

钻井工艺

大位移井井眼净化的理论与方法

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摘 要: 井眼净化是否良好直接影响到井眼摩阻、轨迹控制、钻井效率和安全钻井, 直接关系到大位移钻井的成败, 因此, 井眼净化是大位移钻井的关键技术之一。从工程施工所需参数的角度定性的讨论衡量井眼净化的 4 个基本判别准则、从理论上推导出适用于现场井眼净化的一套计算方法, 且分井段的讨论了在保证井眼净化良好条件下的临界机械钻速计算, 并把井眼净化准则、相关计算和有关经验结合起来, 得出了大位移井井眼净化工作程序, 对现场施工具有指导意义。

关键词: 井眼净化; 大位移井; 流型与流态判别; 悬浮能力; 动/塑比; 流速核直径

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一、衡量井眼净化的基本准则

充分认识和评价井眼净化情况, 是采取正确工艺措施的前提。

1. 岩屑形状评价

实践表明, 磨圆砂样小于 20 % 井眼净化良好, 小于 30 % 井眼净化中等, 30 % ~ 50 % 井眼净化较差, 大于 50 % 则在大斜段必定存在较为严重的岩屑床。

2. 岩屑尺寸评价

当钻头类型、机械钻速和地层岩性基本不变时, 返出岩屑除棱角明显外, 还能见到已钻过地层的较大岩块时, 表明钻井液具有强的携砂能力, 井眼净化良好。

3. 井眼畅通评价

无论是在直井段、大斜度井段、还是水平井段起下钻过程中, 若遇起下钻阻力增大或下钻遇阻, 则表明井下有大量岩屑堆集。

4. 岩屑体积评价

将钻进岩屑体积和返出岩屑体积进行比较, 也可以评价井眼净化程度。

4.1 岩屑输送比^{[1][2]}

岩屑输送比又称井眼净化能力, 以 M 表示, 计算式为:

$$M = \frac{V_a - V_s}{V_s} \quad (1)$$

式中: $\overline{V_a}$ —实际环空平均返速, m/s;

V_s —岩屑下沉速度, m/s。

据经验, $M > 0.5$ 时, 井眼净化相对良好, 可保证安全钻进。

4.2 钻屑含量评价^{[1][2]}

正常钻进时从井里返出的一定数量的钻井液与岩屑的混合物中, 岩屑体积占钻井液与钻屑总体积的百分比, 以 C 表示, 实践表明, C 大于 5 %, 井眼净化基本良好。

二、井眼净化的计算方法

1. 悬浮岩屑能力的计算与分析

对岩屑悬浮起决定作用的是钻井液的静切力和触变性。假设颗粒为球状体, 且钻井液有良好的流变性时, 悬浮颗粒所需最小 L_s 由式(2)计算^{[1][3]}。

$$\overline{L_s} = \frac{100 d_c (\rho_s - \rho_m) K_1 \sin \alpha}{6} \quad (2)$$

式中: L_s —钻井液静切力(10 min), Pa;

d_c —颗粒直径, cm;

ρ_s —颗粒密度, g/cm³;

K_1 —颗粒间摩擦阻力系数;

α —井斜角, °;

ρ_m —钻井液密度, g/cm³。

通过对式(2)的分析, 在起钻前应根据颗粒尺寸调整钻井液性能, 使其满足悬浮颗粒的要求。

2. 流态判别及环空返速确定

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一般来说,为保证钻井安全,大位移井大都需要下 1~2 层技术套管,直井段和小井斜段井眼直径一般都较大,钻进中常采用平板流型净化井眼。而大斜度段和水平段一般较深,井眼直径相对较小,多采用紊流型携带钻屑。为了根据不同流型选择排量和处理钻井液流变参数,可从参考文献[3]中查出环空临界返速计算式,并进行流态判别。

3. 平板流型流速核直径的确定

平板流型流速核直径从参考文献[3]中可查出计算公式。

4. 平板流型的判断

在实际钻井过程中,究竟是否为平板流型应当计算和分析,必须满足下列条件。

4.1 流速核直径大于环空间隙的 60 %

令平板型流速核直径为 $d_{0平}$, $d_{0平}$ 应满足下面的公式:

$$0.60 \left[\frac{D_b - d}{2} \right] \leq d_{0平} < 0.65 \left[\frac{D_b - d}{2} \right] \quad (3)$$

