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Analysis of Coiled Tubing Sidetracking Technology

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Abstract:
Coiled Tubing Drilling (CTD) technology has significant technical advantages over traditional rotary drilling technology and has been widely applied in international oil and gas exploration and development. Its application scenarios include shallow vertical well drilling, re-entry sidetracking, reservoir deepening drilling, underbalanced drilling, and offshore platform drilling. Through continuous technologicalbreakthroughs in recent years, China has made significant progress in the development of coiled tubing sidetracking equipment, supporting tools, and process optimization. The field testing and engineering application of small-hole coiled tubing sidetracking technology have been successfully achieved. This paper systematically reviews the current status of small-hole coiled tubing sidetracking equipment and technological development both domestically and internationally. Through the analysis of typical well cases, the field application effects of small-hole coiled tubing sidetracking technology are explored in depth. Based on the development needs of China's oil and gas fields, future development directions and key research areas for small-hole coiled tubing sidetracking technology are proposed.

Keywords: Coiled Tubing Sidetracking, Drilling Tools, Technological Status

Introduction

International practice has shown that Coiled Tubing Drilling (CTD) technology has become one of the core technologies in modern petroleum drilling engineering. Particularly in North America, the technology has been widely applied, with the United States and Canada accounting for over 80% of the global coiled tubing drilling market (according to SPE statistics). This technology system demonstrates significant technical and economic advantages, achieving remarkable results in improving drilling efficiency and reducing operational costs. Currently, as China's major oil fields gradually enter the middle and late stages of development, reservoir conditions are becoming increasingly complex, and the distribution of remaining oil is becoming more dispersed. In this context, sidetracking technology has become a key means of maintaining stable oilfield production.

Compared to the high operational risks, low construction efficiency, and high economic costs associated with traditional sidetracking technology, coiled tubing sidetracking technology offers unique advantages, including short operation cycles, cost control, and high safety performance. It provides a more efficient technical solution for secondary oilfield development, showing broad application prospects in improving recovery rates and extending oilfield life.

1 连续管侧钻技术简介

Coiled Tubing Sidetracking Technology is an advanced drilling technology that integrates coiled tubing operation systems, downhole power tools, and multifunctional downhole tools. This technology, through an integrated operation mode, can efficiently complete a series of complex construction tasks such as whipstock

positioning and setting, casing window milling, and open-hole directional drilling. Its core technical advantage lies in fully utilizing existing wellsite facilities and wellbore conditions, significantly improving construction efficiency and reducing overall drilling costs through modular and intensive operation methods. According to API statistics, it can save over 40% of operation time and reduce drilling costs by 30%-50% compared to traditional sidetracking technology.

From the perspective of equipment composition, the coiled tubing sidetracking system mainly includes the following core components:

Coiled Tubing Rig System: Includes key equipment such as the injector head, reel, and blowout preventer, with high-precision control capabilities (pressure control accuracy of ±0.5MPa).

Coiled Tubing String: Made of high-strength low-alloy steel, with a diameter range of 1" to 3-1/2", capable of withstanding working pressures up to 70MPa.

Auxiliary Equipment System: Includes hydraulic power units, data acquisition systems, and well control equipment.

The downhole tool system adopts a modular design, mainly including:

Connection Devices: Quick connectors ensure reliable tool string connections.

Window Milling System: Includes whipstocks and specialized milling shoes, with a window milling efficiency of 1.5-2.5m/h.

Safety Control System: Includes check valves and safety subs.

Directional Control System: Adjustable bent housing motors combined with Measurement While Drilling (MWD) systems.

Power Tools: Downhole motors with an output torque of 1500N·m.

Rock Breaking Tools: Polycrystalline Diamond Compact (PDC) bits, suitable for a wide range of formations.

This technology system, through the coordinated operation of various subsystems, achieves precise control and efficient construction of sidetracking operations, providing reliable technical support for old well reconstruction and remaining oil extraction.

2 Current Status of Coiled Tubing Sidetracking Technology

2.1 International Status

Currently, coiled tubing sidetracking rig technology has matured internationally, forming a diversified equipment system that includes truck-mounted, trailer-mounted, skid-mounted, derrick-mounted, and mast-mounted models. In terms of process applications, a series of specialized technologies have been developed, including old well sidetracking, dual-casing window sidetracking, through-tubing sidetracking, nitrogen/foam underbalanced sidetracking, real-time production well sidetracking, managed pressure sidetracking, precise multi-lateral sidetracking, and geosteering sidetracking. With the breakthrough development of small-sized Measurement While Drilling (MWD) technology, combined with the characteristics of coiled tubing drilling, hydraulic directional tools have emerged. These tools achieve real-time control of wellbore trajectory by precisely adjusting the toolface angle, with trajectory control accuracy reaching ±0.1°.

