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New Technology of Coiled Tubing Drilling in Slim Hole

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Abstract
Slim hole coiled tubing is a new drilling technology in the current decade. It combines slim hole technology and coiled tubing technology, which has a considerable number of advantages over conventional drilling methods in certain applications, such as reducing drilling cost and risk, increases drilling efficiency and is more environmentally friendly. Its applicability, technical characteristic, equipment, development and prospection at home and abroad are introduced in this paper.

Key words: Slim hole; Coiled tubing; Drilling technology; Technical characteristics; Drilling equipment

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INTRODUCTION
Slim hole drilling technology includes drilling of oil well with OD less than 120 mm and it matched technology and downhole equipment. The coiled tubing drilling technology is different from the conventional rotary drilling, the coiled tubing can't be rotated, so it must use special downhole tools in order to achieve the drilling process, which is constrained application and development of the coiled tubing drilling in China. Since 1990's, coiled tubing has developed fast as a substitution of traditional drilling technology in domestic[1]. The new research abroad these years tremendously promote its application, including: drilling of shallow slim hole with coiled tubing; evaluating feasibility of slim hole application in deep well; improvement and experiment on small-scaled BHA; miniaturization of geophysical logging equipment and application of micro sensors in seismometer. Now, some of these development has been put into practice, in the near future, slim hole drilling technology will be commercially feasible.

1. APPLICABILITY
Slim hole coiled tubing technology can reduce drilling cost and risk, has the following remarkably potential applicability[2-3]. (1) Shallow well. Application of slim hole coiled tubing in shallow well has a notable advantage, the space and load is only 1/3 of traditional drilling technology. (2) Exploratory well. With slim hole coiled tubing technology, 4-D image of recoverable hydrocarbon reserves and unrecoverable can be obtained and monitored at the optimal depth, without disturbing development or injection. (3) Old well re-entry. Porosity of different horizontal level can be obtained by seismic prospecting system with slim hole coiled tubing and recovery can be increased by vertical injection. (4) Deep well. By re-entry old well and extended slim hole section, reservoirs can be evaluated more economically and the pay zone is easier to access. (5) Perforation, completion and sidetracking out of casing at deep depth, to increase recovery. (6) Ultra-deep and ultra-high temperature well. (7) Offshore deep well with underflow, hydrate or other potential hazards. (8) Area of other high risk environment.

2. TECHNICAL CHARACTERISTICS
Slim hole coiled tubing technology can improve the production rate of shallow well (less than 1,500 m), according to DOE, production of these well is up to 350 × 108 m^3 in US. The advantages involve[4]: (1)

Reduced drilling cost. Comparing with traditional drilling technology, slim hole coiled tubing can save drilling time, reduce material and equipment cost. Drilling cost is expected to be reduced by 1/5, exploration cost 1/3 and development cost 1/2. (2) Environmentally friendly. Microminiaturized equipment take less space and produce less waste, help to relieve environmental pressure. (3) Reservoir image and real time data can be obtained on the fly. The data source can be precisely controlled with slim hole coiled tubing and interruption is decreased so cost is lowered. (4) Less requirement on people and decreased human hazards by automated equipment. (5) Coiled tubing is continuous, no connection is needed and RIH/POOH is fast. (6) Remote control and real time transmission ability is improved by adapting cable in coiled tubing, real time logging is available. (7) Especially suitable for offshore and land rigs with limited space. (8) Easy to transport and make up.

3. SLIM HOLE COILED TUBING EQUIPMENT AND TOOL

3.1 Research Status

In 1993, Los Alamos National Laboratory introduced the concept of slim hole coiled tubing drilling (34.9 mm - 60.3 mm) and put it into research, Deutsche Texaco, Phillips Petroleum Company , 5 oil contractors and 6 service company participated in. By analysis of application in deep well, the conclusion comes to that slim hole drilling can save material dramatically and thus reduce drilling cost immensely and promising. The drilling mud for 300 m is estimated to be only 0.16 m^3 with slim hole drilling while with traditional drilling technology should be ten times of that.

