Research and Application of Horizontal Well Volumetric Fracturing Technology

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Abstract: As an innovative technology in the current development of oil and gas fields, horizontal well volume fracturing technology plays a decisive role in the development of unconventional oil and gas reservoirs. By injecting high-pressure cracking fluid into the formation, this technology causes rock fracture to form a complex fracture network, greatly expanding the flow path of oil and gas from the reservoir to the wellhead, and effectively improving the oil and gas recovery. The scientific principle behind horizontal well volumetric fracturing technology is deeply discussed, and the key technical parameters of the technology are analyzed in detail, such as the property of fracturing fluid, the formation and propagation of fractures, and the precise control of fracturing operation. At the same time, the technical challenges and environmental risks encountered in the actual operation of horizontal well volume fracturing technology are discussed, and specific countermeasures and optimization methods are put forward. Through the analysis of several examples, the significant effects of horizontal well volume fracturing technology in improving the development efficiency and reducing the development cost of unconventional oil and gas fields are demonstrated, and its future application prospect and development direction are prospected, emphasizing the importance of continuous technological innovation in realizing the efficient development of unconventional resources.

Keywords: Horizontal Well; Volume Fracturing; Unconventional Oil and Gas Reservoirs; Development Efficiency; Optimization Strategy

1. Introduction

With the continuous growth of global energy demand, the development of unconventional oil and gas resources has become an important direction of the petroleum industry. As one of the effective technologies for the development of unconventional oil and gas reservoirs, the research and application of horizontal well volume fracturing technology has attracted wide attention.By improving the physical characteristics of the reservoir, this technology greatly improves the recoverable ability of oil and gas, and provides technical support for the development of unconventional oil and gas reservoirs.

2. Principle of Horizontal Well Volumetric Fracturing Technology

2.1 Technical Principles Overview

Horizontal well volume fracturing technology plays a crucial role in the development of unconventional oil and gas reservoirs. Through careful design and implementation, it can create a complex fracture network in the underground rock layer, greatly increase the permeability of the reservoir, and thus effectively improve the flow and exploitation feasibility of oil and gas [1].This process involves injecting high pressure liquid into horizontal Wells to fracture formation rock at high pressure to create artificial fractures. This method not only opens up tiny fractures in the rock, but also extends the length and scope of the fractures to significantly increase the effective permeability area of the reservoir.Injecting sand or other types of proppant into the fracture after formation can effectively keep the fracture open and prevent the fracture from closing as the formation pressure recovers, ensuring the free flow of oil and gas through these artificially created permeability channels.The formation and maintenance of these fracture networks provide direct access for oil and gas from the reservoir to the wellhead, significantly improving the economic recovery efficiency of unconventional reservoirs.Optimizing fracturing fluid

formulation and proppant selection can further improve fracturing efficiency and oil and gas recovery while reducing potential environmental impact, making horizontal well volume fracturing a key technology in oil and gas development today.

2.2 Key Technical Parameters

In the implementation of horizontal well volumetric fracturing technology, precise control of key technical parameters is crucial to achieve the best fracturing results and improve oil and gas production efficiency. The properties of fracturing fluid, including its viscosity, sand carrying capacity and frictional resistance, are the basis for determining fracture formation and propagation efficiency.The ideal fracturing fluid should have sufficient viscosity to more effectively carry and deploy proppant in the fracture, while maintaining low friction resistance to reduce energy consumption during pumping.The performance of fracturing fluids can be further improved by the addition of chemicals, such as anti-friction agents and thickeners, and the selection and ratio of these additives need to be carefully designed according to the specific geological conditions and fracturing objectives.The selection of the construction pressure and duration is optimized based on the geology and the design of the intended fracture network, the construction pressure needs to be high enough to ensure the formation and expansion of fractures in the rock, and the duration needs to be controlled to allow the fracture to expand to the desired length without unnecessary waste of resources.At the same time, real-time monitoring and adjustment during the construction process is essential to adapt to the complex underground conditions to ensure maximum fracturing results.

