套管漂浮技术在海洋钻井中的应用

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摘要　套管漂浮技术主要应用于大位移延伸井和水平井中, 它是在套管柱下部封闭一段空气或低密度钻井液, 使套管柱在大井斜段处于漂浮状态, 以降低下套管摩阻。主要介绍了套管漂浮工具的结构和工作原理以及漂浮技术在国内几个海洋油田钻大位移延伸井和水平井中的应用情况。

主题词　海洋钻井设备　大角度斜井　水平井　(套管漂浮)　接箍　技术

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在边际油田或薄油层油田的开发中, 大位移延伸井和水平井起到了十分重要的作用。钻大位移延伸井和水平井需要许多创新的钻井技术, 套管漂浮技术就是其一。大斜度井中的高摩阻造成技术套管下入困难, 套管漂浮技术是利用套管柱下部封闭的一段空气或低密度的钻井液, 增大套管柱在井内钻井液中的浮力, 从而达到减小摩阻的目的。

由于受空间的限制, 海洋钻井多采用大位移延伸井和水平井开发边际油田或薄油层油田。以下就套管漂浮技术在国内几个海洋油田的应用作一简单论述。

一、套管漂浮技术原理

套管漂浮组件包括漂浮接箍、止塞箍、盲板浮鞋以及与之配套使用的固井胶塞等。盲板浮鞋和止塞箍接在套管串的最下端, 中间隔 2 ~3 根套管。漂浮接箍安装在套管串中部, 漂浮长度就是盲板浮鞋与漂浮接箍之间的套管长度, 套管漂浮就是通过在这段套管内封闭空气或低密度钻井液实现的。如果为空气充填, 下套管过程中漂浮接箍以下不需要灌钻井液; 如果为低密度钻井液充填, 则下套管过程中在漂浮接箍以下灌低密度钻井液。套管漂浮在井眼内的管柱结构, 见图 1。

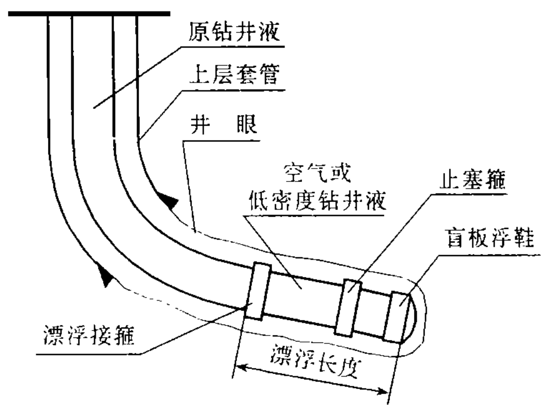

图 1　套管漂浮管柱示意图

目前, 国内海洋钻井主要使用戴维斯(Davis)和哈里巴顿(Halliburton)这两家公司的套管漂浮组件。两家公司生产的漂浮接箍的内部结构和工作原理有所不同, 止塞箍和盲板浮鞋的结构基本相同。

1. 戴维斯漂浮接箍的结构和原理　戴维斯漂浮接箍由内筒和外筒 2 部分组成, 结构见图 2。

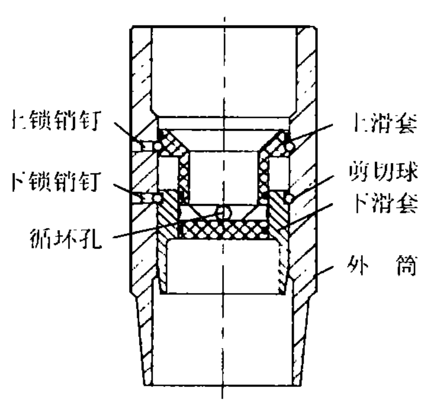

图 2　戴维斯生产的漂浮接箍

图 2 中, 漂浮接箍的外筒材质与套管相同, 其上下端加工有套管丝扣, 与套管柱连接, 安装时使用套管丝扣胶密封。内筒分上滑套和下滑套, 为 PDC 钻头可钻式结构。通过上锁销将上滑套固定在外筒中, 剪切球的剪切压力一般为 35 ~ 38MPa, 也可以根据使用者的要求进行调整。上滑套的底部有 4 个直