式中: D_b —井眼直径, cm;

d —钻杆直径, cm。

4.2 实际环空返速 $V_{a平}$ 小于 V_c 大于 V_s

环空返速与动塑比和环空间隙及流速核直径之比关系式如下:

$$V_a = 0.00125 \tau_0 / \eta_s (D_b - d) \left[\frac{0.333(D_b - d) - 1}{d_0} \right] \quad (4)$$

式中: V_a —钻井液上返速度, m/s;

τ_0 / η_s —动/塑比。

实际钻井中, $V_a < V_c$, V_a 在 0.5~0.7 m/s 条件下, τ_0 / η_s 比值由 300 增至 500 时, 层流流速核 d_0 逐渐增大, 只有 d_0 大于环空间隙的 60 % 时才为平板型流型。

5. 动/塑比上下限

当 $V_{a平}$ 一定时, 动/塑比的大小直接反映流速核直径大小, 因此可用动/塑比值大小来判断环空是否为平板流型。

$d_{0平}$ 下限:

$$\tau_0 / \eta_s = \frac{7200 V_a}{(D_b - d)} \quad (5)$$

$d_{0平}$ 上限:

$$\tau_0 / \eta_s = \frac{31200 V_a}{(D_b - d)} \quad (6)$$

从以上论述可以看出, 降低环空返速和提高动/塑比都能增大流速核直径, 但二者的调整都是有限的。

为了研究 τ_0 / η_s 、 V_a 、 d_0 三者之间的关系, 设 $D_b = 31.1$ cm, $d = 12.7$ cm, 绘出了这三者的关系曲线(图 1), 图 1 表明, 当环空间隙和动/塑比一定时, 返速降低, 流速核直径增大, 但增加的幅度不同。当 $\tau_0 / \eta_s < 200$ 时, d_0 随 V_a 降低迅速增大; 当 $200 < \tau_0 / \eta_s < 600$ 时, d_0 随 V_a 降低有一定幅度增大; 当 $\tau_0 / \eta_s > 600$ 后, d_0 随 V_a 降低增大幅度很小。因此在动/塑比较小时, 适当降低返速对增加流速核直径是有效的, 但返速的降低是有限制的, 返速必须满足岩屑上返的要求, 即 $V_{a平} > V_s$ 。

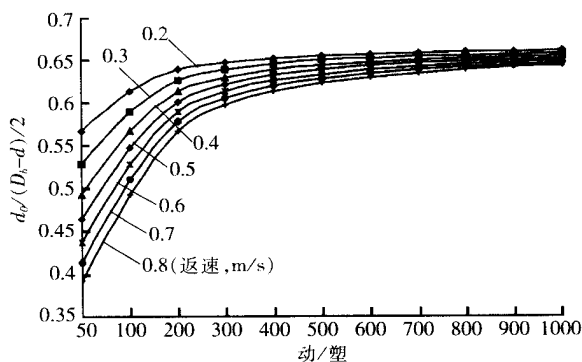


图 1

6. 岩屑下沉速度计算

在层流和平板流型状态下, 如果钻井液返速 V_a 小于岩屑下沉速度 V_s 时, 钻屑全部堆积在井筒中, 将会造成复杂情况和事故。因此在小井斜段采用平板流型净化井眼时, 计算岩屑下沉速度并使其小于环空返速是十分必要的。岩屑下沉速度 V_s 计算见参考文献[4]。

7. 岩屑返出率计算

岩屑返出率即为钻进岩屑返出总体积与钻进岩屑总体积之比, 也可用有效循环携屑时间与钻头进尺时间之比表示。即

$$E = \left(1 - \frac{t_1 + t_2 + t_{停}}{2t} \right) \times 100 \% \quad (7)$$

式中: E —岩屑返出率;

t_1 、 t_2 —刚开始钻进和钻进结束时瞬时钻屑从井底返出井口的时间, h;

