触变性水泥的评价方法及其应用*

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摘　要　触变性水泥是一种适用于破裂压力梯度较低的松散地层、漏失层及挤水泥等注水泥作业的水泥浆体系,它对防止水泥浆凝固过程的气窜问题同样具有一定效果。文章重点对触变性水泥浆的测量和评价方法进行了全面分析和深入的讨论,提出的水泥浆触变性有关模型同样适用于其它非胶凝性宾厄姆流体、幂律流体的触变性评定。文章还对触变性水泥浆的特点、用途、常规配方及国内外应用情况进行了较深入的介绍。

主题词　固井　注水泥　触变性水泥　评价方法

水泥浆的触变性是指搅拌后水泥浆变稀,静止后水泥浆变稠的特性。即水泥浆在一定剪切速率作用下,视粘度随作用时间的延长而逐渐减小,并趋于某一定值,或当剪切作用停止后,水泥浆的视粘度又重新升高,但不一定按原来形状恢复的现象(图1)。

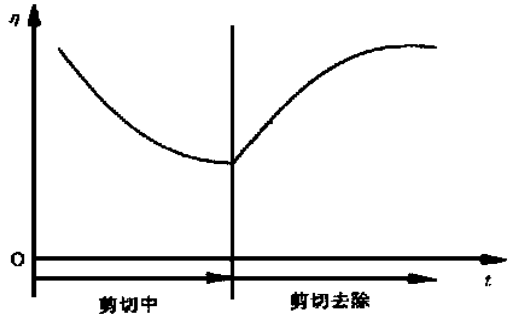

图1　触变性流体视粘度随时间的变化

流体显示触变性的原因,一般认为是由于流体在一定剪切速率作用下,其内部结构发生了变化,而当流体静止后结构又恢复到原来的情况[1]。

触变性水泥浆的特点及用途

1. 触变性水泥浆的特点[2,5]

水泥浆在流动过程和流变曲线上表现出以下特征:

(1) 图2为水泥浆的流变曲线,曲线(向上)、(向下)分别为从低转速到高转速和从高转速到低转速测得的流变曲线,即在某一转速下,前者测得的剪切应力和动切力比后者高。两条流变曲线所形成的滞后环面积(向下)表示了流体的触变性大小。如两条流变曲线重合,滞后环面积为零,该流体无触变性。

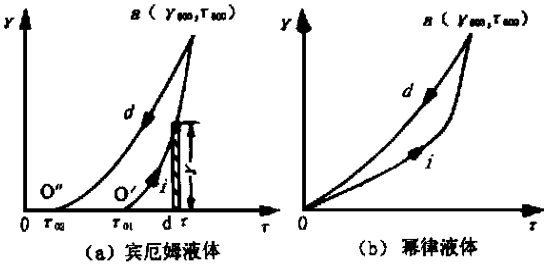

图2　触变性流体的流变曲线

(2) 图3中曲线(a)为触变性水泥浆在一定剪切速率作用下,剪切应力随作用时间增加而降低的现象;曲线(b)则为触变水泥浆静止不同时刻,静切力随静止时间增加而增大的情况。当静止时间达到某一定值后,静切力趋于稳定。水泥浆静切力的增加速度和最大值反映了浆体的触变性大小。

(3) 触变性水泥浆还有一个明显的特征,即在每一次静、动态流动之后,其静切力和动切力趋于增高。在注水泥施工中,反复停泵之后,其停止时间愈长,开始流动所需要的泵压愈高(图4)。因此,注替这种水泥浆时,应避免较长的停泵时间。

2. 触变性水泥浆的用途[2,3,4]

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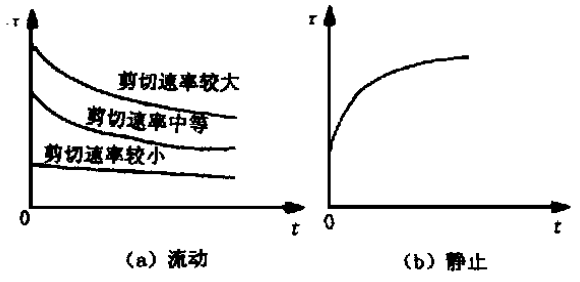