径25.4mm 的循环孔。套管下到位后,地面加压剪断剪切球(地面压力等于剪切球的剪切压力减去钻井液液柱压力)。剪切后,上滑套下移,露出循环孔即可循环。

下滑套由下锁销固定在外筒中,剪切压力设定比较小,一般来说远小于水泥胶塞底塞的破裂压力。固井时,底胶塞下行坐在上滑套上,通过水泥浆的自重即打掉下滑套。现场作业时,这一过程几乎看不到地面压力表压力变化。

在内筒与外筒之间,内筒的上滑套和下滑套之间的光滑接触面均由密封圈密封。

2.哈里巴顿漂浮接箍的结构和原理 哈里巴顿漂浮接箍也由 2 部分组成,比戴维斯产品稍复杂,其结构见图 3。

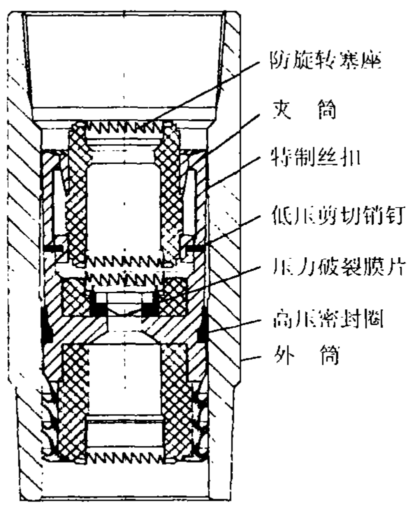

图 3 哈里巴顿生产的漂浮接箍结构图

外筒上下端加工有套管丝扣,与套管柱连接,其材质与套管相同。外筒内壁上部有特殊丝扣,内部组件通过夹筒的丝扣悬挂在外筒中。

夹筒由铝制作,销钉由黄铜制作,其它内部组件由塑料或橡胶制造,该结构也为 PDC 钻头可钻式。夹筒夹持的塞座上下各有 24 个防旋转齿。钻水泥塞时,可防止胶塞旋转,提高可钻性。夹筒的下部与外筒之间通过高压密封圈密封。

压力破裂膜片是用厚 0.406mm 不锈钢片制造,破裂压力一般为 35MPa,特殊设计的可高达 52MPa。套管下到位后,地面加压打破压力破裂膜片,进行固井(地面压力等于膜片破裂压力减去钻井液液柱压力)。当底胶塞碰到漂浮接箍的塞座后,需要 0.5~1MPa 的压力剪断低压剪切销钉,塞座下移,夹筒从外筒内壁的丝扣上脱离,然后继续顶替至止塞箍。

3.止塞箍和盲板浮鞋 止塞箍和常规的浮箍相类似,只是下套管过程中单流阀处于关闭状态,与盲板浮鞋一起构成管串底部双级密封。盲板浮鞋是用混凝土充填单流阀结构和本体之间的空间,单流阀处于关闭状态,而盲板浮鞋底部引鞋处,使用铝制封堵,通过 8 个黄铜销钉固定。固井之前,憋压剪断销钉进行固井作业。盲板浮鞋结构见图 4。

