钻井工艺

磁导向技术在 SAGD 双水平井轨迹精细控制中的应用

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摘　要：随着对稠油/超稠油油藏的开发力度越来越大，SAGD钻井技术已经成为开发这类油藏的一项前沿技术。SAGD双水平井轨迹精细控制成为这项技术的一个突出问题。MGT磁导向钻井技术能够在不考虑完成井的轨迹绝对误差前提下，根据已完成井的轨迹，对待钻井的轨迹实行闭环控制，以有效的减小轨迹误差，达到设计要求。MGT磁导向系统对SAGD双水平井轨迹的精确测量、控制技术，是在传统井眼轨迹测量、控制技术基础上的延伸与发展。这项技术具有性能可靠、高效率等特点，达到了商业化应用的模式。

关键词：磁导向技术；SAGD；双水平井；轨迹控制

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一、SAGD双水平井概况

随着世界经济的不断发展，对石油的需求也在不断上升。未来对稠油/超稠油油藏的开发力度将会越来越大。蒸汽辅助重力泄油（Steam Assistance Gravity Drive)是开发超稠油油藏的一项前沿技术，国外主要以加拿大为代表，国内辽河油田SAGD技术发展较快，最具代表性[1]。SAGD技术按钻探方式与井型的不同可以分为直井井组联采、U型井（直井/水平井）联采、丛式井/（斜直）水平井联动助采和双水平井开采等几种类型[2]。其中以双平行水平井井组开采方式对采收率的贡献最大。

SAGD双水平井由上、下平行的井组构成[2]（如图1所示），上面为蒸汽注入井，下面为生产井。其基本原理是以蒸汽作为加热介质，由注入井连续注入高干度蒸汽，依靠流体的热对流和热传导作用，使得地层中形成蒸汽腔，蒸汽腔的边缘加热原油，蒸汽冷凝成水与原油依靠重力流入水平生产井开采稠油。

二、SAGD双水平井轨迹控制面临的难题[1~8]

钻井实践表明，SAGD双水平井轨迹控制不同于常规水平井井眼轨迹要求，其主要特点表现为：①SAGD双水平一般井深较浅（< 1 000 m），造斜段造斜率大，部分井眼最大造斜率达到15°/30 m；②水平段轨迹必须保证水平，轨迹距靶心垂向误差不超过±1.0 m，平面上水平段轨迹距靶心误差不超过±2.0 m；③水平段长度较大，一般在400 m左右；④两口井纵向、横向间距均有严格要求。如果两口井位置太近，注入的蒸汽将会直接从生产井中排除。如果间距过大，注入的蒸汽将不能很好地实施两井的联合作业。研究和实践都表明，对于典型的SAGD双水平井，当两井水平段之间的间距介于4~10 m时为最优；⑤进入水平段后期，垂深浅、钻压难以直接施加至钻头，存在上下井磁干扰问题。

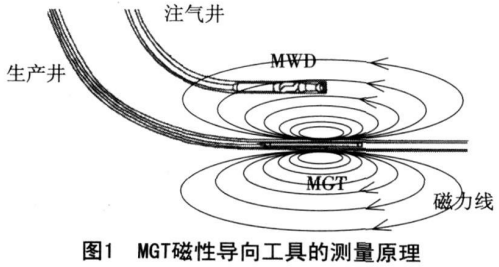

图1　MGT磁性导向工具的测量原理

利用常规测量手段所产生的累计误差远远超过SAGD的精度要求，这是由于传统的水平井井眼轨迹控制实行开环控制，误差累计放大所致。井眼轨迹误差源主要为传感器系统误差、测量深度误差、磁

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偏角误差、磁干扰、磁化纠正、钻具状态、偏心及测量状态等。而测量仪器的精度,是影响误差的主要因素。因此,对不同的井眼轨迹精度要求,使用不同精度的测量仪器。同时 SAGD双水平井的油藏埋深浅,又采用的多段制井眼轨迹,稳斜段垂深损失大,造斜率控制相对常规水平井更加严格,轨迹控制将更加困难。