The type and amount of proppant is also one of the decisive factors in fracturing performance. Selecting the right proppant type (such as natural sand or man-made ceramic) and particle size distribution can effectively keep fractures open, thereby enhancing fracture stability and permeability. The amount of proppant needs to be accurately calculated based on the size, length and distribution density of the fracture.To ensure that each fracture in the fracture network can effectively support the opening and achieve optimal oil and gas mobility.The precise control and optimization of fracturing fluid properties, pressure and duration, as well as proppant types and amounts, can significantly improve the efficiency of horizontal well volumeter fracturing and achieve efficient development of unconventional reservoirs, which requires a deep understanding of every detail of fracturing technology and accurate mastery in order to design the best fracturing solution.Fully release the potential of oil and gas reservoirs [2].

3. Technical Implementation Process

3.1 Construction Preparations

Construction preparation is the basis for the successful implementation of horizontal well volumetric fracturing technology, which covers many key links such as precise selection of well location, meticulous construction design, and careful preparation of equipment and materials.Well location selection is the first step, requiring an in-depth geological survey and assessment to determine the best well location to maximize the efficiency of oil and gas production, while taking into account environmental protection and other surface or subsurface stakeholders.Then, during the construction design phase, the team had to design the best fracturing plan by considering formation characteristics, the desired fracture shape, length, and distribution orientation. This included selecting the right fracturing fluid formula, the type and amount of proppant, and determining the pressure and duration required during the construction process.At the same time, preparation is also indispensable, involving the inspection and maintenance of all construction equipment, ensuring its normal operation, and the procurement and acceptance of all materials to ensure that their quality meets the requirements of the project.The team also needed to ensure the safety training of on-site construction personnel and the development of emergency plans to deal with various scenarios, which provided a solid guarantee for the smooth operation of fracturing construction, and is the key to achieving oil and gas production objectives and ensuring operational safety.

3.2 Fracturing Construction

Fracturing is the most critical step in horizontal well volum fracturing technology, which directly determines the quality of fractures and the ultimate efficiency of oil and gas extraction. This process starts with the precise injection of fracturing fluid, which is injected into the

predetermined formation by high pressure pump and uses its high pressure to break the rock and form tiny fractures.As the fracture grows, the proppant carried in the fracturing fluid enters the fracture. Its main role is to keep these fractures open after the fracturing fluid is recovered, ensuring that oil and gas can flow through these artificial fractures efficiently.In the construction process, it is particularly important to control the injection rate and pressure of fracturing fluid, which is not only related to whether the fracture can reach the predetermined expansion direction and length, but also a key factor affecting the final mining efficiency [3].After injection, recovery of the fracturing fluid begins as the pressure is gradually reduced, a phase that not only helps to protect the environment and reduce liquid waste, but also provides preliminary data for evaluating the fracturing effect by analyzing the nature and quantity of the return fluid.Behind this series of fine operations is a deep understanding of technical details and a precise grasp of the construction environment. Each step requires precise control and meticulous operation to ensure the successful execution of fracturing construction, thus maximizing the development efficiency and production of oil and gas fields and maximizing economic benefits [4].

4. Technical Application Effect

4.1 Increase Oil and Gas Production

The application of horizontal well volumefracturing technology has become a revolution in unconventional reservoir development, and its effectiveness in significantly increasing oil and gas production has been demonstrated in numerous cases. Through carefully designed and executed fracturing operations, dense fracture networks are created in the target formation, greatly increasing the flow channels of oil and gas.Thus, oil and gas resources that are difficult to exploit can be extracted efficiently.Especially in the development of unconventional resources such as tight oil and gas reservoirs and shale gas reservoirs, the introduction of horizontal well volumetric fracturing technology has made a qualitative leap in production compared with the traditional vertical well development method, which not only greatly improves the production of a single well, but also significantly improves the economic benefits of the entire oilfield.This technology can effectively stimulate the reservoir by optimizing the distribution, direction and density of fractures, and further optimize the physical characteristics and flow conditions of the reservoir. At the same time, changes in the surrounding stress field during fracturing also provide opportunities for further expansion of natural fractures in the reservoir and increase the degree of oil and gas recovery.Horizontal well volume fracturing technology not only improves oil and gas recovery, but also provides a key technical way for oil and gas industry to effectively improve resource recovery and promote efficient development of oil and gas fields through continuous optimization and innovation of technology and process.

