侧钻水平井初始井眼条件对起始段轨迹的影响分析*

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石晓兵等. 侧钻水平井初始井眼条件对起始段轨迹的影响分析. 天然气工业, 2003; 23(5): 53~ 55

摘　要　侧钻水平井轨迹起始段工艺技术, 是侧钻水平井钻井工艺的关键技术。为了考虑侧钻点位置及老井的初始井斜、方位对侧钻水平井起始段的影响, 需要对侧钻水平井进行三维轨迹设计考虑。文章运用空间斜平面法分析了对侧钻水平井起始段有重要影响的主要初始井眼条件, 包括侧钻点(地层因素)、侧钻点初始井斜角、侧钻点初始方位角等对起始段轨迹的影响。为满足油藏工程、钻井工程对侧钻水平井方位、水平位移的要求, 达到井眼轨迹平滑, 顺利实现钻井、完井工艺, 提高中靶精度提供了保证。

主题词　侧钻水平井　起始段　井眼轨迹　影响因素　分析

近年来, 为了提高低产油气井、低渗透油气田和老油气田的采收率, 国内外利用原井眼开窗侧钻水平井技术, 取得了明显的经济效益。鉴于侧钻水平井主要用于开采薄油藏、边际油气田和死油气区的剩余油气, 因此侧钻水平井轨迹质量控制就显得特别重要, 影响侧钻水平井轨迹的因素很多, 除满足地质设计要求外, 在进行轨迹设计时, 还应考虑地层因素、工具造斜能力、原井眼状态、侧钻点的位置、侧钻方式等因素。其中侧钻水平井初始井眼条件(原井眼状态、侧钻点的位置、地层因素等) 是影响轨迹设计和控制的关键因素, 尤其是对侧钻水平井轨迹起始段将产生重要的影响。所谓侧钻水平井起始段是指为了实现侧钻水平井的目的, 在套管内一定深度采用不同的开窗方式, 形成一个良好的造斜点, 从而为轨迹起始造斜提供保证, 满足油藏工程、钻井工程对侧钻水平井方位、水平位移的要求, 达到井眼轨迹平滑, 顺利实现钻井、完井工艺, 提高中靶精度的工艺过程[1]。侧钻水平井轨迹起始段工艺技术, 是侧钻水平井钻井工艺的关键技术。该技术直接影响到从开钻到完井各道工序的实施, 影响到侧钻水平井最终目标的实现。通过该技术的研究、应用可以在以下几个方面发挥重要作用: 为减少轨迹控制难度提供条件; 给全部裸眼钻井作业打好基础; 为完井管柱的下入提供条件, 缩短建井周期, 提高工作效率, 减小劳动强度。侧钻水平井的老井初始井斜角和初始方位角完全取决于侧钻点的位置。即不同的侧钻点位置在老井中对应不同的初始井斜角和初始方位角。对侧钻水平井起始段有重要影响的主要侧钻水

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平井初始井眼条件主要包括:[1] 侧钻点初始井斜角;④侧钻点初始方位角;㈣地层因素。

侧钻水平井轨迹设计的空间斜平面法

空间的侧钻轨迹设计比平面的轨迹设计适应性更大,更具有实际意义,因为侧钻时已钻井身与侧钻井身并不一定在一个平面,变化方位是常见的。斜平面法就是在空间某个平面上设计井身。该平面仍是一个斜平面。这个设计三维定向井的斜平面,不是空间任意一个斜平面,而是由给定的设计参数和设计要求所决定的某个斜平面。斜平面法是通过利用纠方位初始点与目标点,建立一个斜平面,在该平面内找到一条适当的曲线代表待钻井眼轨迹,描述待钻井眼在钻进过程中井斜角、方位角随井深的增加而变化的情况[2]。