三、磁导向(MGT)钻井技术对 SAGD水平井轨迹的精细控制

1 磁导向钻井技术基本原理[2~6]

1993年 Sperry Sun钻井服务公司在加拿大第一次尝试使用磁导向系统工具(Magnetic Guidance System Tool)技术钻 SAGD双水平井。磁导向系统工具是由一个 MGT磁场发射源和一个磁场接收传感器组成。当其开始工作时,位于第一个井中的 MGT磁场源产生一个已知强度和方位的磁场,在第二口井中通过一个经过特殊改装过的 MWD传感器来检测这个电磁场强度和方位,进而确定 MGT磁场源和 MWD接受传感器之间的距离和方位。如图 1所示为位于第二口井中的 MGT磁场源产生的磁力线和第一口井中的 MWD接受传感器。通过磁场在注气井井底高边方向上的分量,可以确定出 MGT工具和 MWD传感器之间的相对方位,而根据 MWD测得的磁场径向和轴向强度值,能够计算出这两者之间的相对距离。

需要注意的是,和任何测量工具一样,MGT在实际测量中不可避免存在误差。如 MGT电磁场总会受到套管、油管和大地磁场的轻微影响,不过这种影响可以通过地面标定进行消除。试验表明,由于 MGT系统控制双水平井轨迹实行闭环控制,只要两井之间的距离保持在 10 m以内,精度已经达到足够要求。另一方面,由于磁场强度与距离成三次方关系,所以 MGT测量距离的上限大约为 30 m。

2 磁导向钻井技术轨迹精细控制技术

由于 SAGD双水平井油层垂深小、曲率大,SAGD双水平井水平段垂直距离仅 5 m左右,其轨迹控制不同于常规水平井的井眼轨迹的技术要求。两井眼之间的间距精确控制须采用 MGT磁导向技术,以满足井眼轨迹控制精度要求。采用 MGT轨迹控制系统,在完成上或下水平井施工后,不考虑完成井的轨迹绝对误差,根据已完成井的轨迹,对待钻井的轨迹实行闭环控制,以有效地减小轨迹误差。

为减少仪器误差和人为误差,要求一对 SAGD水平井同钻机、同仪器、同操作人员。生产井轨迹的准确可靠、两套测量仪器的互动。一般的,SAGD双水平井磁导向钻井施工程序如下:

(1)使用 MWD进行轨迹测量和控制技术,钻位于下方的生产井。

(2)生产井完钻后,原钻机移动至注汽井进行钻进作业。

(3)由于注气井只需要钻技术套管附件等,采用小修钻机即可完成。

(4)采用小尺寸(如 Ø89mm)钻杆在生产井水平段中送入 MGT磁场发射装置,每隔一定距离(20~40 m)设置靶点一个(记为靶点 1#、2#、3#、…)。

(5)注气井水平段采用磁导向轨迹控制技术钻进。下入钻具带 MGT探测器(电缆连接),首先以生产井的 1#靶点为目标点,从生产井通过改装的 MWD传感器获取 MGT磁场数据,引导注气井的钻进;

(6)注气井钻进时,随着向 1#靶点逐渐靠近,磁导向信号逐渐增强。当信号饱和时注气井停止钻进。再以 2#靶点为目标点,引导注气井眼的钻进,完成轨迹的精细控制。

(7)重复上述过程,直至完成注气井水平段的钻进。

轨迹需要调整时,利用 MWD的工具面参数,通过滑动钻进的方式,实时的纠正,以调整生产井的井斜角及方位角,实现注气井跟随生产井钻进。在完成一个目标点的跟踪监测校验后,再依次往前推进,以此完成注气井水平段的钻进。这样传统的水平井地质靶窗要求在注气井的水平段钻进就显得不重要了,只要控制两井井眼轨迹的相对误差在一定范围内即可。可见,SAGD双水平井轨迹的精确测量、控制技术,是在传统井眼轨迹测量、控制技术基础上的延伸与发展。

