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Research progress of key technologies for drilling and completion of ultra-deep oil and gas production

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Abstract: *With the continuous growth of global demand for oil and gas resources, ultra-deep oil and gas exploitation has gradually become an important direction for the development of the petroleum industry. This paper aims to discuss the research progress of key technologies for drilling and completion of ultra-deep oil and gas production. This paper first summarizes the research background and importance of ultra-deep oil and gas extraction, and then analyzes the key research contents, methods, processes and achievements of current drilling and completion technologies in detail. By comparing the advantages and disadvantages of different technologies, the paper also summarizes the challenges faced by the current drilling and completion technology and the future development trend. Finally, the article lists the main references cited in the course of the research, which provides convenience for readers to further understand the field.*

Keywords: *ultra-deep oil and gas; Drilling and completion technology; Research progress; Challenge*

1. Introduction

Drilling and completion engineering, a critical part of the oil and gas exploration and development process, accounts for approximately 50% of the total cost.[1] In recent years, the key technologies of drilling and completion for the exploitation of ultra-deep oil and gas reservoirs have made remarkable progress, providing strong support for the efficient and safe exploitation of ultra-deep oil and gas. This paper will focus on the progress of key drilling and completion technologies for ultra-deep oil and gas exploitation, including drilling technology research and breakthrough, automatic drilling rig and equipment upgrade, intelligent drilling technology progress, deep drilling and completion supporting technology, drilling and completion speed tools and equipment, drilling fluid material optimization and innovation, wellbore integrity technology system and research achievements of special structure Wells. However, the geological conditions of ultra-deep reservoirs are complex and changeable, which brings great challenges to drilling and completion technology, such as the stability of drilling fluid under high temperature and pressure environment, and the aggravation of bit wear caused by complex formation structure. Therefore, it is of great practical significance and application value to study the key technologies of drilling and completion of ultra-deep oil and gas exploitation and improve the efficiency and safety of exploitation.[2]

2. Overview of drilling and completion technology for ultra-deep oil and gas exploitation

2.1 Introduction to drilling technology

Drilling engineering technology is one of the core technologies in the exploration and development of underground resources such as oil and natural gas. Through drilling operations, people can go deep underground and obtain information such as formation structure, reservoir characteristics and resource occurrence, which provides an important basis for subsequent oil and gas development. Drilling technology involves many subject areas, including geology, mechanics, mechanical engineering, chemistry, etc. It is a comprehensive technical system. Well location selection is the primary task of drilling engineering, which directly affects the success of subsequent drilling operations. When choosing well location, it is necessary to consider many factors such as geological structure, formation lithology, reservoir distribution and ground conditions. At the same time, well location design is also an important work, including the determination of wellhead location, well structure, drilling depth and other parameters to meet the needs of exploration and development. Drilling fluid is an indispensable and important substance in drilling operations, it has the functions of cooling bit, carrying cuttings,

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balancing formation pressure and so on. Selecting suitable drilling fluid type and formulation is of great significance to improve drilling efficiency and protect reservoir. In addition, drilling tools are also the key components of drilling engineering, including drill bit, drill pipe, drill collar, etc., their performance and quality directly affect the smooth progress of drilling operations.[3]

2.2 Drilling technology and flow

Drilling technology refers to the selection of appropriate drilling methods, drilling speed, drilling pressure and other parameters according to formation characteristics and exploration and development needs to achieve efficient and safe drilling operations. Drilling process includes pre-drilling preparation, drilling operation, intermediate testing, completion and other links, each link needs to be strictly controlled and managed to ensure the smooth progress of drilling operations. During the drilling process, the properties and state of the drilling fluid will change, such as viscosity, density, PH, etc.[4] Therefore, real-time monitoring and control of drilling fluids are needed to meet the needs of different formations and drilling stages. This includes adjusting the formulation of drilling fluid, adding additives, treating contamination and other measures to ensure the stability and effectiveness of drilling fluid. The optimization of drilling parameters is the key to improve drilling efficiency and reduce cost. Through real-time monitoring and adjustment of drilling speed, weight on bit, torque and other parameters, the dynamic optimization in drilling process can be realized. In addition, advanced drilling technologies, such as automated drilling and intelligent drilling, can be utilized to further improve the efficiency and safety of drilling operations. In the process of drilling operation, it is necessary to monitor and record all parameters and data in real time in order to find and solve problems in time. At the same time, it is also necessary to evaluate the effect of drilling operations, including drilling quality, reservoir protection effect, cost effectiveness and so on. This is helpful to sum up experience and lessons, optimize drilling technology and improve the level of exploration and development. Well completion is the last stage of drilling operation, which involves many steps such as hole cleaning, cementing and testing[5]. The selection and implementation of well completion technology directly affects the smooth progress of subsequent oil and gas development. At the same time, the safety of drilling operations can not be ignored, it is necessary to formulate a strict safety management system and operating procedures, strengthen safety training and inspection, to ensure the safety of drilling operations.(As shown in figure 1)