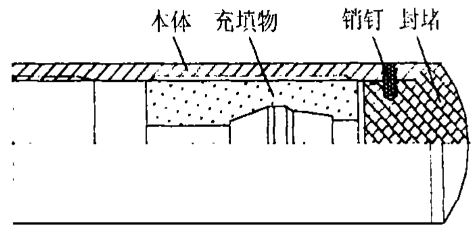

图 4 盲板浮鞋结构图

4.套管漂浮长度的确定 套管漂浮长度是漂浮技术的关键,一般由漂浮组件的生产厂家确定。生产厂家根据作业者提供的有关资料,通过计算机软件进行模拟计算,确定套管漂浮长度。计算依据包括:井眼轨迹数据(测量井深、井斜角和方位角)、钻井液体系和性能、顶驱重量等等。套管与套管之间以及套管与裸眼之间的摩擦系数是模拟计算漂浮长度的最关键参数,通过经验和计算机软件反算而得。典型的套管漂浮长度模拟曲线见图 5,图中模拟的油井造斜段在 400~1500m,最大井斜为 80°,摩擦系数为0.38,漂浮长度 1643m。从图 5 中可见,漂浮段套管下入井中后,下放和上提时的摩阻大幅度降低。如不使用漂浮技术,下套管至5000m 左右,套管将遇阻而无法正常下入。

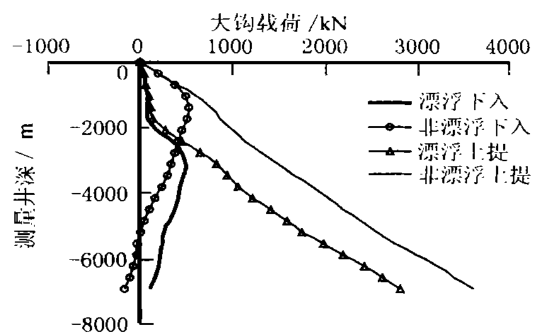

图 5 计算机模拟的漂浮长度曲线图

二、套管漂浮技术的现场应用

套管漂浮技术主要应用在大位移延伸井和水平井的技术套管上,多数用在井斜角较大的稳斜段,以减小套管和井壁的摩阻。现场需要不同,施工程序就不相同,以下是国内几个海上油田的使用情况。

1.渤海海域歧口 17—2 油田　歧口 17—2 油田为自营油田,位于渤海西部海域,是典型的边际小油田。利用歧口 17—2 油田西部构造上的导管架,成功钻成了 3 口大位移延伸井(P30 井、P31 井、P33 井)和 1 口水平井(P32H),用来开发油田的东部构造。

4 口井的稳斜段为 Ø311.2mm 井眼,井斜角 70°左右,使用加强型PEM 钻井液体系钻进。戴维斯公司通过模拟计算得出结论,必须下漂浮接箍,否则 Ø244.5mm 技术套管难以下入。4 口井均使用戴维斯制造的漂浮工具,下入步骤如下:

(1)下套管,管串最下端安装与漂浮接箍配套的盲板浮鞋、止塞箍,使用套管丝扣胶密封。盲板浮鞋和止塞箍之间隔 3 根套管。

(2)下套管至设计漂浮长度后安装漂浮接箍,并用套管丝扣胶密封。下套管期间不灌钻井液。另外,在下漂浮段套管时,大钩载荷(不包括顶驱)增加到一定值后又降低,若降低到 50kN 时,则需提前安装漂浮接箍。

(3)继续下套管到井底。下套管过程中,每下 10 根套管灌满钻井液 1 次。向套管内灌入的钻井液和井眼中的一样,密度为 1.24 ~1.26g/cm³。

(4)地面加压打开漂浮接箍。排放漂浮段空气和灌钻井液交替进行。然后继续加压打开盲板浮鞋密封。

(5)循环钻井液,采用单级双封固井方法封固油层段和上层套管鞋,漂浮数据见表 1。

表 1　渤海海域漂浮数据

井　　名	P30	P31	P32H	P33	A26H
漂浮接箍深度/m	1949	1916	2648	1970	2302
打开漂浮接箍压力/MPa	8	8	6	8.2	11
打通盲板浮鞋压力/MPa	11.5	11.8	14	13	—
漂浮段长/m	1511	1514	1486	1517	432
技术套管鞋深/m	3460	3430	4134	3487	2734
止塞箍深度/m	3422	3392	4096	3449	2696