图3　触变性流体流动和静止后剪切应力的变化情况

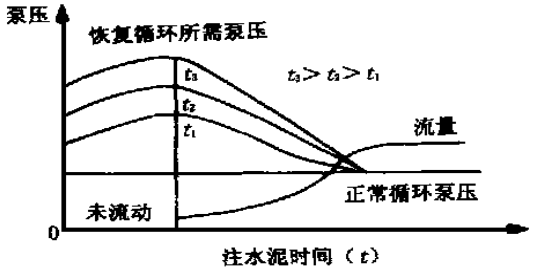

图4　触变性水泥浆静止时间与启动泵压、流量的关系

(1) *适用于松散地层的注水泥作业。这种地层破裂压力较低,即使采用低密度和静液柱压力较低的水泥浆固井也易破碎,常常出现水泥浆下落的现象,从而造成需要水泥浆封固的井段未能达到封隔的要求。使用触变性水泥浆后,由于胶凝强度增加,水泥浆的重量被悬挂和支撑在井壁上,降低了作用在地层上的浆柱压力,防止或减轻了水泥浆的下落问题。*

(2) *适用于漏层的注水泥作业和处理钻井过程的井漏问题。当触变性水泥浆进入漏失层后,其流速减慢,浆体结构迅速形成,随之水泥浆的流动阻力增大,漏失层易被堵塞,从而使注水泥作业和堵漏的成功率得到提高。*

(3) *触变性水泥浆在一定条件下可以防止气窜的发生。该条件是:当触变性水泥浆失重值等于过平衡压力时,其胶凝强度如能增至*240 Pa*,则固井气窜发生的可能性较小。这也是水泥浆防止气窜的基本原理。*

(4) *当渗透地层进行补救挤水泥时,可采用触变性水泥浆作为先导浆,以达到增加挤注压力和提高挤水泥成功率的目的。*

(5) *修补破裂或被腐蚀的套管。*

触变性水泥浆的评价方法[5,12]

1. 滞后环法

滞后环的面积实际上反映了触变能的储存大小,即浆体结构拆散与形成所需能量之差。储存能用剪切速率与剪切应力的乘积表示,其表达式为:

$$E = \gamma\tau \qquad (1)$$

式中: E *为单位时间、单位体积水泥浆的储存能*, J/m^3 s; γ *为剪切速率*, s^{-1}; τ *为剪切应力*, Pa。

*由图*2 *可知,当升速测定水泥浆的流变性能时,其流变曲线之下的面积反映了水泥浆结构破坏所需之能量*(E_1)*为*:

$$E_1 = \int_0^{\tau_{600}} \gamma \mathrm{d}\tau$$

如采用宾厄姆模型,则 E1 *可表示为*:

$$E_1 = \int_0^{\gamma_{600}} \eta_{p_1}\gamma \mathrm{d}\gamma = \frac{1}{2}\eta_{p_1}\gamma_{600}^2 \qquad (2)$$

当降速测定水泥浆流变性能时,其流变曲线之下的面积反映了水泥浆结构形成所需之能量 E_2 *为*:

$$E_2 = \frac{1}{2}\eta_{p_2}\gamma_{600}^2 \qquad (3)$$

水泥浆的触变能 E *则为*:

$$E = E_2 - E_1 = \frac{1}{2}\gamma_{600}^2(\eta_{p_2} - \eta_{p_1}) \qquad (4)$$

或

$$E = \frac{1}{2}\gamma_{600}(\tau_{01} - \tau_{02}) \qquad (5)$$

对于适合幂律模型的水泥浆,则触变能的表达式为:

$$E = \gamma_{600}\tau_{600}\left(\frac{n_2}{1+n_2} - \frac{n_1}{1+n_1}\right) \qquad (6)$$

可以通过测定升速或降速的流变参数(η_{p1}、τ_{01}、n_1 *或* η_{p_2}、τ_{02}、n_2)*及* γ_{600}*和* τ_{600}*,计算水泥浆的触变性。* $\gamma_{600} = 1\,022$ s^{-1}, τ_{600}*为* γ_{600}*所测剪切应力。*