Figure 1: Drilling process and flow

3. Progress of key technologies for drilling and completion of ultra-deep oil and gas exploitation

3.1 Research and breakthrough of drilling technology

In the process of ultra-deep oil and gas exploitation, the key to efficient exploitation is to make breakthroughs in drilling technology. In view of the special geological conditions of ultra-deep oil and gas reservoirs, the drilling technology is constantly optimized and innovated. For example, high temperature and high pressure drilling technology has been developed for high temperature and high pressure formation, improving the stability and safety of drilling operations. At the same time, for hard

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rock formation and complex formation structure, the optimization of bit design and drilling parameters can achieve efficient drilling and reduce bit wear.[6]

3.2 Automatic drilling rig and equipment upgrade

The upgrading of automated RIGS and equipment is also an important advance in drilling and completion technology for ultra-deep oil and gas production.[7] Through the introduction of advanced automatic control system and intelligent monitoring technology, the automatic operation and remote monitoring of the rig are realized. This not only improves the efficiency of drilling operations, but also reduces the risk of manual operations. At the same time, the development and application of new drilling equipment has further improved the reliability and stability of drilling and completion operations.

3.3 Progress of intelligent drilling technology

Intelligent drilling technology is another important development of drilling and completion technology for ultra-deep oil and gas production. Through the introduction of advanced technologies such as artificial intelligence and big data, the intelligent control and optimization of the drilling process are realized. Intelligent drilling technology can monitor and analyze drilling data in real time, predict possible problems during drilling, and take appropriate measures to deal with them. This not only improves the accuracy and efficiency of drilling operations, but also helps reduce operational costs and risks.

3.4 Supporting technology for deep well drilling and completion

The development of deep well drilling and completion technology has also provided strong support for ultra-deep oil and gas exploitation. Continuous technological advances in well structure design, well safety assessment, and completion method selection ensure smooth drilling and completion operations. At the same time, with the continuous improvement of measurement while drilling technology, wellbore reaming technology and other supporting technologies, the quality and efficiency of deep well drilling and completion operations have been further improved.

3.5 Drilling and completion acceleration tool equipment

In order to further improve the speed and efficiency of drilling and completion of ultra-deep oil and gas production, significant progress has been made in the development and application of new acceleration tools and equipment. For example, the application of high-speed drill bits and efficient rock breaking tools has significantly increased drilling speed and bit life. At the same time, the automation and intelligent tool equipment in the drilling and completion process also greatly improves the efficiency and quality of the operation.

3.6 Drilling fluid material optimization innovation

Drilling fluid plays a vital role in ultra-deep oil and gas production. In recent years, the optimization and innovation of drilling fluid materials have achieved remarkable results. The new drilling fluid material not only has better resistance to high temperature and high pressure, but also has good anti-pollution, anti-wear and other characteristics, which can effectively protect the drill bit and drilling tool, and improve the stability of drilling operations.

3.7 Wellbore integrity technical system

Well integrity is an important step in the drilling and completion of ultra-deep oil and gas production. In order to ensure the stability and safety of the wellbore, a complete wellbore integrity technology system has been established. Advances in wellbore design, wellbore sealing technology, and wellbore monitoring and evaluation provide a strong guarantee for wellbore integrity.

3.8 Research results of Wells with special structure

In view of the complex geological conditions of ultra-deep oil and gas reservoirs, the study of special structure Wells has also made important achievements. For example, the design and

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construction technology of special structural Wells such as extended reach Wells and horizontal Wells has been continuously optimized and innovated, providing more options for the exploitation of ultra-deep oil and gas. These special structure Wells can effectively improve the reservoir connectivity and recovery efficiency, and provide a strong support for the efficient production of ultra-deep oil and gas.(As shown in figure 2)

Figure 2: Key drilling and completion technologies for ultra-deep oil and gas production

4. Challenges and difficulties in drilling and completion technology for ultra-deep oil and gas exploitation

4.1 Geological conditions are complex and changeable

Ultra-deep oil and gas reservoirs are usually located in the area of complex geological structure and variable formation lithology. The complex and varied geological conditions in these areas pose great challenges to drilling and completion techniques. For example, there are a lot of fractures, folds and other structures in the formation, which may lead to wellbore instability, hole collapse and other problems. In addition, the change of formation lithology may also lead to increased bit wear and lower drilling speed. In addition, there may be toxic and harmful gases or radioactive substances in the formation, which pose a threat to the health of drilling operators. In addition, deep-sea drilling operations also face the interference of Marine climate, waves and other natural factors, increasing the difficulty of operation and safety risks.