下漂浮段套管时是在上层套管内的直井段和造斜段,由于不灌钻井液,套管承受较大浮力,悬重增加缓慢(每 100m 约增 10kN)。随着下入长度的增加,套管所受的摩阻增大,悬重增加到一定值后非增反降。现场施工时,考虑所使用的顶驱不能下压,因此悬重降至低于 50kN 后,必须提前安装漂浮接箍。

安装漂浮接箍并灌钻井液后,开始下套管时悬重上升较快。随着井深增加和井斜角增大,特别是下入裸眼段后,摩阻会有较大增加,悬重则会转而下降。如果不使用漂浮技术,套管垂于井眼低边,就增大了对井壁的接触力,也就大幅度提高了摩擦阻力,下到一定深度时,就有下不去的危险。

盲板浮鞋和止塞箍之间隔 3 根套管,防止固井时替空,保证固井质量;灌钻井液过程中,要求每隔 10 根套管灌满 1 次,必要的话,随下随灌,防止发生阻卡现象;记录下套管深度和对应的悬重数据,应用计算机软件反算套管和地层的真实摩阻系数,为下一口井漂浮的理论计算提供可靠数据。采取正确的施工措施后,保证了套管漂浮工具在歧口 17—2 油田的成功应用。

2.南海海域西江 24—3 油田　西江 24—3 油田为中海油、菲利普斯和派克顿 3 家石油公司合营开发的油田,菲利普斯石油公司担任作业者。该油田位于南海珠江口盆地,距香港东南约 128km,水深 100m。利用西江 24—3 构造上的现有生产平台,成功钻成 4 口高难度、具有世界水平的大位移延伸井,开发距离该构造 8km 的西江 24—1 构造。

四口大位移延伸井的井深均超过 8600m,稳斜段为 Ø311.2mm 井眼,该段井斜角 80°左右,使用无毒油基钻井液钻进,钻井液的密度为1.10g/cm³。常规的下套管工艺根本无法满足施工要求,必须采用套管漂浮技术。其中 3 口井(A14、A17、A18)使用戴维斯漂浮工具,1 口井(A20)使用哈里巴顿漂浮工具。由于井况和现场使用设备不同,施工工艺有别于渤海海域。其施工步骤如下:

(1)安装与漂浮接箍配套的盲板浮鞋、止塞箍,使用套管丝扣胶密封。

(2)下 Ø244.5mm 套管,开始不要灌钻井液。

(3)下到一定深度后,大钩载荷(不包括顶驱重量 450kN)为零。使用部分顶驱的重量下压继续下套管,直至剩余顶驱重量 150kN 时,安装漂浮接箍,用套管丝扣胶密封。

(4)继续下套管,使用自动灌浆系统边下边灌油基钻井液。

(5)地面加压打开漂浮接箍,排放漂浮段空气和灌钻井液交替进行,然后继续加压打通盲板浮鞋。

(6)循环油基钻井液,采用单级固井方法封固套管鞋以上 200 ~300m。漂浮数据见表 2。

表 2　西江油田漂浮数据

井　　名	A14	A17	A18	A20
漂浮接箍深度/m	4606	613	2563	2357
打开漂浮接箍压力/MPa	7	—	22.4	19.6
理论打开压力/MPa	—	—	20.4	15.4
漂浮长度/m	2146	3582	2489	4213
技术套管鞋深/m	6752	4195	5052	6570
止塞箍深度/m	6727	4170	5027	6545

现场施工时,采用顶驱下压来增加漂浮段的长度;采用自动灌浆系统边下边灌钻井液,减小灌钻井液时阻卡的几率;遇阻后采用灌密度 2.0g/cm^3 的加重钻井液,增加垂直段的悬重,解决复杂情况。采取以上措施保证了套管漂浮技术在 A14、A18 和 A20 三口井中成功应用。