In 1994, Baker Hughes pioneered the development of a wired coiled tubing drilling tool system, which provides power to downhole tools and enables signal transmission through an internal cable in the coiled tubing. This technological breakthrough significantly enhanced the applicability of coiled tubing sidetracking technology. Currently, several mature wired coiled tubing bottom hole assembly (BHA) systems have been developed internationally, including Baker Hughes' CoilTrak directional drilling system, Schlumberger's VIPER directional drilling system, and AnTech's COLT directional drilling system.

With continuous technological advancements, the advantages of coiled tubing sidetracking technology have become increasingly prominent, with expanding application scales and continuously updated operation

records. According to statistics, Baker Hughes has conducted large-scale applications in Alaska and the Middle East. Between 1996 and 2015, they successfully completed 777 sidetracking operations using 60.3mm (23/8 in) and 92.1mm (35/8 in) wired coiled tubing BHA systems. In 2013, ConocoPhillips set a record in Alaska with a sidetracking project reaching a maximum depth of 4012m and a horizontal displacement of 1287m. Weatherford achieved a window opening at 3586m in Saudi Arabia, completing a horizontal displacement of 750m with a maximum inclination of 94° and a build rate of 25°/30m. Schlumberger successfully drilled to a depth of 6937m in high-temperature deep wells in the Middle East, setting a record of 427m drilled in 24 hours during a single run, which is 200% faster than the average through-tubing sidetracking speed in the oilfield.

2.2 **Domestic Status**

The development of coiled tubing sidetracking technology in China started relatively late, and there is still a significant gap in technological level and application scale compared to international advanced standards. In recent years, under the strategic deployment of CNPC, companies such as Great Wall Drilling Company, Bohai Drilling Engineering Company, Research Institute of Petroleum Exploration and Development, and Baoji Oilfield Machinery Co., Ltd. have collaborated to make significant breakthroughs in the development of coiled tubing sidetracking equipment and field applications. Through independent research and development of single-mode coiled tubing rigs, composite coiled tubing rigs, specialized coiled tubing materials, and supporting downhole tools, they have successfully completed field tests of 11 small-hole coiled tubing sidetracking wells, marking a critical step forward in this technological field in China.

During the "12th Five-Year Plan" to the "13th Five-Year Plan" period, the Research Institute of Petroleum Exploration and Development systematically carried out independent research and development of coiled tubing rigs, successfully developing two core equipment: single-mode coiled tubing rigs and composite coiled tubing rigs. The single-mode coiled tubing rig adopts a modular design and requires coordination with workover rigs and other equipment. Its core component, the injector head, has a lifting capacity of 58 tons and can accommodate 73.0mm (27/8 in) coiled tubing, with a maximum drilling depth of 3500m. The composite coiled tubing rig achieves technological integration and innovation, equipped with a 90-ton injector head, a hydraulic lifting system, and a hydraulic rotary table, capable of independently completing the entire process of small-hole coiled tubing sidetracking. It has passed strict type testing verification.

In terms of downhole tool development, the Research Institute of Petroleum Exploration and Development successfully developed a wireless directional drilling tool system for coiled tubing. This system consists of key components such as connectors, non-rotating joints, safety subs, and hydraulic orienting tools. The hydraulic orienting tool adopts an innovative fluid pressure differential drive mechanism, converting hydraulic energy into rotational kinetic energy through piston movement to precisely control the bend angle of the mud motor, achieving accurate wellbore trajectory control. The safety sub device uses a ball-drop activation mechanism, allowing quick disconnection in emergency situations such as downhole sticking, ensuring the safe retrieval of coiled tubing and creating conditions for subsequent accident handling using conventional drilling tools. This wireless directional drilling tool system has advantages such as low manufacturing cost, simple operation, and strong compatibility, effectively integrating existing mature speed-enhancing tools and significantly improving operational efficiency.

3 Case Analysis of Well DH in Western Sichuan Oilfield

3.1 Field Conditions

The Z21 formation mainly consists of interbedded gray, dark gray, and gray-green mudstone with gray-white siltstone, unevenly granular sandstone, medium-fine sandstone, pebbly medium sandstone, and feldspar sandstone. The interbeds in this area are generally stable and widely distributed, mostly extending across the

entire region, with thicknesses mostly ranging from 2 to 3m, a minimum of 1m, and a maximum of 12m. The previous Well DH in the Western Sichuan Oilfield experienced severe sand production and lost circulation, with wellhead overflow during operations, making it impossible to continue production through additional perforations. The use of small-hole coiled tubing window sidetracking in this well aimed to tap the remaining oil and gas between wells, improve hydrocarbon recovery, and reduce comprehensive oil and gas extraction costs.

3.2 Construction Overview

Well DH is the first demonstration well in China to adopt small-hole coiled tubing sidetracking technology, jointly implemented by Great Wall Drilling Company and the Research Institute of Petroleum Exploration and Development under CNPC. The well was designed with a window opening at 1052m, a total depth of 1759m, and an open-hole section length of 707m, presenting typical technical challenges. The project team commenced on-site installation and preliminary preparations on September 27, 2023, successfully setting the whipstock at the designed depth of 1052m on October 16. The casing window milling operation officially began on October 17, followed by open-hole directional drilling, which reached the designed depth of 1759m on October 31. The completion structure is shown in Figure 2.

