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螺杆泵采油技术在稠油热采开发后期的应用

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摘要：辽河油区欢西油区稠油区块层内出水问题严重、油井吞吐效果差，为此，在采出程度低的稠油高含水井上探索不注汽直接应用螺杆泵冷采的可行性，并结合现场应用情况，浅析了增油机理。在锦45块和锦611块等区块部分高含水井上应用螺杆泵采油技术，采用变频控制柜控制合理的生产压差，取得了较好的降水增油效果，投入产出比为1.0∶5.2。

关键词：稠油；螺杆泵采油；高含水井；锦45块
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引 言

辽河油区欢西稠油区块随着蒸汽吞吐轮次增加，地层压力下降，在注汽过程中，由于蒸汽上覆作用，厚层明显动用不均，而这些油层具有边底水活跃、能量充足的特点，注入蒸汽大部分进入水侵通道[1]，而目前的堵水措施不能很好地解决层内出水问题，造成油井蒸汽吞吐效果差、高含水、采出程度低，甚至有部分油井不得不关井停产。为此，提出在采出程度低的稠油高含水井上开始探索不注汽直接应用螺杆泵冷采，螺杆泵举升与抽油机相比具有连续平稳出液的特点，在地层中易形成稳定的油流通道。通过对比往复泵和螺杆泵的生产状况，在油井采用蒸汽吞吐开采的往复泵生产阶段，也有短期高产现象，但含水很快就上升到90%左右[2]，而采用螺杆泵冷采后，随着时间延长，含水逐渐下降并稳定在80%～90%左右，螺杆泵目前在国内外稀油井及稠油携砂冷采井上得到了广泛的应用，但在稠油高含水井上应用螺杆泵降水增油还没有相关的研究。采用螺杆泵冷采，一方面可以节省注汽费用，降低燃油量，提高原油商品率；另一方面，可以减少注汽及作业时间，增加生产时效，同时起到节能降耗、减少投资及节约地面维护费用的作用。螺杆泵具有一次性投资小、占地面积小、能耗低、出液平稳、适应性强等优点[3]。利用螺杆泵出液平稳的特点减少了普通抽油泵对油层的扰动，同时利用变频控制柜调节转速，合理控制生产压差，达到控水稳油的目的。

1 现场应用情况

1.1 前期试验

锦91块属于锦45块的次级断块，为典型的层状砂岩边底水稠油油藏，边水体积为原油体积的1.25倍，边底水压力为10～11MPa，原始原油粘度为7 697 mPa·s，区块单井注汽轮次已达11.1轮。整个区块构造形态为北西—南东倾斜，位于区块东部的油井水淹严重。水淹区油井含水普遍高于90%，靠近边水区的井均因高含水停产。中部地层压力下降较多而水淹区地层压力为7～8 MPa，水淹区内部分油井由于层间及层内物性的差异导致采出程度不均，东部采出程度为29.8%，整个区块的采出程度为34.5%。因此，部分油层、油井仍有一定潜力。首选的3口井分别为锦45－018－193、锦45－07－21、锦45－19－253井，3口井的回采水率均高于450%，说明油井已被水淹，实施螺杆泵采油前含水均高于95%；单井采出程度均低于区块平均采出程度；地层条件下原油粘度较低，易于流动。实施螺杆泵前各井的基础数据见表1。

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表1 2004年锦91块实施螺杆泵井基本情况

井号	采油层段/m	厚度/层数/(m/层)	注汽轮次	累计注汽量/m^3	累计产油量/t	累计产水量/m^3	回采水率/%	采出程度/%	50℃原油粘度/mPa·s
锦45-018-193	1010.5~1028.6	6.7/3	8	14290	5661	70067	490	26.0	3646
锦45-07-21井	970.4~986.6	12.4/4	10	28983	38036	139815	482	31.7	3864
锦45-19-253井	991.8~1005.4	11.0/2	4	6912	11435	56535	818	13.8	1832

经过1 a的生产运行,试验效果十分理想,达到了不注汽长期生产的目的,油井见到了降液增油、含水下降的效果。平均日产液由原来的50 m^3/d降到35 m^3/d,日产油由原来的1.4 t/d上升到4.2 t/d,平均单井日增油达2.8 t/d,含水由98.2%下降到88%,累计增油2 318 t,累计降水20 424 m^3(表2)。

表2数据说明,利用螺杆泵在稠油重水淹区冷采是完全可行的。而且在高含水井上实施螺杆泵采油与普通往复泵相比,还能达到增油效果,这在国内外还没有相关的研究和报道。

表2 2004年锦91块3口井实施螺杆泵采油前后生产情况对比

井号	抽油机生产		螺杆泵生产			增油/t
	平均日产液/(m^3/d)	平均日产油/(t/d)	平均日产液/(m^3/d)	平均日产油/(t/d)	生产时间/d	
锦45-018-193	60	0.7	41	1.5	356	238
锦45-07-21	44	1.0	27	3.0	354	590
锦45-19-253	51	2.4	36	7.8	333	1490