如图1所示,点划线为原设计井眼轴线,实线为

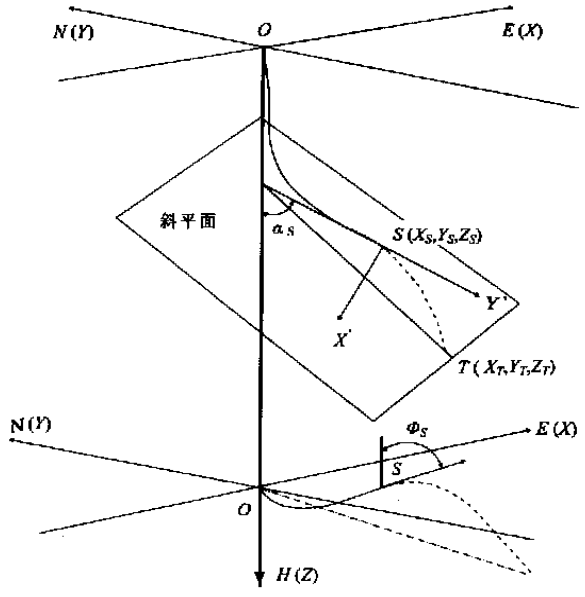

图1　三维斜面法示意图

实钻井眼轴线,虚线为纠偏的井眼轴线。当该井钻至 S 点时,井眼轴线严重偏离设计井眼轴线,此时需要设计纠偏井眼,以便准确钻达目标点 T。设计点 S 到 T 点间的纠偏井眼就是三维侧钻井的设计。此时,已知条件是 S 点的坐标$(X_s、Y_s、Z_s)$和井身参数 α_s 和 Φ_s 以及目标点坐标$(X_T、Y_T、Z_T)$。S 点的位置由坐标$(X_s、Y_s、Z_s)$决定,S 点的井眼方向由井身参数(α_s, Φ_s)决定。为了设计 $S-T$ 间的待钻轨迹,可以 S 点的井眼方向线和 T 点作一平面,此平面即为一个斜平面,也就是新设计的井眼轴线所在的平面。在此斜平面上设计井身,就可以从 S 点出发,直钻至 T 点。这就将本属于三维设计的问题变为二维设计的问题。

斜面法设计三维定向井的关键在于坐标的转换。原设计和实钻的井眼,是在以井口为原点的 $O-ENH$ 坐标系里。新设计的待钻井眼是在某个空间斜平面上。所以,必须找到这个斜平面与原坐标系 $O-ENH$ 之间的关系。这样才能将新设计的待钻井眼转换到 $O-ENH$ 坐标系里。

将坐标系 $O-ENH$ 用 $O-XYZ$ 代替,X、Y、Z 轴分别与 E、N、H 轴相对应。在 $O-ENH$ 坐标系中,只有原点 O 可以变化,其三根坐标轴的方向是不改变的。利用解析几何法,将 $O-XYZ$ 坐标系经过四次转换(平移和旋转),转为 $S-X'Y'Z'$ 坐标系。经过转换,可以导出 X'_T 和 Y'_T 的计算公式。

$$X'_T = \sqrt{X''^2_T + Z''^2_T} \tag{1}$$

$$Y'_T = \sin\alpha_s \sin\Phi_s(X_T - X_s) + \cos\alpha_s \sin\alpha_s(Y_T - Y_s) + (Z_T - Z_s)\cos\alpha_s \tag{2}$$

$$Z'_T = 0 \tag{3}$$

式(1)中的 X''_T 和 Z''_T 表达式为:

$$X''_T = \cos\alpha_s \sin\Phi_s(X_T - X_s) + \cos\alpha_s \cos\Phi_s(Y_T - Y_s) - \sin\alpha_s(Z_T - Z_s) \tag{4}$$

$$Z''_T = (X_T - X_s)\cos\Phi_s - (Y_T - Y_s)\sin\Phi_s \tag{5}$$

弄清利用坐标变换求出各系数、装置角、方位弯角之后,就可以讨论如何应用空间斜面法进行侧钻水平井老井初始井眼条件对井眼轨迹的影响分析了。为了考虑老井的初始井斜、方位对侧钻水平井起始段的影响,需要对侧钻水平井进行三维轨迹设计考虑。侧钻点的初始北、东坐标是影响扭方位三维设计的重要因素。在一般的侧钻井设计中目标仅是一个点,而在侧钻水平井设计中目标是一个水平段,如果侧钻点的北东坐标偏移设计面过远,将导致过长的扭方位井段,增加施工难度。