2. 静切力法

*用特殊形状的叶片,在剪切速率接近零时(约*1 s^{-1}*),测定水泥浆静止* 10 s(*或* 1 min)*和* 10 min*,浆体开始流动的静切力* τ_1 *和* τ_{10}*,用其差值* $\Delta\tau = \tau_{10} - \tau_1$ *表示水泥浆的触变性。由于水泥浆静止* 10 min *以后的静切力变化不大,且* τ_{10}*比* τ_1 *大得多,因此一般将其视为浆体的最大静切力,并以此描述水泥浆的触变性程度。水泥浆的触变性也有用* 10 min *静切力和动切力之差表示*[2,6]*。静切力又通称*

为静胶凝强度。

3.滞后环总能量法

使用旋转粘度计各挡转速(或不同的剪切速率),分别测出水泥浆启动时的最大剪切应力(τ_{imax})和稳定后的剪切应力(τ_{is})。则不同剪切速率下,水泥浆的滞后能为 $\gamma_i(\tau_{imax}-\tau_{is})$。水泥浆的总滞后能(或触变能)为各剪切速率滞后能的总和,其表达式为:

$$E=\sum_{i=i_1}^{i_2}\gamma_i(\gamma_{imax}-\tau_{is}) \qquad (7)$$

式中:i = 5.11、10.22、170.3、340.6、511 和 1 022 s^{-1}。

几种常见的触变性水泥浆配方

触变水泥体系主要由水泥和触变剂组成。触变剂包括无机类触变剂和可交联的聚合物体系触变剂。无机类触变剂[6]主要有膨润土体系、硫酸钙体系、硫酸铝—硫酸亚铁体系。用可交联的聚合物体系作触变剂的触变水泥。这类触变剂包含两个组分,即交联剂和被交联物质。当水泥浆静止时,它们能迅速发生交联而形成网状结构,使水泥浆在较短时间内获得较强的触变性。触变性水泥常用的配方有:

(1)粘土基水泥体系。含有吸水膨胀粘土(如膨润土)的波特兰水泥体系,可产生胶凝强度,并呈现出一定程度的触变性能(Messenger,1980)。这类水泥体系已被证明能够在某些环境下控制气窜。膨润土的含量和水泥浆的密度可分别在0.05%～2.0%(与水泥重量比)和1.4～2.5g/cm^3的范围内变化。

(2)硫酸钙水泥体系。配制触变性水泥使用的最普遍的材料是硫酸钙半水化合物($CaSO_4\cdot\frac{1}{2}H_2O$,或用水泥符号表示 CSH(2))(也称为巴黎灰浆)。当把这种材料加入波特兰水泥时,它首先水化而形成石膏。而后,与铝酸三钙(C_3A)反应而生成硫代铝酸钙矿物,这种矿物有时也称为"钙铝钒"。其反应化学方程如下(Kalousek,1973 年):

$$3CaSO_4\cdot 2H_2O+3CaO\cdot Al_2O_3\xrightarrow{H_2O}3CaO\cdot Al_2O_3\cdot 3CaSO_4\cdot 32H_2O\ (钙铝矾)$$

钙铝钒以针状的、似六方的单轴晶体存在,并沉积在水泥颗粒的表面。钙铝钒晶体的出现,会促进水泥颗粒之间较大的自然结合,导致网状或凝胶结构的形成。当搅拌时,网状结构很容易破坏,水泥浆又转变为流体状态。

大多数波特兰水泥可以与硫酸钙半水化合物一起,用以配制触变性水泥浆。根据水泥的品种不同,最佳的CSH(2)的加量可在8%～12%(与水泥的重量比)之间调节。然而,C_3A 含量少于5%的水泥却不能用于配制触变性水泥,因为钙铝钒不足,将会使水泥结晶而损害触变性。含有硫酸钙半水化合物的水泥浆,所需水量要高于常规的水泥体系,因此水泥浆的密度较低。含有硫酸钙半水化合物的触变性水泥与大多数降失水剂是不配伍的。为了适当控制失水,这类水泥浆通常要采用低失水量的隔离液。硫酸钙半水化合物的水泥体系,除具有触变性之外,还具有很好的抗硫酸盐性,因为 C_3A 可有效地与硫酸盐中和。同样,水泥浆开始凝固后,钙铝钒继续形成,结果在水泥基体内部产生较大的体积膨胀。

