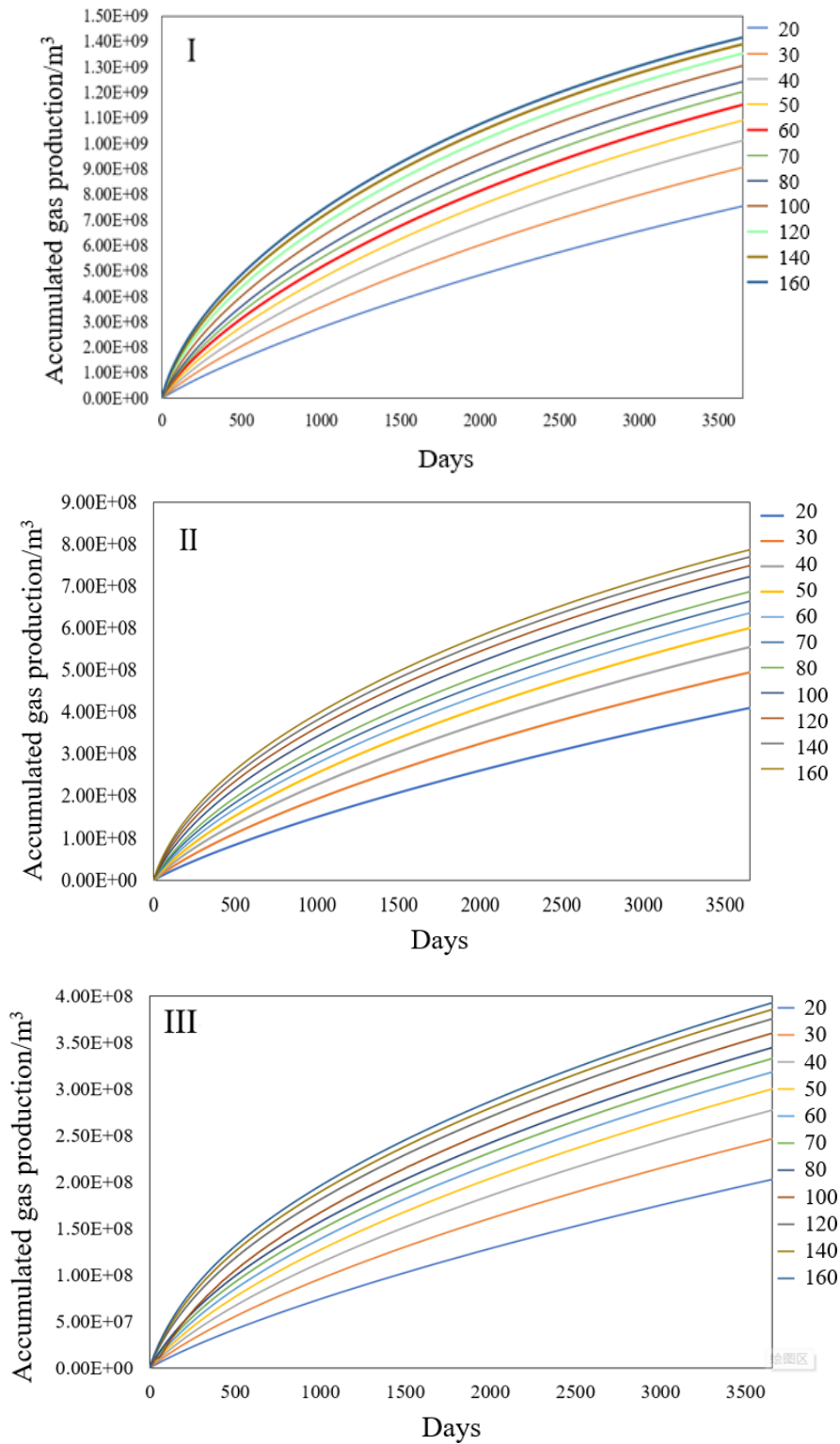


Figure 3. Impact of Different Reservoir Types' Fracture Conductivity on 10-Year Cumulative Gas Production.

Based on the cumulative production data over a period of 10 years, it can be observed that the cumulative gas production of hydraulic fracturing horizontal wells increases with the increase in fracture conductivity[9]. However, when the conductivity reaches a certain level, the increment in cumulative gas production starts to slow down. This is because even though fracture conductivity increases, the reservoir's permeability remains very low, limiting the reservoir's gas supply capacity. As a result, optimizing the fracture conductivity should consider the following recommendations for different reservoir types:

Type I reservoir: recommended fracture conductivity of $60\mu\text{m}^2\cdot\text{cm}$ to $70\mu\text{m}^2\cdot\text{cm}$.

Type II reservoir: recommended fracture conductivity of $70\mu\text{m}^2\cdot\text{cm}$ to $80\mu\text{m}^2\cdot\text{cm}$.

Type III reservoir: recommended fracture conductivity of $70\mu\text{m}^2\cdot\text{cm}$ to $80\mu\text{m}^2\cdot\text{cm}$.

Both fracture length and fracture conductivity have a significant impact on the cumulative gas production over 10 years. They exhibit a pattern of rapid increase followed by a tendency to level off, indicating the existence of optimum values for fracture length and fracture conductivity. Based on

the research results, the following understanding is obtained: for reservoirs with high geological sweetness, characterized by relatively good reservoir properties, the optimal fracture length is relatively small, and the optimal fracture conductivity requirement is relatively high. On the other hand, for reservoirs with lower geological sweetness and relatively poor reservoir properties, the optimal fracture length is relatively large, and the optimal fracture conductivity requirement is relatively low. In summary, under the premise of meeting the minimum fracture parameters of the reservoir, low-geological sweetness reservoirs with poorer properties require longer fractures and lower fracture conductivity, while high-geological sweetness reservoirs with better properties have the opposite requirements.

4. Conclusion

The study categorized three typical reservoir types (I, II, and III) as preferred layers for hydraulic fracturing and established numerical models for hydraulic fracturing to investigate the impact of fracture length and fracture conductivity on post-fracturing productivity. The optimal fracture morphology was determined based on the research results.

Based on the geological and reservoir characteristics of the S block, considering the coupling between the matrix system and the fracture system, stress sensitivity, and non-Darcy flow effects on gas phase flow, a three-dimensional two-phase gas reservoir mathematical model for segmented hydraulic fracturing horizontal wells was established.

Three typical reservoir hydraulic fracturing mechanism models were established to analyze the impact of fracture half-length and fracture conductivity on post-fracturing productivity. It was found that for high-geological sweetness Type I reservoirs, due to their relatively good properties, the optimal fracture length is relatively small, and the optimal fracture conductivity requirement is relatively high. Conversely, for low-geological sweetness Type III reservoirs, due to their poorer properties, the optimal fracture length is relatively large, and the optimal fracture conductivity requirement is relatively low.

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