In terms of key technological breakthroughs, the project team successfully completed the thick-walled casing window milling operation in a total of 22 hours, setting a new domestic record for small-hole coiled tubing window milling. The tool assembly used was: Φ118mm mill + Φ102mm straight screw + Φ73mm heavy-weight drill pipe + cable sealing sub + safety sub + non-rotating sub + connector + Φ73mm coiled tubing. During the window milling operation, precise control of construction parameters ensured operation quality: weight on bit (WOB) was maintained at 10-30kN, pump pressure was controlled at 21-23MPa, and flow rate was stabilized at 12L/s, ultimately achieving a 5m window milling length that met design requirements.

The successful implementation of this well marks a significant breakthrough in China's small-hole coiled tubing sidetracking technology, accumulating valuable experience for subsequent large-scale applications.

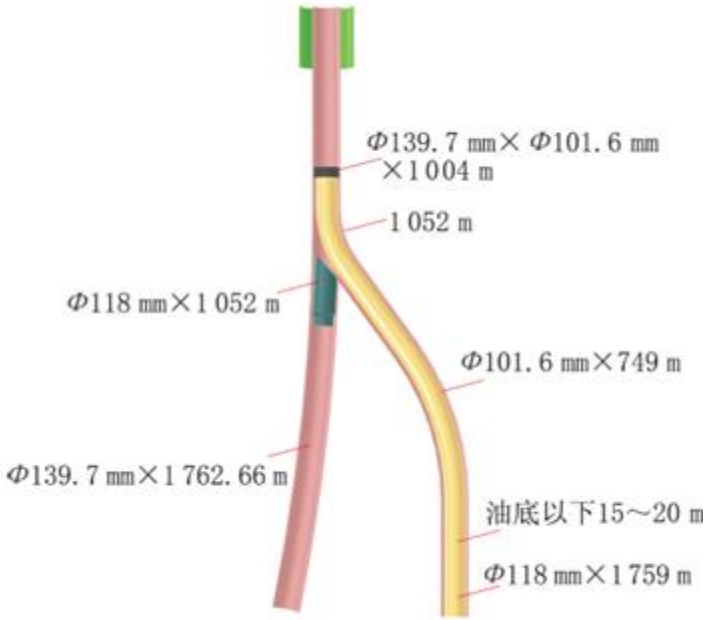

Fig.1 Schematic Diagram of Well DH Sidetracking Depth

3.3 Results Evaluation

The total drilling cycle for this well was 16 days, consuming 1 mill, 3 roller cone bits, and 2 PDC bits. During the 707m drilling operation, the cumulative pure drilling time was 126.87 hours, with an average rate

of penetration (ROP) of 5.54m/h, placing the operational efficiency at a leading domestic level. Although downhole complications were encountered during drilling, primarily manifested as formation cuttings in the shale shaker returns, leading to extended reaming time and drill string sticking, timely and targeted measures ensured smooth operation, ultimately completing the pilot test of small-hole coiled tubing sidetracking in Well DH.

The successful implementation of this well holds significant technical demonstration value: firstly, it provides a reliable technical solution for restoring production in long-shutdown wells in the Western Sichuan Oilfield; secondly, the innovative application of small-hole coiled tubing sidetracking technology effectively slows the decline in oilfield production; finally, the project has accumulated valuable field experience, laying a technical foundation for the large-scale application of small-hole coiled tubing sidetracking in horizontal wells, offering important reference value for promoting efficient development of unconventional oil and gas resources in China.

4 Conclusions and Recommendations

（1） Domestic research has focused on key technologies for small-hole coiled tubing sidetracking, initially establishing a complete technical system that includes coiled tubing casing window milling, build-up drilling, hold-angle drilling, and supporting drilling fluid technologies. Through pilot tests on 11 wells, this technical system has demonstrated significant effects in restoring production in long-shutdown wells and slowing production decline, providing innovative solutions for stabilizing and increasing production in mature oilfields. The use of continuous circulation during tripping has effectively addressed wellbore shrinkage issues during drilling, creating favorable conditions for the smooth running of completion tailpipe strings.

（2）The innovative use of continuous circulation characteristics of coiled tubing has effectively solved the problem of wellbore shrinkage during drilling, ensuring the safe running of completion tailpipe strings and creating favorable conditions for subsequent completion operations. Field data indicate that this technology improves wellbore stability by approximately 40% and increases the success rate of tailpipe running to over 95%.

（3）Due to the depth measurement errors caused by injector head clamping force and drilling fluid lubricity, it is recommended to add depth markers to the coiled tubing body during manufacturing. To address the depth measurement errors caused by injector head clamping force limitations and drilling fluid lubricity, it is recommended to add a depth marking system to the coiled tubing body during manufacturing to improve depth measurement accuracy, with an error control target of less than 0.1%. Research and development of completion tools and processes suitable for small-hole coiled tubing sidetracking and small-hole coiled tubing sidetracking in horizontal wells are needed.

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