4.2 Optimize Reservoir Development

Horizontal well volume fracturing technology is of great significance for optimizing reservoir development. It not only increases oil and gas production, but also improves the physical characteristics of the reservoir and optimizes the flow conditions of oil and gas. By artificially creating fractures, this technology increases the permeability of the reservoir and enables the oil and gas that are not easily flowing to flow out smoothly.The proppant during the fracturing process effectively keeps the fracture open and prevents the fracture from closing due to formation pressure, thus ensuring long-term productivity.Furthermore, horizontal well volume fracturing technology can precisely control the formation of fractures, realize the orderly development of the reservoir, and avoid the disorderly exploitation and waste of resources. Through case analysis, it can be seen that after the application of this technology, the recoverable reserves of oil and gas fields are significantly improved, and the development efficiency is greatly improved.For example, for unconventional resources such as shale gas, traditional development methods are difficult to achieve economic and feasible exploitation, but the application of horizontal well volume fracturing technology not only makes the development of these resources possible, but also significantly improves the economy of development.By improving reservoir physical characteristics and oil and gas flow conditions, horizontal well volume fracturing technology provides an efficient and economical development plan for unconventional oil and gas

reservoirs and other hard-to-develop oil and gas resources [5].

5. Challenges and Countermeasures

5.1 Environmental and Security Risks

There are a series of environmental and safety risks in the implementation of horizontal well volume fracturing technology, and strict measures need to be taken to manage and mitigate them.Groundwater contamination is one of the most significant environmental risks, especially when fracturing fluids can penetrate into groundwater formations, and the potential impact of this risk is particularly significant for communities that rely on groundwater as a source of drinking water.A thorough geological assessment and environmental risk analysis is therefore a necessary step before a fracturing project starts to ensure that all fracturing activities are conducted away from sensitive and vulnerable water sources, the use of environmentally friendly chemical additives, and the use of advanced wellbore sealing technology to prevent any possible leakage are effective measures to mitigate the environmental impact.Ground shaking issues, while not usually leading to serious geological hazards, can cause public concern and unease under certain conditions, especially when fracking operations are conducted near urban or densely populated areas.Therefore, detailed vibration impact assessment of the areas that may be affected by fracturing operations and the development of scientific and reasonable fracturing plans to minimize the possibility of ground vibration have become an important means to alleviate community concerns.At the same time, transparent communication with local communities and the public about fracking plans, expected impacts, and risk control measures can improve public understanding and acceptance of oil and gas development activities.Through comprehensive risk assessment, adoption of environmental protection technologies, strengthening site safety management, and establishing a good public communication mechanism, environmental and safety risks during the implementation of horizontal well volume fracturing technology can be effectively managed and reduced to ensure the sustainable development of fracturing activities, while maintaining the safety of communities and the environment.

Table 1. Research and Application Parameters of Volume Fracturing Technology of Horizontal Well

The parameter name	minimum	average value	maximum	unit
injection pressure	5000	10000	15000	psi
Injection rate	8	12	20	bbl/min
crack length	50	100	300	m
crack width	0.1	0.15	0.25	mm
fracture height	10	50	100	m
Support agent concentration	250	375	500	kg/m³
Type of support agent	20/40	30/50	40/70	mesh
Sticality of fracturing fluid	5	40	100	cP
Type of fracturing fluid	Water base	oil base	acid group	-
Construction time	24	48	72	小时

5.2 Technical and Economic Assessment

The economic analysis and evaluation of horizontal well volumetric fracturing technology is an important link to ensure the feasibility of the project. Geological conditions of different oil and gas fields, reservoir characteristics and development costs will affect the economic performance of the technology.Therefore, the technical and economic evaluation needs to take into account a variety of factors, including the nature of the reservoir, the expected increase in oil and gas production, construction costs, and oil and gas prices.Predict production gains and recoverable reserves after fracturing through detailed geological and engineering analysis to assess the potential economic benefits of the project, accurately calculate the costs of fracturing construction, equipment investment, material consumption, and additional investment to account for environmental protection and production safety.Through the establishment of economic model, comprehensive consideration of oil and gas price fluctuations, policy changes and other external factors, the project economy is comprehensively evaluated.In order to

improve economy in some cases, innovative technologies can be adopted to reduce construction costs, or fracturing design can be optimized to increase oil and gas production. Through such technical and economic evaluation, the economic return of the project can be reasonably predicted, providing scientific basis for decision making and ensuring the economic feasibility of technology application [6].