(3)硫酸铝与硫酸亚铁水泥体系。由 $Al_2(SO_4)_3$ 和 $FeSO_4$ 组成的添加剂也要依赖于钙铝钒的形成,以使水泥浆具有触变性(Nelson,1983 年)。这种添加剂在与 C_3A 含量低于5%的波特兰水泥混合使用方面已取得了进展。此外,这种材料对非波特兰水泥,如J级水泥也是有效的。它还可以以液态的形式使用,便于海上施工。硫酸铝与泥浆中的氢氧化钙反应,生成钙铝钒。

$$2Al(OH)_4^- + 3SO_4^{2-} + 6Ca^{2+} + 12OH^- \xrightarrow{H_2O} 3CaO\cdot Al_2O_3\cdot 3CaSO_4\cdot 32H_2O$$

上述反应的速度比硫酸钙半水化合物在水泥浆中的反应要快得多。硫酸铝是一种很强的水泥促凝剂,如果将它单独加入水泥中,将会形成一种很强的、不能转变的胶凝结构。体系中所含的硫酸亚铁,是一种较弱的缓凝剂,它可抑制硫酸铝并在整个泵送期间保持水泥浆的触变性。由于该体系的快速流动,在水泥浆凝固后只形成很少的钙铝钒。因此,水泥没有明显的膨胀,除非养护温度低于38 ℃。

(4)用锆、钇等过渡金属元素作交联剂的触变水泥[7]。这种水泥主要用于挤水泥作业中封固油气井套管。它以高价金属离子与水溶性纤维素酯反应生成触变剂。其主要成份包括:水化水泥、水、高价金属离子(多用二氯化氧锆)、水溶性纤维素酯、少量膨润土及分散剂。高价金属离子主要包括锆、钇、Fe^{3+} 等镧系过渡金属元素的离子,其用量以0.1%～3%(BWOC,即By Weight of Cement,下同)为宜。水溶性纤维素酯包括 CMC、HEC 或 CMHEC 等纤维素的衍生物,为达到合适的粘度,要求其取代度保

持在0.3～1.5,分子量为50～300万,用量为0.1%～0.75%。所用水量为23%～60%,为避免引起闪凝,需除去水中的Ca^{2+}。分散剂用量为0.75%。配制时,先将所需要的水量进行搅动,再加入干混水泥和纤维素酯及多价金属盐,继续搅动直到形成均相体系。现场利用此法配制的一种典型触变水泥配方为:API H级水泥∶HEC∶二氯化氧锆∶少量膨润土(增粘)∶CFR-2(分散剂)(100∶0.25∶2.0∶46∶0.75)。配制完毕后,初粘为1.7 Pa·s,注入井中10 min后粘度无变化。泵压停止后,粘度在20 min内上升到7.5～10.0Pa·s。泵压恢复后,粘度又迅速下降且极易泵送。总凝结时间为2 h。用该配方在两口井中挤水泥成功。但该配方触变性有限,尤其在高温和低密度水泥浆中不易获得触变性和不易控制胶凝强度的发展。

(5)用钛螯合物作交联剂的防漏失、防气窜触变水泥。通过大量实验发现,大多数螯合物尤其是钛螯合物是很好的交联剂[8,9],通用结构式如图5。其中X与X'为含有O、N的官能团,X'与Y代表含2～3个碳原子的双键,R'和R''可以是H原子或为被取代的烷基、芳基或卤原子等。有代表性的钛交联剂主要有:

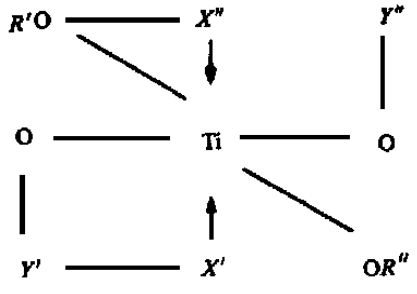

图5　钛螯合物作交联剂通用结构式

①间戊二酮钛螯合剂-$[(CH_3)_2CHO]_2Ti[OC(CH_3)=CHCOCH_3]_2$;