1.2 推广应用

2006~2008年在辽河油田欢西稠油高含水区块实施螺杆泵143口井,平均单井日增油0.37 t/d,平均日降液11.7 m^3/d,平均含水下降5个百分点,平均单井日节电63 kW·h/d,投入5 289.4×10^4元,增产原油63 352 t,节省电费213×10^4 kW·h,节约108台抽油机投资费用,降低回采水62×10^4t,共创效27 505×10^4元,投入产出比达到1.0∶5.2(表3)。

从表3中可以看出,锦611块应用效果最好,锦91块实施的井次较多,增油效果也较好。分析认为,这2个区块边水能量充足,采出程度低,原油粘度相对较低,较适合应用螺杆泵冷采。

表3 稠油井下螺杆泵前后生产情况对比

油品	区块	井数	措施前			措施后平均			累计增油/t
			日产液/(m^3/d)	日产油/(t/d)	含水/%	日产液/(m^3/d)	日产油/(t/d)	含水率/%	
稠油	锦91	53	1547	65	96	799	79	90	17592
	锦45	16	467	18	96	261	21	92	1170
	锦7	32	428	10	98	495	18	96	7508
	锦611	8	282	34	88	267	50	81	13170
	锦271	7	114	8	93	89	16	82	6740
	锦25	6	159	7	96	90	3	96	468
	锦626	6	157	18	89	176	29	83	5761
	千12	5	45	0	100	95	2	98	1097
	欢17	5	94	5	94	118	16	86	6416
	其他	5	100	5	95	122	12	90	3430
小计	合计	143	3393	170	95	2512	246	90	63352

1.3 选井条件

根据现场实施情况,选井主要遵循以下原则:①注汽3轮以上,保证地层温度条件下原油可以流动;②油井单井采出程度相对较低,一般不超过30%;③能量充足,生产条件下沉没度应在200m以上;④原油粘度小于10 000 mPa·s;⑤优先考虑有单层厚度大于4 m的油井。

在设计方案时,考虑到稠油井供液不稳定,泵挂设计到油层上界,同时设计排量和抽油机生产时平均产液量相当,配备变频器,根据由低到高的原

则调整排量,视含水率和动液面变化情况确定合理工作参数。

2　增油机理分析

稠油因含有胶质、沥青质、石蜡等高分子化合物,易形成空间网状结构,具有非牛顿流体的性质,其结构随剪切应力的增大而破坏,破坏程度与流动速度有关[4],即当原油流速慢时结构破坏小,粘度相对较大;流速快时则破坏大,粘度相对较小。共用同一渠道的多相流体流动时相互干扰,流度比越大干扰越严重,低流度的水相更易侵入油相,使油相变为孤立的油滴,油滴一旦被滞留下来,要起动它必须克服更大的附加毛管阻力。

螺杆泵连续抽吸避免了稠油结构的恢复,稠油形成稳定的流动油带,在油带前缘,油滴被启动而增溶到油带中,因此油带具有很好的流动能力,表现到生产上就是含水下降。而抽油泵的脉动抽吸,使得地层孔隙中的油流难以形成连续流,水相侵入到油流通道,微观上表现为降低了油滴前后的压差,油滴更难启动,若水相能量充足,油滴就一直不能流动,表现到生产上就是长期高含水。

以锦45－06－19井原油为例。在50℃条件下使用德国HAKKE公司生产的流变仪HAKKE RS600测量原油粘度为650 mPa·s(固定剪切速率GP=10 s^{-1});以恒压泵向岩心注入一定基压模拟螺杆泵生产,在基压基础上增加0.2 MPa的波动压力模拟抽油泵生产进行试验。试验结果见图1。可以看出,螺杆泵生产时产水量先增加后下降然后趋于稳定,产油量先增加,增加到一定值后稳定;而抽油泵抽油时产水量不断增加,到一定值后稳定,而产油量减少,减少到一定值也稳定下来。对比这几条曲线可以看出,螺杆泵在相同条件下比抽油泵采油量有所增加,含水有一定下降。

通过初步的理论分析和试验分析认为,螺杆泵在稠油重水淹区实现增油,主要有2个基本条件:一是要有稳定的驱动压差,可克服地层原油的启动压力,进而形成连续油带,若压差过大,油滴低于油带的流动速度,也会导致油带断开,若压差过小,油滴不能起动,不能形成连续油带;二是粘度有一定范围限制,粘度太低与水差别不大,渗流差异小,不会有明显效果,粘度过高,渗流阻力太大,所需要的压差过大,油滴难以流动。因此在稠油重水淹区应用螺杆泵时选择边水驱动或水驱稠油油藏,粘度一般要求地层温度条件下小于10 000 mPa·s,并保持合理的生产压差。