The slim hole drilling system is designed as Figure 1. Traditional coiled tubing unit is small-scaled, complicated component is simplified and requirement on human is decreased, making automated drilling available. Until now, this system has undergone 3 field tests. In the feasibility test, it performed well in 44.5 mm OD section of vertical well; In the test of motor and drilling bit, ROP excessed 30 m/h in dolomite; In the deposit and sediments test, 40.3 mm OD section can be drilled to 255 m.

3.2 SURFACE EQUIPMENT

Figure 1
Slim Hole Coiled Tubing Drilling System

Surface equipment consists of slim hole drilling unit, well control equipment and control panel[5-6]. Slim hole drilling unit is the main equipment of slim hole coiled tubing technology; it is composed of injector head, drum and hydraulic system. Injector header is the power source for trip in/out, drum is to preserve and protect the coiled tubing and the hydraulic system supply power for all the system. The well control system consists of 2 double ram typed preventer and one annular preventer. The control panel is a complicated and sophisticated system, can monitor and control drilling process, inclination and deflection of BHA, trajectory parameters and well control equipment condition.

The control unit of a modern CT-drilling unit is highly sophisticated compared with that of just a few years ago. In addition to having the capability to monitor downhole conditions and change tool settings, it has a computerized capability to monitor CT conditions and update CT service-life predictions continually, to do hydraulics calculations, to predict borehole friction, and much more (Figure 2).

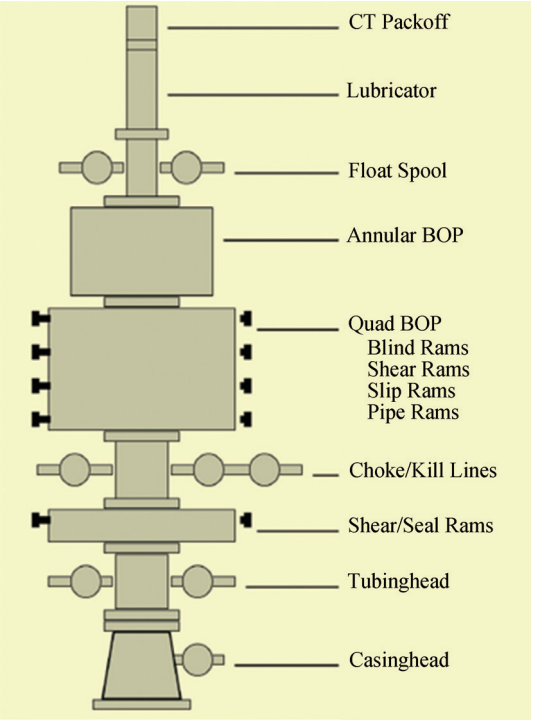

Figure 2
Typical BOP Assembly for Underbalanced Coiled Tubing Drilling

3.3 Downhole Equipment

(1) Slim hole bit. It can be penetrate into rock with small-scaled cutting effectively. Now the available sizes are: 95.3 mm, 66.7 mm, 44.5 mm, 25.4 mm OD.

(2) At-bit survey sub. Including real time sensors of inclination and azimuth, WOB and torque, downhole memory, at-bit motor and other real time logging sensors.

(3) Slim hole motor. Including slim hole rotary motor

and combined motor. Rotary motor can convert hydraulic power into rotary mechanical energy and combined motor can convert low velocity and high pressure hydraulic energy into impacting energy.

(4) Sleeve sub. It separates at-bit survey sub, saves it from resonance from motor and coiled tubing vibration and rotation, and reduces the affection of pulsing.

(5) Safety sub. Including motor and separator sub and can retrieve real time measurement and recording sub, coiled tubing and run in fishing neck.