一般侧钻时,侧钻点以前的井身均已取得了测量数据。利用空间斜平面法可以对影响侧钻水平井起始段的老井初始井眼条件进行分析。影响侧钻井起始段轨迹的主要因素有:初始方位角;初始井斜角;地层造斜能力。

侧钻水平井初始井眼条件对起始段轨迹的影响分析

1. 初始方位角对起始段的影响

侧钻点初始方位与设计方位之间的差值对扭方位设计和施工影响很大。当初始方位与设计方位一致时, 若侧钻点在设计方位面上, 不需要扭方位作业。否则扭方位作业不可避免(参见图 2) 。

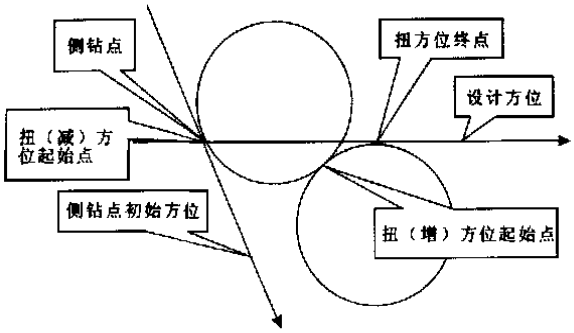

图 2　侧钻起始段水平投影图

(1) 方位差决定了扭方位井段的长度。侧钻点初始方位角与设计方位角的差值对扭方位设计和施工影响很大。当初始方位与设计方位之间存在差异时, 由作图分析可以看出, 方位差越大, 扭方位所需的井段长度就越大, 从钻井施工的角度来看, 这就会增大施工的难度和延长施工时间, 增加施工费用。从作图分析可明显看出, 随着方位差的增大, 扭方位井段的长度增加, 这就增加了施工的难度。侧钻点初始方位与设计方位的方位差随选择不同的侧钻点而改变, 因此, 可以采用优选侧钻点的方法来减少这一方位差值。

(2) 方位差影响扭方位段的水平位移。由作图分析可以看出, 方位差对扭方位段的位移也会产生明显的影响。开始时随着方位差的增加, 扭方位段的位移增加, 但是这种增加的趋势到一定的情况下就会达到一个最大值, 之后随着方位差的增大, 扭方位段的位移将会出现下降的趋势。扭方位井段的水平位移即是扭方位结束点距侧钻点的水平距离。

2. 地层因素对起始段的影响

地层因素对扭方位作业的影响是通过对工具的造斜能力的影响而表现出来的。在易造斜地层, 工具的造斜能力高, 扭方位所需要的井段就短; 而对于不易造斜地层, 工具的造斜能力低, 扭方位所需要的井段就长。

3. 初始井斜角是影响扭方位段长的最重要因素

初始井斜角是影响扭方位段长的最重要的因素。由作图分析可知, 随着初始井斜角的增大, 扭方位井段长度直线增加。从井眼轨迹控制的角度来看, 老井的初始井斜角较大时, 扭方位所需的工作量就大。这告诉我们, 扭方位作业最好是在小井斜井段进行, 对侧钻水平井的施工来说, 当侧钻出老井眼后, 若需扭方位应尽早进行, 这样可大大节约扭方位施工时间。老井初始井斜角对侧钻水平井轨迹起始段的影响还表现在扭方位段的水平位移大小上。由作图分析可以看出, 随着初始井斜角的增加, 扭方位段的水平位移将增大。

结　论

(1) 侧钻点的选择对侧钻水平井起始段有很大影响。侧钻点初始方位与设计方位之间的差值决定了扭方位井段的长度和扭方位井段的水平位移。

(2) 地层因素对扭方位作业的影响是通过对工具的造斜能力的影响而表现出来的。在易造斜地层, 工具的造斜能力高, 扭方位所需要的井段就短; 而对于不易造斜地层, 工具的造斜能力低, 扭方位所需要的井段就长。