4.2 Difficulty in well structure design

Well structure design is one of the key links in drilling and completion technology. In ultra-deep oil and gas production, well structure design is faced with many difficulties. First, the temperature and pressure of the ultra-deep formation are extremely high, and the requirements for well materials are also more stringent. Secondly, due to the complex and changeable geological conditions, the well structure needs to have strong adaptability and stability to cope with various challenges brought by formation changes. In addition, the well structure also needs to consider many aspects of drilling fluid circulation, cementing operations and other factors, which makes the design further difficult.

4.3 High temperature and high pressure environment challenges

Ultra-deep reservoirs are usually located in high-temperature and high-pressure environments, which poses great challenges to drilling and completion techniques. High temperature environments can lead to degraded drilling fluid performance and increased bit wear, while high pressure environments can lead to safety incidents such as borehole collapse and blowout. Therefore, how to maintain the stability and safety of drilling operations under high temperature and high pressure environment is the drilling and completion technology needs to solve. In addition, the impact of Marine climate on drilling and completion technology for ultra-deep oil and gas production cannot be ignored. Marine climate is changeable, and factors such as wind and waves may adversely affect drilling operations. For example, strong winds may cause drilling platforms to sway, affecting the stability and accuracy of drilling operations. Large waves can hit drilling equipment, causing damage or failure. Therefore, when drilling and completing ultra-deep oil and gas production in the Marine environment, it is necessary to fully consider the influence of Marine climate factors and take corresponding

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countermeasures.

4.4 Drilling fluid stability problem

Drilling fluid plays a vital role in the drilling and completion process, and its stability directly affects the effectiveness and safety of drilling operations. However, in ultra-deep oil and gas exploitation, the stability of drilling fluid is often difficult to guarantee due to the complex formation conditions and the influence of high temperature and pressure environment. Problems such as changes in viscosity and increased solids content may occur in drilling fluids, which may lead to drilling operations being hindered or safety incidents occurring.[8]

4.5 Technical difficulties in deep-sea drilling

For offshore ultra-deep oil and gas exploitation, deep-sea drilling technology is faced with many difficulties. First of all, the deep sea environment is harsh, and natural factors such as waves and tides have serious interference with drilling operations. Second, deep-sea drilling requires special RIGS and equipment that are expensive to build and maintain. In addition, deep-sea drilling operations also need to consider environmental protection and ecological safety and other issues, increasing the technical difficulty and cost.(As shown in figure 3)

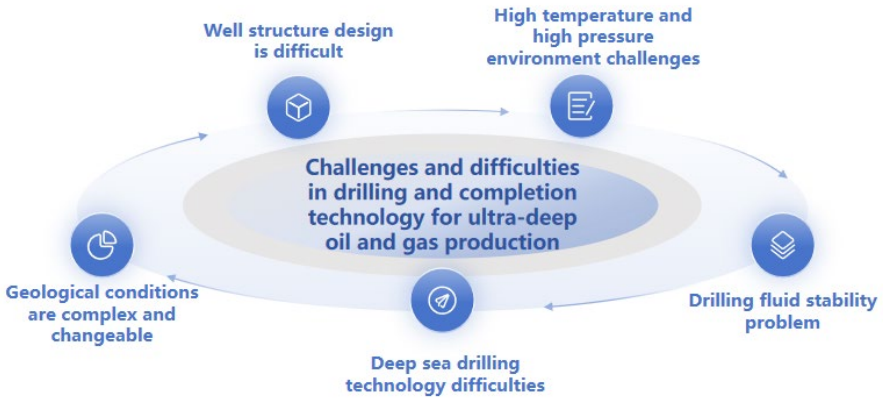

Figure 3: Challenges and difficulties in drilling and completion technology for ultra-deep oil and gas production

5. Development suggestions on key technologies for drilling and completion of ultra-deep oil and gas exploitation

5.1 Select the appropriate drilling technology

According to the characteristics of ultra-deep reservoirs, suitable drilling technology should be selected. For example, for high temperature and high pressure formations, high temperature and high pressure resistant drilling technology and materials can be used to ensure the smooth progress of drilling operations. In order to standardize the development and application of drilling and completion technology, the relevant technical specifications should be perfected. Formulate scientific and reasonable technical standards and operating norms, clarify technical indicators and requirements, and provide clear guidance and basis for drilling and completion operations. It is also necessary to strengthen the publicity and training of technical standards to ensure that technical personnel can accurately understand and implement relevant standards, and improve the standardization and safety of drilling and completion operations. In view of the technical difficulties and bottlenecks in ultra-deep oil and gas exploitation, more efforts should be made in technical research. Through in-depth basic research and application research, key technical problems are broken through to improve the adaptability and stability of drilling and completion technology. In addition, in the development of drilling and completion technology, attention should be paid to the integration and application of mature technology. Through the organic combination of a variety of mature technologies and optimal configuration, a more efficient and stable drilling and completion technology scheme is formed. This

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not only improves the efficiency and quality of drilling and completion operations, but also reduces costs and risks, providing more reliable technical support for ultra-deep oil and gas extraction.