A17 井 Ø311.1mm 井眼深度为 5842m, 下 Ø244.48mm 套管至 4195m 时卡套管, 反复活动套管柱, 最大上提 1800kN, 不能解卡。决定打通漂浮接箍, 利用循环, 冲下套管。但逐步憋压至 34.5MPa, 未能打开漂浮接箍。受套管内屈服强度及地面设备耐压强度的限制, 最终放弃憋压打通漂浮工具的作法, 采用下钻具钻穿漂浮工具的方法, 钻穿漂浮接箍后继续下钻至 1159m 遇阻, 划眼至 1863m, 遇阻严重, 划眼难以进行, 怀疑钻掉的漂浮接箍残片留在井内。

换用 Ø215.9mm 锥形铣鞋继续磨铣套管至 2102m 发生井漏, 由此可知套管已经破裂。继续下钻通井至 4095m 再次遇阻, 磨铣 1.3m 后无进尺。下 RTTS 封隔器验证套管的破裂点在 4078m 以下。下 Ø244.48mm 套管封隔器, 坐封在 4070m, 挤水泥固井。然后从封隔器以上侧钻进行 Ø215.9mm 井眼作业。

从这一例子不难看出, 套管漂浮技术只是降低摩阻的一种手段, 能否将套管顺利下到位, 还要考虑井眼状况等其它因素。正确选配和安装漂浮工具附件也至关重要。

3.渤海海域秦皇岛 32—6 油田　秦皇岛 32—6 油田位于渤海湾中部, 为中海石油、德士古、阿科 3 家石油公司合营开发的油田。秦皇岛 32—6—A 平台共有 26 口开发井, 其中钻 2 口水平井用以开发馆陶组薄油层。水平井稳斜段为 Ø311.2mm 井眼, 使用加强型 PEM 体系钻井液钻井。

水平井 A26H 井使用套管漂浮技术下 Ø244.48 mm 套管, 下入方法与歧口 17—2 油田相似, 下套管顺利, 这里不再赘述。漂浮数据见表 1。该井打开漂浮接箍, 灌满钻井液后, 逐渐升高地面压力至 25MPa, 并上下活动套管, 没能打开盲板浮鞋。遂采取补救措施, 下 Ø215.9mm 牙轮钻头, 小钻压(10 ~ 20kN)低转速(50 ~60 r/min)钻穿漂浮接箍、止塞箍和盲板浮鞋。采用单级双封固井方法封固套管鞋和上层套管鞋, 测固井质量合格。分析认为本井事故的主要原因是有杂物堵塞止塞箍。

三、结论

1.套管漂浮技术是大位移延伸井和水平井的关键技术之一, 它可以减小下套管时的摩擦阻力, 是下套管作业的有力保障。

2.套管漂浮技术在现场应用表明, 必须要有良好的井眼状况和精心操作才能避免套管漂浮设备失效。

3.套管漂浮组件的操作可靠性和产品质量不容忽视。

4.比较 2 口井事故的处理过程, 及时果断地钻穿漂浮设备, 进行积极的补救固井作业, 可以最大限度地挽回损失。

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HOLE CLEANING DETECTING METHOD FOR EXTENDED REACH WELLS BY MONITORING ANNULUS PRESSURE CHANGE

by Li Xiangfang, Sui Xiuxiang, Liu Jutao, Guan Wenlong, Tang Dezhao (Petroleum Engineering Dept. of Petroleum University)

Abstract Hole cleaning Detecting is vitally important in the drilling of directional and extended-reach wells. Experimental and theoretical research has improved that hole cleaning detecting is efficient by monitoring annular pressure change. Traditional methods used to determine the change of the annular pressure through measuring static bottom hole pressure using sensor near the bit do not work well for this purpose because of its high cost and high failure in hole. This paper presents a new and economical method to calculate annulus pressure by measured standpipe pressure and the pressure drop of the bottom hole assemble calculated by some models. Examples are presented that represent actual field cases and demonstrate the advantages of using the advanced method compared to conventional methods of estimating hole cleaning in Bohai Oilfield.