(3) 初始井斜角是影响扭方位段长的最重要的因素。随着初始井斜角的增大, 扭方位井段长度直线增加。随着初始井斜角的增加, 扭方位段的水平位移将增大。

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working pressure range, sufficient energy and strong and vigorous gas gush; and the loss caused by out-of-control was very serious. Such a drilling operation, that on the basis of combining plugging with well-killing by raising drilling fluid density, the follow-up works will not be continued until the well-killing is successfully finished, may be adopted for the formation with both mud loss and well blowout. Straight flushing channel is a commonly-prepared equipment of controlling gas well and the best way is to make the well killing as soon as possible because long-term shut-in well and intermittent flush are unfavourable for the safety in well control. Matching well control equipment should be further strengthened on the basis of professional standard and it is also necessary to carry out the high and low pressure gas sealing tests besides the high pressure water sealing test. The well killing is in need of more heavy drilling fluid and more complicated operating sequence and some thermal insulation measures should be adopted during throttling flush.

SUBJECT HEADINGS: Sichuan, East, Drilling, Well control, High pressure, Gas well

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MECHANISM AND COUNTERMEASURES OF GAS RESERVOIR DAMAGE CAUSED BY HIGH-SALINITY BRINE DRILLING-COMPLETION FLUID

Yang Xianyou, Li Shubai and Fang Hui (Research Institute of Petroleum Exploration and Development, PCL). *NATUR. GAS IND.* v. 23, no. 5, pp. 48~ 50, 9/ 25/ 2003. (ISSN 1000- 0976; **In Chinese**)

ABSTRACT: The brine drilling-completion fluid can play an important role in preventing the occurrence of hole unstability and the formation of reservoir water-sensitive damage caused by the dissolustion of anhydrock-salt beds and the hydration swelling and dispersion of clay minerals in strata. Research results, however, indicated that the gas reservoir damage caused by high-salinity drilling-completion fluid was very serious and the damage rate of permeability was up to 90%. The damage mechanism is that the reservoir pore passages were plugged by the salt crystals formed from the high-salinity brine drilling-completion fluid in the process of back-flowing displacement with dry gas. The technical countermeasures of preventing and controlling such a damage are introduced in the paper also.

SUBJECT HEADINGS: High salinity, Brine, Drilling-completion fluid, Gas reservoir, Damage, Mechanism, Countermeasure

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FINITE ELEMENT ANALYSIS ON EFFECT OF WEAR ON CASING COLLAPSING STRENGTH[2)]

Han Jianzeng, Li Zhonghua (Shanghai Jiaotong University), Zhang Yi, Yu Baiqin (Baoshan Iron & Steel Co., Ltd.), Yang Long, Lian Zhanghua, Shi Taihe (Southwest Petroleum Institute), Zhang Yuanze and Li Fude (Sichuan Petroleum Administration). *NATUR. GAS IND.* v. 23, no. 5, pp. 51~ 53, 9/ 25/ 2003. (ISSN 1000- 0976; **In Chinese**)

ABSTRACT: With the development of petroleum industry, there are more and more deep well, ultra-deep well, horizontal well and extended-reach well. Due to their particularities, the wear caused by drill string inside casing wall during drilling makes casing strength decrease. Thus, the effect of the wear on casing collapsing strength should be considered while casing design. But the effect was not considered among the collapse-pressure equations given in API Bulletin 5C3. In this paper, the effect is lucubrated by both finite element method and theoretical analysis. The difference between crescent-shape wear model and eccentric cylinder approximation wear model, and that between crescent-shape wear model and minimun wall thickness uniform wear model are discussed respectively in details. At the same time, the mechanisms leading to the differences among the three wear models are also discussed.

SUBJECT HEADINGS: Casing, Collapsing strength, Wear, Finite element method.