$t_{停}$ —钻井过程中停泵时间, h;

t —钻进时间, h。

当钻井液动/塑比适合, 具有较强的悬浮岩屑和携带能力时, 钻进中若岩屑能及时返至地面, 表明井眼净化好, 反之则较差。

8. 临界机械钻速计算

临界返速即是在保证井眼净化良好条件下的机

械钻速。由于大位移井存在着直井段、斜井段和水平段,并且直井段和部分斜井段大多属于大直井段,因此,临界返速计算分上述两种情况进行。钻进中应使实际钻速低于临界钻速。

8.1 直井段和小井斜(30°以内)井段临界机械钻速计算

在大位移井中直井段和小井斜井段一般都是大井眼井段,钻井液环空返速不可能达到紊流,一般 0.3~0.7 m/s。因此,这一井段钻进中多采用平板流型净化井眼。根据这些特点,推导出下述临界机械钻速计算方法。

$$R_{\text{临}} = \frac{60 h_x}{\frac{V_s t_{\text{停}}}{V_a - V_s} (1 + \Phi_{\text{沉}})} \quad (8)$$

式中: $R_{\text{临}}$ —临界机械钻速, m/h;

h_x —接单根时井底允许岩屑堆集高度, m;

V_a —钻井液上返速度, m/s;

$t_{\text{停}}$ —接单根停泵时间, min;

$\Phi_{\text{沉}}$ —岩屑堆集在井底的孔隙度, 小数。

从式(8)可以看出,临界机械钻速受预计岩屑堆集高度、接单根时间影响较大。从式中还可清楚地看出岩屑在井底堆集高度 $h_x = 0$ 时,此式无意义。 $h_x > 0$ 表示井底堆积有钻屑。为了满足井眼净化要求,一般可确定 $h_x = 1 \sim 2$ m 计算临界机械钻速,如实际机械钻速超过临界机械钻速,岩屑将在井底堆集越来越多,易卡钻,所以,为保证井下安全,实际钻速最好不要超过该临界机械钻速。

8.2 大斜度段和水平段临界机械钻速计算

大斜度段和水平段在深大位移井中都是比较深的井段,钻进中,多采用紊流流型,必要时还需注入高切高稠钻井液洗井。为了安全钻进,临界岩屑床厚度 h 不超过井眼直径的 15%~19%为宜,临界机械钻速计算公式如下,推导从略,仅供参考。

$$R_{\text{临}} = \frac{6114.45 h \sqrt{h(2R - h)} \times (V_a - V_s \cos \alpha) K}{D^2 (1 + \Phi_{\text{沉}})} \quad (9)$$

式中: h —临界岩屑床厚度, m;

R —井眼半径, m;

D —井眼直径, m;

K —系数,一般取 0.04~0.06;

α —井斜角,°。

9. 钻柱转动有利于井眼净化的讨论

在大斜度段和水平段,钻柱在重力作用下躺在井眼低边,钻柱转动时钻柱与岩屑和钻井液间产生引带力和撞击力,该力方向与钻柱转动方向相同。在这种引带力和撞击力的作用下,钻屑被撞松并涌向井眼中心,随被上返的钻井液向上运移。这两种力随着井斜角增加作用力增强,因此大斜度段和水平段效果十分明显。

三、大位移井井眼净化工作程序

该程序将井眼净化准则、相关计算和有关经验结合起来,指导施工中的井眼净化工作。

根据地层特点和钻井施工工艺需要确定钻井液体系、配方和性能;根据不同井段和设备能力确定钻井液环空返速和流型;根据环空返速和流型确定钻井液静切应力、动/塑比、视粘度等相关性能,使其满足流型和井眼净化需要;根据井下情况计算井眼净化有关参数,比如钻井液悬浮能力、动/塑比、流速核直径、临界返速、需要的环空返速、岩屑下沉速度、岩屑返出率和临界机械钻速等;根据井下情况和计算结果调整钻井液相关指标,以满足井眼净化需要;采用本方法净化大位移井时,还需与短起下钻、不定期注稠泥浆和必要的停钻循环相结合。

四、结论

(1)从钻井液流数入手,结合钻井工程施工技术,推导出井眼净化相关参数的计算方法。

(2)从洗井本身的钻井液和工程因素中提出了井眼净化的基本理论和方法,计算简便,具有实际意义。

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DI Qinfeng (Applied Math and Mechanics Research Institute of Shanghai University), **DPT** 28(6), 2005:16~18