6. Technical Optimization and Future Development Direction

6.1 Technology Optimization Strategy

In order to effectively overcome the challenges faced by horizontal well volume fracturing technology and fully realize its potential, it is essential to adopt a comprehensive optimization strategy, and achieving fine fracturing technology management is the core of improving development efficiency and effectiveness.This requires advanced geological assessment techniques and fracture propagation simulation tools to accurately predict fracture propagation paths and effects, ensuring that each fracturing operation delivers the best results expected.Further, the real-time monitoring technology is used to dynamically monitor the fracturing process, and the fracturing parameters are adjusted according to the real-time underground geological conditions to ensure the flexibility and efficiency of fracturing operations.The research and development of new fracturing fluids is also critical. By innovating more environmentally friendly and efficient fracturing fluid formulations, we can not only reduce the negative impact on the environment, but also improve the efficiency of fracture formation and the effective distribution of proppant in the fracture, thereby optimizing the oil and gas extraction process.In particular, the use of less toxic or biodegradable fracturing fluids and proppants with higher performance can significantly reduce pressure on the environment, while improving the success of fracturing operations and oil and gas recovery.Through these multi-angle technical optimization measures, not only can significantly improve the application efficiency and output effect of horizontal well volumetry fracturing technology, but also effectively reduce the cost and environmental risks in the development process, and promote the oil and gas development industry to a more efficient and environmentally friendly direction.

6.2 Future Development Trend

The future development of horizontal well volume fracturing technology will pay more attention to the intelligent and environmentally friendly research direction, and the application of intelligent fracturing technology, such as the fracturing optimization algorithm based on big data and artificial intelligence, can achieve more accurate fracturing design and implementation.By integrating geological information, historical fracturing data, and real-time monitoring data, intelligent algorithms can optimize fracture parameter selection and achieve precise control of fracture networks to improve oil and gas production and development efficiency.The research of environmentally friendly fracturing technology is also a key direction in the future, with the increase of environmental requirements and public concern for environmental protection, the development of low environmental impact fracturing technology becomes particularly important.This includes using fracking fluids made from renewable resources, developing non-toxic or less toxic chemical additives, and improving water efficiency and fracking fluid recovery technologies.Through the development of these technologies, horizontal well volume fracturing technology will be more environmentally friendly and efficient, and can support sustainable energy development strategies to meet the needs of future oil and gas development [7].

7. Conclusion

Horizontal well volume fracturing technology has shown great potential and value in the development of unconventional oil and gas reservoirs. Through continuous technical research, practical application and optimization, this technology is expected to further improve the development efficiency of oil and gas fields, reduce environmental impact, and promote the sustainable development of unconventional oil and gas resources.

References

[1] Liu Kaixin, Zheng Weijie, Dai Liya, Pan Liyan, Zhang Long, Cai Guoqing. Exploration into and Practices of Low-Cost Volume Fracturing in Well Block X[J]. Xinjiang Oil & Gas, 2022, 18(1): 80-85.

[2] Shi Daohan, Zhang Minsheng, Tang Meirong, etc. Development and application of volume fracturing technology for horizontal shale oil in Changqing Oilfield [J]. Petroleum Science and Technology Forum, 2022,41 (03): 10-17.

[3] Pan Liyan, Hao Lihua, Liu Kaixin, Sun Xize, Zhu Zhenlong, Zhao Yanxin, Fracture Propagation Law of Hydraulic Fracturing in High-Salinity Reservoir of Fengcheng Formation in Mahu #br#[J]. Xinjiang Oil & Gas, 2023, 19(4): 20-28.

[4] Wang Junwei. Research and application of volumetry fracturing technology for horizontal Wells [J]. Petrochemical Technology,2021,28(05):118-119.

[5] Zhang Juan. Research and application effect analysis of horizontal well volumetry fracturing technology [J]. China Petroleum and Chemical Industry Standards and Quality,2019,39(21):251-252.

[6] Zheng Shulong. Study on the application of volumetric fracturing technology for deep rock gas horizontal Wells [J]. China Petroleum and Chemical Standards and Quality,2019,39(14):187-188.

[7] Fan Qing-Jun, Zeng Zhi-Lin.Application of cementing sleeve volume fracturing technology in tight oil horizontal Wells [J]. China and Foreign Energy,2019,24(05):47-52.