②乳酸钛螯合剂-$[(HO)_2Ti(OCH(CH_3)COO^-)_2][M^+]_2$,式中,$M^+$可为H原子、碱金属阳离子、$NH_4^+$等;

③三乙醇胺钛螯合剂-$[(CH_3)_2CHO]_2Ti[OCH_2CH_2N(CH_2CH_2OH)_2]_2$。

被交联物质采用水溶性纤维素衍生物或聚乙烯醇。上述触变体系可使水泥在短时间内获得高胶凝强度和高触变性。钛螯合物对稠化时间影响小,易在低密度水泥浆中获得触变性,但对温度较敏感。这种体系配制的高压层堵漏触变水泥配方为[6],API H级水泥∶飞灰(50∶50)+17%微硅+0.4%木钙+0.4%硼酸钾+1.0%CMHEC+0.4%三乙醇胺钛。为解决气窜问题,采用了另一配方[6]:孤星H级水泥+30%微硅+4%CMHEC+0.5%硼酸钾+0.5%木钙+0.25%三乙醇胺钛。以上配方用于现场施工均取得明显成效。

此外,还有RFC触变水泥[6]和LXT胶乳膨胀触变水泥[10,11]。

触变水泥浆的现场应用

(1) Purdy油田利用触变水泥浆改善了挤水泥作业[11]。挤水泥作业中常遇到的问题是无法封固一些低压产层的射孔孔眼。Purdy油田的产油层主要集中在Hart和Springer两个砂岩层。过去采用双油管完井法,两层间用封隔器隔开。由于Hart层产层逐渐降低,故决定挤入触变水泥封堵其射孔孔眼而集中开采Springer层。5口井的作业结果表明,利用触变水泥挤水泥作业切实可行,减少了用其它水泥进行同样施工所带来的注水泥塞的麻烦,节约了时间和施工费用。

(2) Conoco和ARCO公司应用触变水泥浆防止气窜。得克萨斯的Webb郡油田气井压力较高,过去固井时用低滤失API H级水泥封固,并采用了套管居中、提高环空返速、改善隔离液配伍性等一系列措施来提高水泥环胶结质量,但仍有部分井由于严重的气窜而被迫停产。1983年开始,Conoco公司使用触变性水泥浆在得克萨斯州进行了15口尾管及2口套管的固井工作[6]。固井结果表明,不仅声幅测井得到了改善,其中15口井再无气窜现象发生。另外,尾管顶部封隔良好,无需再挤水泥,试压也较理想。ARCO公司应用触变水泥浆在得克萨斯的Permian盆地[10]油井中防止气窜也取得了极明显的效果。该地区过去用低失水水泥体系固井,曾多次发生气窜和层间串通现象。此外由于胶结不良导致酸化作业时,挤入的酸液进入射开的下部井段后,沿水泥环内部的沟槽上下窜入环空,大大减少了油井产量。为解决上述问题,采用了具有"短过渡时间"和"强触变能力的"LXT水泥体系,在连续8口井的固井施工中取得了成功。水泥胶结测井曲线表明,使用这种措施不仅改善了气层上、下水泥环的胶结

质量,而且减少了射孔作业中的气窜问题。所采取的酸化增产措施也见到了成效,提高了油井产量。

1986年,大庆油田曾使用哈里伯登的触变剂A和B在6口调整井中进行了试验工作,效果并不理想。1994～1995年,长庆油田[13]曾使用微硅低密度触变水泥浆解决了陇东地区洛河层固井中的漏失问题。从已固的181口井可知,触变水泥浆防止地层漏失的当量密度提高了0.07～0.18 g/cm^3;水泥浆返高的合格井为179口;洛河层的声幅测井总合格率由1993年的44%提高到76.2%。

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科技建设中国石油天然气管道
——中国国际石油天然气管道建设展即将举办

21世纪,天然气将是全世界增长最快的主要能源。管道运输是我国的朝阳产业,国家已将"加强输油气管道建设,形成管道运输网"列入"十五"发展计划,随着西气东输工程开工在即,我国石油天然气管道发展进入了一个崭新的阶段。为进一步吸收和引进世界先进技术与科技装备,高质、高效、高速地建设我国石油天然气管道,由中国贸促会化工行业分会、中国石油天然气管道运输企业联合会、中国测绘学会、中国石油学会油气储运学会和建设部科技委地下管线专业委员会共同主办的"2001年中国国际石油天然气管道建设与油气储运装备展览会"将于2001年6月20日～23日在北京全国农业展览馆举行。展会得到了中国石油天然气集团公司、中国石油天然气股份有限公司管道公司以及规划总院、管道科学研究院和中国石油和化工行业协会的大力支持。