Abstract: The well Gucheng 2 was one of wild cat well in Gucheng structure 2 in Tarim base, a straight hole. There was a fault while drilling, and the formation dip become steep suddenly and inclination increased quickly, which resulted in setting cement plug and sidetracking. It was no use to slide drilling for dropping angle by 1.5 degree bent sub, and good result has been got by 2 degree bent sub. After dropped angle, normal BHA was changed and run in hole to resume drilling, the inclination increased again. If the BHA had not been replaced, the trips would be increased many times. Rig site analysis has been done and decision has been achieved, one degree bent house motor was used, slide drilling and rotary drilling was utilized alternately for the need of well path control. In practice, the actions has been taken from 2885 to 3115m and from 3166m to 3380m, and the inclination was perfect, which realized the slide drilling and rotary drilling alternately, fast ROP, less times of trips. This paper analyze the application of both slide drilling and rotary drilling, an example has been achieved for the similar operation in such well.

Key words: Well Gucheng 2, slide and rotary drilling techniques, anti-deviation while faster penetration

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APPLICATION OF PRESSURE CORING TECHNOLOGY IN THE FOURTH OILFIELD OF TAZHONG

CHEN Li, LI Ning, WANG Qi, XHEN Xiaobing, ZOU Qiang, FENG Ming and ZHU Mingyu (Coring Center, Drilling & Production Technology Research Institute of SPA), **DPT**28(6), 2005:19~21

Abstract: The paper presents the field application and technology of MQX194-115 pressure coring tool in well 4-7-19 in Tazhong oilfield. Water cut of Tazhong 4 oilfield is over 40ml/kg due to waterflooding operation for long time, the polarity of core surface is strengthened, thus avidity of closed fluid is reduced to core surface. The closed effect is influenced. Through controlling bottom-hole pressure drawdown, optimized design coring bit and selecting performance stable closed coring tool, 88.8m cores have been obtained from Carboniferous sandstone by means of pressure coring technology in Well 4-7-19 of Tazhong, recovery ratio and sealing ratio are 98.4% and 88% respectively. It created good achievements in the fourth oilfield of Tazhong in terms of coring in high water-bearing formation.

Key words: Tazhong 4 oilfield, pressure coring, influence factors, field application, result

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DESIGN AND APPLICATION OF HIGH INCLINATION PILOT WELL IN LENG 41-PING 1 HORIZONTAL WELL

ZHANG Wei (Engineering Research Institute, Liaohe Petroleum Exploration Bureau), **DPT** 28(6), 2005:22~23

Abstract: In development of leng 41 thick bottom water super-heavy oil reservoirs by adopting leng41-ping1 horizontal well technology, there are some problems existent in drilling, such as bottom water zone of great energy, serious coning, unconfirmed water-oil depth and so on. In order to confirm water-oil surface depth, insure horizontal section drilling in oil zone, high inclination pilot well is proposed to drill cross the oil zone and bottom water zone before the first target. This article introduces geologic framework, design, construction and so on of high inclination pilot well. Through construction of high inclination pilot well, the drill footage of horizontal well is decreased, and the good drilling effect is obtained.

Key words: horizontal well, pilot well, bottom water, inclination

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THEORY AND METHOD FOR THE BORE-CLEANING PROBLEM OF REACH-EXTENDED WELL

YANG Xiaoli, FAN Xiaoping (Engineering Technology Research Institute of Liaohe Petroleum Exploration Bureau), LIU Sujun (Drilling & Production Technology Research Institute, SPA), **DPI** 28(6), 2005:24~26

Abstract: The quality of hole cleaning is directly influence on many drilling circumstance such as borehole friction, path trajectory, drilling efficiency and safe drilling, and directly related to the success or failure of the reach-extended well, so the hole cleaning technology is one of the key technologies of the reach-extended well. This paper discusses the four basic distinguish principles of hole cleaning from the need of operation parameter, put forward a set of calculation method used for application, and discusses the method on calculate the critical penetration rate (ROP) through 4 well sections. By combining the guideline of bore cleaning, correlated calculation into the related experience, the work process of measuring bore cleaning summarized in this paper will be available for the operation on-site.

Key words: reach-extended well, bore cleaning, drilling parameters

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ANALYSIS AND PRECAUTION OF DRILLING TOOLS FAILURE IN DEEP WELL