5.2 Research and development of automated and intelligent drilling rig

In view of the special conditions of ultra-deep oil and gas exploitation, the development of automatic intelligent drilling rig is the key to improve operation efficiency. Through the introduction of advanced automatic control system and artificial intelligence technology, the autonomous navigation, intelligent decision-making and remote monitoring of the rig are realized, reducing the degree of manual intervention, and improving the accuracy and safety of the operation. In addition, drilling design software is an important tool for optimizing drilling plans and improving operational efficiency. The research and development of drilling design software should be strengthened to improve its simulation accuracy and prediction ability, so as to provide more accurate and reliable guidance for drilling operations.

5.3 Downhole fault identification and diagnosis

A perfect fault identification and diagnosis system should be established for the underground faults that may occur in ultra-deep oil and gas exploitation. Through real-time monitoring of various parameters in the drilling process, faults are detected and diagnosed in time to provide support for rapid response measures and reduce the impact of faults on drilling operations. In the process of ultra-deep oil and gas production, drilling and completion operations are faced with many uncertainties and risks, so it is very important to improve the fault handling ability. The research and application of fault warning and monitoring technology should be strengthened to find and solve potential problems in time. At the same time, a sound emergency plan and rescue mechanism should be established to ensure rapid response and treatment in the event of failure or accident, and reduce losses and risks.

5.4 Development of multi-parameter real-time measurement technology

On the one hand, multi-parameter real-time measurement technology is an important means to improve the efficiency and safety of drilling operations. Through real-time monitoring of key parameters such as temperature, pressure and vibration during drilling, accurate control and adjustment of drilling state can be realized to ensure smooth operation. On the other hand, pre-drilling while drilling technology is an important means to achieve accurate drilling and formation evaluation. Through the introduction of advanced measurement while drilling and imaging technology, real-time formation information is obtained to provide a basis for bit trajectory adjustment and optimization, improving drilling efficiency and accuracy.

5.5 Accelerate the pace of technology localization

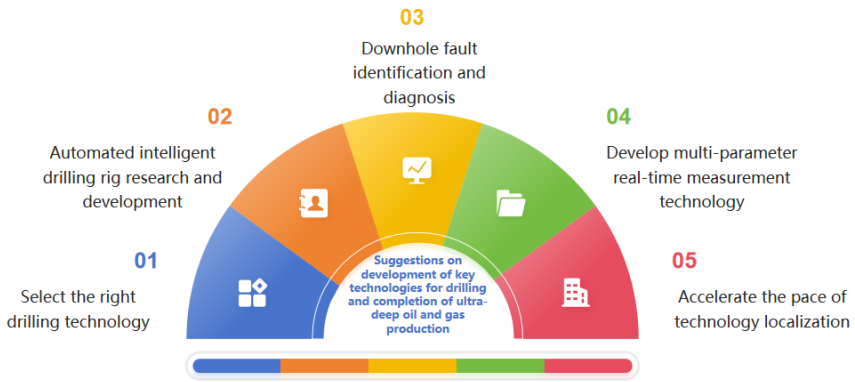

Figure 4: Development recommendations for key drilling and completion technologies for ultra-deep oil and gas production

In order to reduce the cost of drilling and completion technology and improve the ability of autonomy and control, the pace of technology localization should be accelerated. The scientific research institution should strengthen the support and cultivation of domestic enterprises, encourage them to participate in the research and development and application of ultra-deep oil and gas extraction

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drilling and completion technology, and enhance the competitiveness of the entire industry. While actively introducing foreign advanced technology, we should pay attention to the integration and promotion of technology. Through the digestion, absorption and re-innovation of the imported technology, a technical system suitable for the characteristics of ultra-deep oil and gas exploitation in China has been formed.(As shown in figure 4)

6. Conclusion

In summary, the key technologies of ultra-deep oil and gas extraction drilling and completion have made remarkable progress in the aspects of drilling technology research and breakthrough, automatic drilling rig and equipment upgrade, intelligent drilling technology progress, deep drilling and completion supporting technology, drilling and completion speed accelerating tools and equipment, drilling fluid material optimization and innovation, wellbore integrity technology system and research achievements of special structural Wells. These technological advances provide strong support for the efficient and safe exploitation of ultra-deep oil and gas, and promote the sustainable development of the petroleum industry. In this paper, the research progress of the key technologies in drilling and completion of ultra-deep oil and gas production is deeply discussed, the achievements and challenges of current technologies are summarized, and the future development trend is prospected. In the future, with the continuous innovation and improvement of relevant technologies, it is believed that the efficiency and safety of ultra-deep oil and gas extraction will be further improved.

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