四、成功案例分析

X-IP井为某油田上的 SAGD双水平井组,生产井(P井)采用 MWD技术控制井眼轨迹施工,注气井(I井)则采用 MGT技术进行轨迹控制钻进。要求轨迹距靶心垂向误差不超过 ±1.0 m,平面上水平段轨迹距靶心误差不超过 ±2.0 m,两井间距为 5 m。P井和 I井的设计水平段着陆点垂深分别为 217.7 m和 212.7 m,完钻点水平位移分别为 570.7 m和 549.6 m。

图 2、图 3分别为该井组水平段实钻轨迹垂直剖面局部图和水平投影局部图。由图可见,采用 MGT磁导向轨迹控制技术,I、P两井井眼轨迹走向

基本一致,两井井眼间垂向距离变化最大为 5.8 m,误差为 0.8 m;垂向最小距离为 4.3 m,误差为 0.7 m,垂向间距平均为 5.1 m,误差为 0.1 m。水平投影图上二者轨迹基本吻合,两井眼间平面偏差小于对应井深垂向偏差,该井组完全达到施工设计要求,满足设计精度。

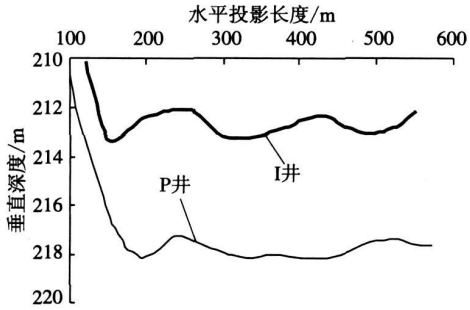

图2　X-IP井组水平段实钻轨迹垂直剖面局部图

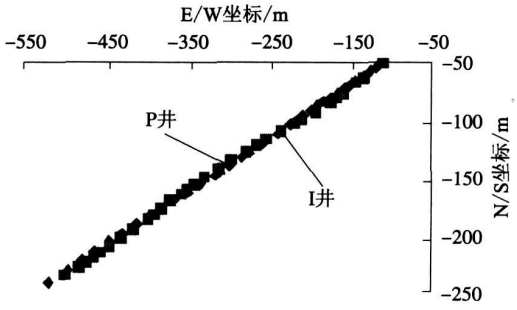

图3　X-IP井组水平段实钻轨迹水平投影局部图

五、结论

(1) SAGD双水平井垂深浅、造斜段造斜率大,两口井纵向、横向间距相对距离精度要求高,轨迹控制难度大。

(2)MGT磁导向系统对双水平井轨迹实行闭环控制,精度高,两井之间距在 10 m以内测量精度能够满足工程施工要求。

(3)MGT磁导向轨迹控制系统不考虑完成井的轨迹绝对误差,根据已完成井的轨迹,对待钻井的轨迹实行闭环控制,以有效地减小轨迹误差。

(4)MGT磁导向系统对 SAGD双水平井轨迹的精确测量、控制技术,是在传统井眼轨迹测量、控制技术基础上的延伸与发展,其应用前景广阔。

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ABSTRACTS

USING UNCONVENTIONAL CASING PROGRAM TO IMPROVE BORE FRAME DESIGN OF DEEP AND ULTRA – DEEP WELL

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Abstract: This article analyzed the basic situation and existing flaw of the unconventional casing program which were used in deep and ultra–deep well's bore frame design. The suitable principle and recommendation plan between the unconventional casing and bit size were proposed to meet the requirements of hole structure design of deep and ultra–deep well. The article also suggested to carry out the specialized standard research of the casing and bit size which can meet the needs of actual situation in China.