Subject heading high angle deviated well annulus testing well cleanout monitoring

EFFECTIVE MEASURES FOR IMPROVING THE PENETRATION RATE OF DEEP WELL

by Tao Xinghua (Drilling Research Dept. of Exploration and Development Research Inst., SINOPEC)

Abstract The rotary percussion drilling technology has been widely used in oil and gas well drilling. The rock cutting characteristics in percussion drilling are described and its influence on bit life, together with the working principle of the rotary percussion drilling system is also investigated. By laboratory study, the rotary percussion drilling parameters are determined and six field tests are conducted. Tests show that the use of this technology in deep well drilling can improve the penetration rate by 20%-160%, and this technology is very effective for the fast drilling of deep wells.

Subject heading deep well rotary percussion drilling hoisting speed rock breaking mechanics bit life

NEW CONCEPT FOR DETERMINING THE TOP TANGENTIAL POINT ON BHA

by Song Zhiwu, Gao Deli (Petroleum Engineering Dept. of Petroleum University)

Abstract The tangency point of Bottom Hole Assembly is located at where the drill string just touches the wall of the borehole, and the contact force is zero here. Therefore, the method to determine the position of tangency point should be based on this condition instead of the traditional one which requires the moment is zero here. The formula of this new method was deduced, the different results of the two methods were shown through examples, the rationality of the new method was proved by the result of the examples.

Subject heading Bottom Hole Assembly drill stem mechanics boundary condition top tangent

HIGH ANGLE MULTI-TARGET DIRECTIONAL WELL DRILLING IN LONG OPEN HOLE

by Tang Dapeng, Shi Jiangtao, Lv Chengyuan, Xue Jianguo (Henan Petroleum Exploration Bureau)

Abstract Well Zhang-1102 and Zhang-1301 are two directional wells of long open hole, high inclination and multiple targets in Henan Oilfield, Zhangdian area. The total depths range from 2430m to 2500m, with the highest inclination up to 72°, and precise target hitting is required. The geology design, drilling engineering plan, well stabilization and trajectory control programs for the two wells are introduced. Five-section profile is adopted for both wells. Bottom Hole Assembly in the two wells combines the use of dual-stabilizer with short drill collar. As for drilling fluid system, low solid content and non-dispersion inhibitive polymer drilling fluid is used, and temporary shield plugging technology is carried out for formation protection. Drilling practice offers some successful experience for developing such similar reservoirs.

Subject heading open hole high angle deviated well directional drilling trajectory control procedure

DRILLING PRACTICES IN LUNPOLA BASIN OF TIBET

by Chen Tiancheng (Drilling Research Dept. of Exploration and Development Research Inst., SINOPEC)

Abstract Hole deviation, lost circulation and hole sloughing is very serious in Lunpola Basin of Tibet, a strike-slip tension basin of the Tertiary, which has very complicated geological conditions, and deep well drilling is especially difficult in this area. In the four deep wells that over 2200m, only well Xilun-2 is successfully drilled to TD at 2802m, while other three wells, well Zang-1 of 2334.47m, well Xilun-3 of 2362.86m and well Xilun-6 of 2286m, all encountered serious hole collapse at about 2000m. By improving the casing program and drilling technology since 1996, well Banshen-1 of 3223.32m of TD is successfully drilled.. The downhole troubles and their causes are investigated, and the corresponding solutions are illustrated.

Subject heading Lunpola Basin formation pore pressure hole deviation hole caving lost circulation directional well hole straightening casing program

APPLICATION OF CASING FLOATING TECHNOLOGY IN OFFSHORE DRILLING

by Chen Jianbing, An Wenzhong (Drilling and Completion Center of Bohai Oil Co.), Ma Jian

Abstract The casing floating technology is used chiefly in extended reach wells and horizontal wells. That is a section of air or light density drilling fluid holded inside lower casing string to keep casing string floating in section of high deviation well to decrease drag running casing. This article introduces mainly construction of casing floating tool and working theory and floating technology used in extended reach wells and horizontal wells in several national offshore oil fields.