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ANALYSING THE INFLUENCE PRODUCED BY INITIAL HOLE FACTORS ON THE PRIMARY SECTION TRAJECTORY IN RE-ENTRY HORIZONTAL WELLS[2)]

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ABSTRACT: The technology of hole trajectory primary section is the key of drilling in re-entry horizontal wells. In order to research the influences produced by sidetracking position, the primary hole deviation and azimuth of used wells on the primary section of the re-entry horizontal wells, it is necessary to consider the 3 D trajectory design of the re-entry horizontal wells. The principal initial hole factors influencing primary section trajectory, such as sidetracking position (formation factors), primary deviating angle and primary azimuth of the sidetracking position are analysed by spatial plane-tilted method. A guarantee is provided for the azimuth and deviation of the re-entry horizontal wells of oil reservoir engineering and drilling engineering to make the hole trajectory smooth, achieve the drilling and well completion techniques without a hitch and raise the target rate.

SUBJECT HEADINGS: Re-Enrty horizontal well, Primary section, Hole trajectory, Influence factor, Analysis.

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RESEARCH ON CASING FATIGUE FAILURES IN CASING DRILLING[2)]

Yuan Guangjie, Yao Zhenqiang, Liu Longquan (Mechanical and Power Engineering Institute of Shanghai Jiaotong University) and Lin Yuanhua (Petroleum Engineering School of Southwest Petroleum Institute). *NATUR. GAS IND*. v. 23, no. 5, pp. 56~ 58, 9/25/ 2003. (ISSN1000– 0976; **In Chinese)**

ABSTRACT: It makes the casing working conditions worse by casing-drilling technique, which presents a new demand for the casing property. Fatigue damage brought by cyclic loading is one of the most common failure forms of casing. The existing fatigue research about casing thread connections is summarized and the effect factors of casing fatigue failures at common position are pointed out on the basis of analysing the casing working conditions during casing drilling. A suit of measures for detecting and controlling casing fatigue failures is also provided for field engineers to employ and handle.

SUBJECT HEADINGS: Casing drilling, Fatique, Casing, Failure

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TOOTH ARRANGEMENT DESIGN AND POST APPLICATION OF ƒ222. 2 MM PDC BIT IN CHANGQING OILFIELD[2)]

Teng Zhaofeng, Luo Jianyong (Zhongcheng Company, Dagang Oil Field), Liu Qingyou, Zhu Xiaohua and Wang Hailan (Southwest Petroleum Institute). *NATUR. GAS IND*. v. 23, no. 5, pp. 59~ 61, 9/25/2003. (ISSN1000– 0976; **In Chinese)**

ABSTRACT: On the basis of investigating the lithology in Changqing oilfield and spot experiment, the design on tooth arrangement, including crown structure, tooth outcrop, tooth density, radial and circumferential tooth arrangement, etc., of ƒ222. 2 mm PDC bit emploied in Changqing oil field is carried out. In addition, the windage of the radial tooth arrangement data is analysed, and the graph of effective breadth and cutting area is visualized with mathematic softwares as Matlab etc. The anticipative drilling technical indexes of the ƒ222. 2 mm PDT bit are attained by an experiment in Changqing oil field and the superiority and economic benefit by using the ƒ222. 2 mm PDC bit are very considerabl as compared with using roller bit in adjacent wells.

SUBJECT HEADINGS: PDC bit, Bit tooth, Tooth arrangement design, Lithology, Technical index

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ANALYSING THE FAILURES OF THE STABILIZER WITH TUNGSTEN CARBIDE BUTTONS[2)]

Lu Ruidian, Chen Yu (Southwest Petroleum Institute) and Luo Faqian (Talimu Petroleum Exploration Headquarter). *NATUR. GAS IND*. v. 23, no. 5, pp. 61~ 63, 9/25/2003. (ISSN1000– 0976; **In Chinese)**

ABSTRACT: Through investigating the typical failure cases of the stabilizer with tungsten carbide buttons on the spot, the main failure forms of the centering section of the stabilizer are