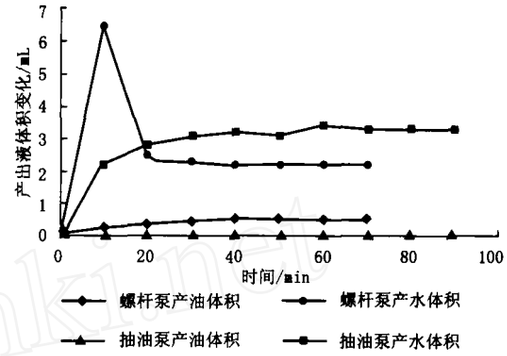

图1　模拟螺杆泵和抽油泵生产试验曲线

3　结　论

(1) 2006～2008年在辽河油田欢西稠油高含水区块实施螺杆泵143口井,投入5 289.4×10^4元,增产原油63 352 t,节电213×10^4 kW·h,节约108台抽油机投资费用,降低回采水62×10^4t,共创效27 505×10^4元,投入产出比达到1.0∶5.2。

(2) 应用螺杆泵在稠油高含水区块进行冷采具有良好的规模化效益。

(3) 对于边水能量充足或水驱稠油区块,在蒸汽吞吐开发中后期利用螺杆泵采油系统冷采可成为该类区块新的低成本开发方式。

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natural energy is not sufficient to meet development requirement and stimulation measures are necessary. The reservoir has extensively distributed sensitive minerals. Reservoir damage factors are analyzed through laboratory experiment; the formula of fracturing fluid has been optimized for this area; and a less harmful, viscosity - variable fracturing fluid system has been developed including pre - and post - fracturing treatment liquid. This fracturing fluid system protects reservoir, reduces damage and secondary contamination, and has advantages of anti - swelling and fast break, prevents water lock, and remains good flow conductivity after fracturing. Field application in 13 oil wells has shown notable stimulation effect.
Key words: less harmful; viscosity - variable; fracturing fluid; treatment liquid; secondary contamination; Shuanghe Oilfield

Synthesis of oleic amide propyl betaine as the main agent of viscosity - variable - diverting - acid

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Abstract: Polymer - based heavy oil acidizing system has potential damage to reservoirs, so that a new amphoteric surfactant, oleic amide propyl betaine, whose apparent viscosity increases with pH value increasing, has been developed. This surfactant can be applied to heterogeneous reservoirs for diverted acidizing without secondary damage to reservoirs. The viscosity of this acidizing fluid system will change automatically along with the reaction between acid and rock.
Key words: amphoteric surfactant; oleic amide propyl betaine; diverted acidizing; viscosity - variable acid

Study and computer simulation of cementing dynamic process

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Abstract: In order to improve cement job quality, this paper analyzes the dynamic process of cementing and establishes a computation model of dynamic parameters such as annulus flow rate, wellhead pressure, vacuum section length, and annulus dynamic pressure. Computer simulation software has been developed for dynamic process of cementing and verified by Jianghan Oilfield data to be satisfactory to engineering requirements, thus provided technical guidance to cementing design and operation.
Key words: well cementation; cementing; computer simulation; "U"—tube effect; vacuum section

Research and improvement of complexity treatment techniques for sidetracked hole reaming

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Abstract: In order to improve cement job quality, prolong sidetracked hole life, economically and efficiently develop old oilfields, this paper analyzes the complexity in sidetracked hole reaming, summarizes experiences and lessons from field complexity treatment, researches and improves techniques of continuous, steady and safe reaming under complex well conditions, and establishes rational drilling assembly, technical parameters and operation instructions, which are of important significant to popularization of sidetracked hole reaming techniques.
Key words: sidetracked hole; reaming; annulus clearance; cement job quality; technical research

Application of screw pump technique in the late period of heavy oil thermal recovery

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Abstract: Huanxi heavy oil block in Liaohe oil province has serious water breakthrough problem and poor cyclic steam stimulation effect. Hence the feasibility of screw pump cold production without steam injection has been studied in high water cut heavy oil wells with low degree of reserve recovery. The mechanism of enhancing oil production has been analyzed combining with field application. Screw pump oil recovery technique has been applied in some high water cut wells in Jin 45 and 611 blocks, producing pressure drop has been properly controlled by using frequency conversion control box, the result of decreasing water and increasing oil has been obtained, and the input/output ratio is 1.0: 5.2.
Key words: heavy oil; screw pump oil recovery; high water cut well; Jin 45 block

Research and experiment of carbon dioxide slug assisted fracturing technique

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Abstract: Carbon dioxide slug assisted fracturing technique has been studied and tested in accordance with the problem of drastic decline of producing energy and the difficulty of fracturing fluid flowback in extra - low permeability reservoirs. Liquid carbon dioxide is injected before fracturing to supplement producing energy and improve post - fracturing cleanup by using miscible phase and dissolved gas actions. Laboratory study and numerical simulation have been conducted to determine the minimum miscibility pressure between crude oil and carbon dioxide for typical low permeability reservoirs such as Zhuang 74 Block, and to optimize shut - in time and fracturing operation parameters. Field application in 5 wells has achieved good result and economic benefit.
Key words: low permeability reservoir; carbon dioxide; fracturing; assisted; minimum miscibility pressure; shut - in time optimization; operation parameters optimization; field application