展会以"科技建设中国管道"为主题,结合多种行业优势和支持,展品涵盖管道技术及产品、施工机械、防腐蚀技术及产品、焊接技术及设备、无损检测、仪器仪表、油气储运技术与装备、测绘仪器设备等。通过国内外相关专业媒体的广泛宣传与推广,现已有ABB集团、美国捷特、百莱玛—威猛、武钢、本钢、华创天元、美国韦林公司、美国埃谟公司、美最时洋行、里奇公司、辽阳大型钢管厂、胜利股份、松下电焊机、时代集团、耐莱斯·詹姆斯伯雷阀门、阿克苏、诺贝尔红狮粉末涂料等几十家海内外知名企业入会参展,筹备工作进展顺利,预计展会规模将达到350家。同期,主办机构将邀请政府官员、专家就"我国天然气发展规划"、"西气东输工程给我国能源结构和产业结构调整带来的作用"等主题举行系列报告会和专业技术讲座。

供稿:中国国际石油天然气管道建设与油气储运装备展览会组委会
北京振威展览有限公司

二〇〇一年三月二日

property; ③its electric property;and ④its fluid property and its distribution,etc. They are the geological bases of a fine log interpretation and evaluation of oil and gas reservoir with low resistivity and the degree of the influence of these geological factors on various log responses is the petrophysical base of evaluating reservoir by logging data.

SUBJECT HEADINGS: Reservoir, Mineral, Resistivity, Low,Log response,Log interpretation,Recovery factor

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STUDY AND APPLICATION OF CORROSION-RESISTANT LOW-DENSITY CEMENT SYSTEM

Yang Yuanguang, Guo Xiaoyang, Zhang Yulong and Liao Gang (Southwest Petroleum Institute). *NATUR. GAS IND.* v. 21, no. 2, pp. 48～51, 3/25/2001. (ISSN 1000-0976; **In Chinese)**

ABSTRACT: The mechanism of set cement corrosion is discussed by using phase analysis method in this paper. It is pointed out that the unconsolidated phase and diffusional effect as a result of the action of formation water solution matrix $Ca(OH)_2$ with $Ca(OH)_2$ are the basic reason causing the corrosion of the set cement and casing's exterior wall and a technical idea of using corrosion-resistant cement to from a protection ring to prevent casing's exterior wall corrosion is put forward. A new low-density cement system suited to sealing Luohe formation is developed and, by using it, the difficult problem of casing's exterior wall corrosion in Luohe aqueous layer in Changqing Oil Field is successfully solved, effectively prolonging the production phase of oil and gas wells.

SUBJECT HEADINGS: Changqing oil field, Oil and gas well, Well cementing, Light weight cement, Corrosion

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A LABORATORIAL RESEARCH ON ESTIMATING CHANNELING-PREVENTING ABILITY OF CEMENT SLURRY BY USE OF GEL STRENGTH METHOD

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ABSTRACT: How to objectively and accurately evaluate the channeling-preventing ability of cement slurry is still a difficult problem which is not solved up to now in the well cementing circles at home and abroad. In this paper, through lab experiment, the quantitative relationship between the effective slurry column pressure and gas cutting resistance and the factors which affect the former two is studied and their calculation model in the process of cement slurry setting is set up, making the condition to cause the breakthrough flow in annulus quantization, which can be used for predicting and evaluating the channeling-preventing ability of cement slurry in the process of setting, providing thus a new reference method for the design to prevent channeling in well cementing.