Subject heading offshore drilling equipment high angle deviated well horizontal well casing floating pipe joint technology

INFLUENCE OF MAGNETIC TREATMENT ON ZETA-POTENTIAL BETWEEN GRANULES OF GRADE G CEMENT AND ADDITIVES

by Fan Zhenzhong, Wan Jiagui (Daqing Petroleum Inst.), Tian Jianlong

Abstract It is known that the method of magnetic treatment can be used to improve the performance of cement slurry. The test instruments, reagents and experimenting methods are presented. By measuring the zeta potential between cement granules before and after magnetization, it shows that under the premium magnetic induction strength of 0.23T, the absolute value of zeta potential after magnetization increased by 2.5mV. Six conventional cement additives are also tested, and the increases of absolute value of zeta potential range from 5~40mV. The test provides the theoretical evidence for interpreting why magnetic treatment can improve the performance of cement slurry.

Subject heading magnetization treating cement particle electrical potential magnetic induction effect

ANALYSIS ON THE PHYSICAL PROPERTY CHANGES OF CEMENT RING AND ITS INFLUENCING FACTORS

by Cai Xing (Drilling Research Inst. of Daqing Petroleum Administration, Daqing), Xiao Zhixing, Cai Yongmao

Abstract For the extending of testing time after cementing, the cementing quality of adjustment wells in Daqing Oilfield decreases dramatically, and this can not meet the requirements of Oilfield development. Combining the physical property of Grade A cement slurry with the formation characteristics, the causes that influencing the acoustic changing differences in time-delaying condition are analyzed. By analyzing the section-increasing curve of cement strength, and studying the changing tendency of cement volume contraction, permeability, porosity, capillary force, elastic modulus and the washing out of formation fluid seepage flow vs. time, it is proposed that the differences of acoustic change is caused by the variation of formation fluid conditions and formation stress conditions. By adjusting and controlling the underground conditions, the differences of acoustic change can be amended. The boundary conditions for good cementing quality of Grade A cement are recommended, i.e., the formation pore pressure is lower than 12MPa, the differential between layers is lower than 3MPa, and the formation elastic modulus is higher than 20GPa.

Subject heading cement reservoir characteristic acoustic property testing

STUDY AND APPLICATION OF THE POLYOL DRILLING FLUID SYSTEM

by Yu Peizhi (Exploration and Development Research Inst. of SINOPEC)

Abstract When using the conventional water based drilling fluid for high angle deviated directional well drilling, high friction is often caused by the high deviation angle during rotary drilling and tripping. Experimental study is carried out on the polyol drilling fluid system, and results show that there are minor changes found on the rheological property and fluid loss; the aging resistance is greatly improved, and the temperature resistance reaches 120 ℃, friction rate reduces by 50%. Field using indicates that the system has good lubricity, and the clay hydration is inhibited, which effectively prevents the hole from collapsing. The rock permeability improved by 20%, which is 87.3%, and this is beneficial for formation protection.

Subject heading directional well polyol drilling fluid lubricity shale control friction loss

LABORATORY STUDY OF AQUEOUS ACCELERATED MATERIAL IN PETROLEUM ENGINEERING

by Ji Chaofeng, Hu Chengliang (Technology Dept. of Research Center, Dagang Oilfield Co.) Ge Hongjiang

Abstract The aqueous material is a kind of inorganic gelling material that can rapidly get solidificated under high water to cement ratio of 2.0~3.0, and then forms the cement bond with certain strength. Its performances that related to the petroleum engineering are tested, and the feasibility of using this material in petroleum engineering is also investigated. A kind of petroleum used aqueous material is developed, and the cement slurry mixed with this material can be used in the cementing operations of low formation pore pressure and in fragile formations, as its density reaches 1.2~1.3g/cm^3, and strength after 24h is 3MPa, thickening time can be adjusted to 200~400mins. This material can also be used in MTC technology, to convert the waste drilling fluid into cement slurry. For its feature of long thickening time in flowing and fast solidification in static, it can be used in lost circulation plugging and water plugging. Sand control by this material is also possible when the particle size is controlled.