Key words: casing program, deep well, ultra–deep well, well structure

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APPLICATION OF LLT–2–TYPE LIQUID LEVEL MONITORING SYSTEM

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Abstract: In Sichuan basin, the reservoir pressure has generally been reduced in old well. Most of the formation pressure coefficient has lower than 1.0, it isn't easy to control fluid leakage in the workover process. In order to operate successfully, the well killing must be done by using low–density killing fluid to stabilize the in–hole liquid column. Because of the leakage of killing fluid, underground liquid level conditions couldn't be mastered in time and accurately, thereby it would result in well control safety hazards, increase the operation cost and technology risks. This paper discussed working principle and the field application of LLT–2–type liquid level monitoring systems. It is proved that LLT–2–type liquid level monitoring system could accurately monitor the liquid level to ensure the operation safety, and it was very useful to establish the technology of the next step and guide the safety production.

Key words: old well killing, liquid level monitoring, principle, application

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ERD TECHNOLOGY BY CASING SIDETRACK IN LIUHUA OILFIELD OF SOUTH CHINA SEA

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Abstract: The oil reserves of Liuhua oilfield is one of the biggest reserves in the eastern area in South China Sea, drilling operation has been performed by extended reach drilling with casing sidetrack, and important geological achievements have been achieved by the ERD hole. The paper showed the ERD geometry, proposal profile, main challenging points, main key technology and main professional achievements. The main challenging points are building holding, Anti–collision, drilling into pay zone in same 215.9mm hole, which has different pressure gradient, and might cause lost circulation and result in pipe stuck, and hard to maintain mud performance due to long open hole in shale and clay stone. It also introduced the RSS Xceed675 application and its results, technology on BHA design and torque and drag analysis, ERD drilling parameter optimization and safe drilling operation procedures, drilling fluid technology. Briefly talked about the operation summary, time breakdown and hitting targets. The paper summarized some technical achievements, and some lesson learnt has been got, and finally useful suggestion and conclusion have been put forward accordingly.

Key words: Liuhua Oilfield, ERD, sidetracking, drilling technology, exploration drilling, development, casing sidetracking, RSS, trajectory control

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MGT SYSTEM APPLIED TO ACCURACY WELL TRACKS CONTROLLING IN SAGD HORIZONTAL TWIN WELLS

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Abstract: With the degree of heavy oil exploitation expanding increasingly, the SAGD drilling technology has became one of the frontier. The accuracy well tracks controlling in SAGD horizontal twin wells is one noticeable problem in this process. The Magnetic Guidance system (MGT system) has the unique features of effective decreasing the track error and closed loop control track, which depending on completed well track, to attain design requires. The MGT system is the development of the tradition well tracks controlling which has features of accuracy well tracks controlling and measure in SAGD Horizontal Twin Wells. And the MGT system has reached the level of commercially available.

Key words: MGT system, SAGD, horizontal twin wells, well tracks controlling

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CORING DIFFICULTIES AND CASE ANALYSIS OF THE RIGHT SIDE OF AMU DARYA RIVER AND GUNORTA ELOTEN BLOCK IN TURKMENISTAN

CHEN Xiaobin, ZOU Qiang, WANG Chengxue and FU Xiaoping (CCDC Petroleum Coring Technology Co., Ltd.), **DPT** 33(3), 2010: 15–18, 21

Abstract: In a long time, core jamming and grinding are always the bottleneck problem occurring during coring in formation due to the fragility of carbonate rocks. The average footage of Turkmenistan coring operation is 13.79m and the fastest drilling speed is 6m/h. This paper gave a brief introduction and summary of the coring situation and achievement in Chuanqing drilling and exploration area of Turkmenistan. And it quoted data of single well coring with typical structures. It focused on the complication and arduousness of formation coring in the Turkmenistan carbonate rock. In the end, based on the on–site situation, some suggestions were put forward, such as increasing the coring hardware performance, strengthening the coring software measures, improving the drill fluid performance and rationalizing the drilling idea in production area. These suggestions are great references with high value.

Key words: exploration, coring achievement, difficulties, case analysis, measures, suggestion

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