SUBJECT HEADINGS: Well cementing, Cement slurry, Gel strength, Annulus breakthrough flow, Channeling prevention, Evaluation method

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EVALUATION METHOD OF THIXOTROPIC CEMENT AND ITS APPLICATION

Liu Chongjian and Liu Xiaoliang (Southwest Petroleum Institute). *NATUR. GAS IND.* v. 21, no. 2, pp. 56～60, 3/25/2001. (ISSN 1000-0976; **In Chinese)**

ABSTRACT: Thixotropic cement is a cement slurry system used for cementing operation suited to the loose formation with small fracture pressure gradient and thief zone and it has a certain effectiveness in preventing the breakthrough of gas in the setting process of cement slurry. The measurement and evaluation methods for thixotropic cement slurry are emphatically and overall analyzed and discussed in this paper and the raised model related to the thixotropy of cement slurry is also suitable for the thixotropy evaluation of other Bingham fluid and power-law fluid with non-gelling property. The characteristics, use and formula of the thixotropic cement slurry and its application situation at home and abroad are thoroughly introduced also in this paper.

SUBJECT HEADINGS: Well cementing, Cementing,

Thixotropic cement , Evaluation method

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A DISCUSSION ON RAISING DRILLING SPEED IN THE UPPER FORMATIONS WITH HIGH ANGLE IN SICHUAN REGION

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ABSTRACT : In the upper formations with high angle in east Sichuan high and steep structures , some complexities , such as hole deviation , well slough , lost circulation and sticking , etc. ,are easy to happen in the process of drilling , but the target area in objective formation is strictly limited. How to effectively control the hole deviation , guarantee the wellbore quality ,raise the penetration rate and reduce the drilling cost becomes a difficult problem in drilling wells in high and steep structures. In this paper , through analyzing the complex geological characteristics of the upper formations with high angle ,some new tools , new technology and new technique are proposed to be used to achieve effectively in controlling the wellbore quality and greatly raising the drilling speed in the upper formations with high angle.

SUBJECT HEADINGS : Sichuan , East , High angle formation ,Wellbore quality ,Drilling speed ,Analysis

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7NB PLUNGER DISPLACEMENT PUMP WITH STRAIGHT AXIS AND ITS WORKING MECHANISM

Liu Qingyou , Zhong Qing and Huang Bensheng (Southwest Petroleum Institute). *NATUR. GAS IND*. v. 21 , no. 2 , pp. 64 ～65 , 3/ 25/ 2001. (ISSN 1000-0976 ; **In Chinese)**

ABSTRACT : Oil and gas exploration and development is being conducted in the regions in which the circumstances is more adverse and the geological condition is more complex such as desert , highland , deep sea , swamp , sludge , jungle and polar region ,etc. For this reason , the mud pump is asked to reduce the weight and volume ,to improve the structure and to raise the efficiency to adapt to various adverse circumstances and conditions. In this paper , the structure and working mechanism of 7NB mud pump —a new mud pump for drilling are presented. As compared with traditional mud pump , this pump has such features as short stroke ,high stroke rate ,high and uniform flow rate ,high pressure ,small pressure fluctuation , simple structure , small volume and weight ,etc. and its application prospects are good. The existent problems for 7NB mud pump at present and the direction of further improvement are put forward also.

SUBJECT HEADINGS : 7NB mud pump , Structure feature ,Working mechanism , Improvement direction

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RESEARCH ON A NEW METHOD OF CALCULATING BOTTOMHOLE PRESSURE BY THE GAS COLUMN PRESSURE IN ANNULAR SPACE OF GAS WELL AND ITS APPLICATION

Yang Tao (University of Staff and Workers , SPA) and Yang Hua (Research Institute of Petroleum Exploration and Development , Beijing). *NATUR. GAS IND*. v. 21 , no. 2 , pp. 66 ～70 , 3/ 25/ 2001. (ISSN 1000-0976 ; **In Chinese)**

ABSTRACT : The exactly solved mathematical model and approximately solved mathematical model of calculating bottomhole pressure by the gas column pressure in annular space of gas well are derivated according to the properties of natural gas in the well ; a calculation program by taking the calculated result through the approximately solved mathematical model as the initial value of the exactly solved mathematical model is made up ; and its application to gas lift technological design and diagnosis is introduced in the paper. Through practically applying it is shown that the mathematical models and calculation program derivated and proposed by the authors are scientific , reasonable , reliable and practical , being of not only an obviously promotional action in deepening the topical research but also an obvious popularization and application value in solving some practical problems of gas production engineering.