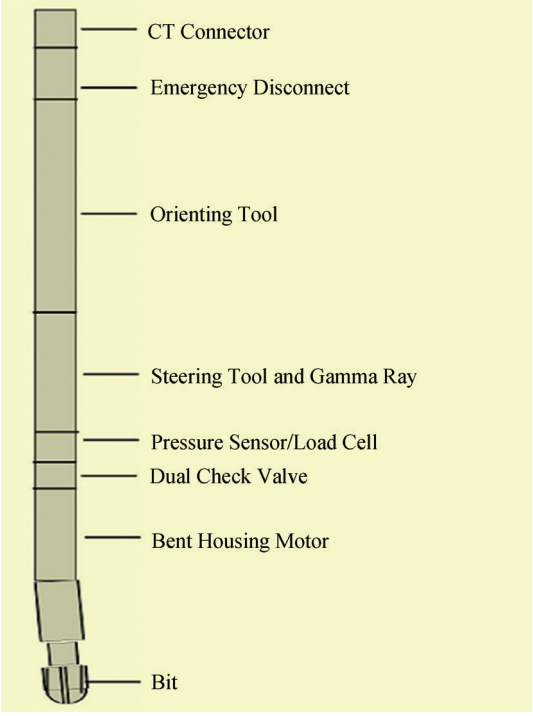

Figure 3
Typical Bottom Hole Assembly for Coiled Tubing Horizontal Drilling

4. SLIM HOLE COILED TUBING DRILLING TECHNOLOGY PRACTICE

To reduce exploration cost of oil reservoir less than 1,500 m, DOE support 6 projects concerning slim hole drilling technology[7-8].

(1) Modulation of coiled tubing drilling system. Applied by Baker Hughes Incorporated, downhole two-way communication module and surface coiled tubing is connected and communicated through real time wireless monitor of the well. This "intelligence" drilling system will improve the application of slim hole drilling. DOE contributed 8 billion dollar and expected to finish in 2 years.

(2) Reversed downhole rotary motor drilling system. Applied by AGA, WOB is expected to be exerted on a limited area and all the torque is expected to be exerted on the coiled tubing, thus efficiency of coiled tubing drilling can be dramatically increased. ROP is expected to be increased by 25% - 60% while drilling cost decreased by 40%. This system is especially suitable for unconventional reservoir, DOE contributed 6 billion dollar and expected to finish in 3 years.

(3) Slim hole coiled tubing drilling measurement system. Ultima Lab is working on a economical measurement system by combining MWD with LWD system, exclusively for slim hole coiled tubing drilling of less than 1,500 m, two sets of field test prototype is expected. DOE contributed 8 billion dollar and expected to finish in 3 years.

(4) Effective downhole motor and new type of bit. To meet the requirement of high RPM and low WOB, GNT is working on high-power turbine drilling string for slim hole coiled tubing drilling technology. To meet the requirement of application in 88.9 mm OD section in hard formation and increase the bit life, high temperature cutting tooth is introduced. DOE contributed 8 billion dollar and expected to finish in 2 years.

(5) Field test of slim hole coiled tubing drilling technology. To ensure its ability to drill to 1,500 m, GTI is working on a field test on MOXIE slim hole coiled tubing system manufactured by Solution Company. The first field test was carried out in Kansas field in 2003, with ROP up to 84 - 120 m/h. It is estimated that the drilling cost will reduced by 28% - 38%, production will be increased and environmental hazard will be decreased remarkably. DOE contributed 10 billion dollar and expected to finish in 1 year.

(6) Improvement on BHA. Applied by CTES LP Company, downhole tractor in traditional slim hole is to be replaced with agitator in the drill string. It aimed at decreasing drilling cost of slim hole deeper than 1000m, whose production rate is as 2 - 3 times high as vertical well. DOE contributed 7 billion dollar and expected to finish in 2 years.

CONCLUSIONS AND SUGGESTIONS

(1) Slim hole coiled drilling technology can not only reduce drilling cost but also reduce the hazard on environment, it is taken as a revolution in 21 century of drilling technology. Oil industry is putting more and more emphasis on this technology; we should follow this technology and make new research, achieve or even exceed international standards.

(2) Until now, no notable progress in this technology has been reported in China; what's more, recently material technology and technical level are not strong enough to support this technology. The study of basic subject in coiled tubing technology is an effective way to promote its development. And also, introducing more experience from countries (such as Canada and USA) where coiled tubing technology is more mature is another aspect to improve this technology.

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