

# 不动管柱酸化工艺在渤海油田的应用

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**摘要** 由于海上油田开发的特殊性, 渤海油田多采用基质酸化技术解除堵塞, 加速回收投资。针对动管柱酸化作业施工工艺复杂、作业周期长、作业费用较高等缺点, 阐述了不动管柱酸化工艺在渤海绥中 36—1 油田的应用情况。考虑高孔高渗油田伤害特点及增产机理, 选用溶解力相对较弱、作用半径相对较大的酸液体系, 通过室内试验, 筛选出以氟硼酸为主的酸化液配方, 并提出采用与不动管柱酸化工艺相配套的暂堵酸化工艺和残酸返排工艺。不动管柱酸化采用平台支撑酸化作业, 无需动用钻井船, 残酸使用电潜泵返排并直接进入生产流程处理。间隔注酸效果评价试验和电缆腐蚀试验证明不动管柱酸化工艺能够达到海洋酸化作业和不影响后续生产的要求, 从而简化施工程序, 节约作业成本。

**关键词** 酸化 增产措施 酸化工艺 不动管柱 渤海

海上油田通常采用动管柱酸化作业, 即起出生产管柱后, 使用酸化管柱进行酸化作业, 完成后恢复生产管柱进行生产。显然, 这种作业方式存在以下缺点: 施工工艺复杂, 难度较大; 周期长、施工费用高; 施工受船期影响大; 动管柱后恢复生产管柱和洗井对储层会造成新的污染。

渤海绥中 36—1 油田位于渤海辽东湾南部海域, 面积 43.3 km<sup>2</sup>, 原油地质储量 2.5 × 10<sup>8</sup> t 以上, 油田分布范围广, 埋藏浅, 层系多, 油层厚, 有良好的开发前景。油田进行一期动管柱酸化, 动用钻井船和拖轮进行酸化作业, 取得较好的酸化效果。为了更好地满足海上作业特殊性的要求, 降低作业成本, 提高生产时效, 提出并开展了渤海不动管柱酸化技术研究, 即直接通过原管柱油套环空反挤和油管正挤注酸。对于管柱无单流阀的井, 在井口压力允许的条件下通过提高注入压力正注酸液实现, 实现不动管柱酸化。对于无单流阀的 Y 管柱井, 可通过捞出 Y—Block 后正注酸液。该技术在绥中 36—1 油田、歧口 17—2 油田进行了大规模应用, 取得了巨大经济效益。

## 1 不动管柱酸化工艺的酸液体系

### 1.1 酸液体系的岩心流动试验

酸液配伍性和酸液质量好坏是影响酸化效果的

因素之一。首先不动管柱酸化的酸液配方必须针对渤海高孔、高渗储层伤害范围大的特点, 选择能够实现深度穿透、解堵的酸液体系, 而且由于酸化过程中易破坏储层结构, 甚至会导致出砂及储层垮塌等严重问题, 为此通过室内试验筛选出对黏土和地层微粒有稳定作用的氟硼酸体系。

**试验顺序:** 驱替清洗液 → 正驱 4% NH<sub>4</sub>Cl (测  $k_0$ ) → 正驱前置液 → 正驱处理液 → 正驱后置液 → 反驱后置液 → 反驱 4% NH<sub>4</sub>Cl。

**酸化效果分析:** 表 1 是采用盐酸、氢氟酸、氟硼酸对绥中 36—1 油田岩心酸化的试验结果。主体酸液分别采用盐酸与氢氟酸、盐酸与氟硼酸复合酸液。其中, SZ36—1—12—2、SZ36—1—12—4 和 SZ36—1—18—4 号岩心使用的主体酸液为 3% HCl + 0.5% HF; SZ36—1—12—6、SZ36—1—12—8 和 SZ36—1—18—6 号岩心使用主体酸液为 3% HCl + 6% HBF<sub>4</sub>。试验结果表明, SZ36—1—12—2 号和 SZ36—1—18—4 号岩心获得了较好的酸化效果, 其酸化后的渗透率分别增加了 1.62 倍和 0.96 倍。但 SZ36—1—12—4 号岩心酸化效果较差, 酸化过程中渗透率变化较大, 酸化后岩心渗透率降低。岩心电镜扫描分析结果表明, 酸化中溶解的微粒脱落、运移, 造成堵塞, 使酸化后渗透率下降。由此可见, 采

用低浓度盐酸与氢氟酸复合酸酸化虽然可以取得一定的酸化效果,但对胶结疏松的储层容易造成微粒脱落、运移,堵塞喉道。采用盐酸与氟硼酸的3块岩心酸化后渗透率均获得增加,酸化效果较好,随着前置液、处理液和后置液的注入,渗透率不断提高,酸化中没有出现微粒运移堵塞喉道现象,渗透率变化

规律好,其酸化后渗透率比基准渗透率增加0.5~1.46倍。说明氟硼酸具有稳定黏土微粒的作用,不会对储层造成二次伤害,对岩石骨架破坏小,采用氟硼酸酸化可以取得好的酸化效果,是一种首选的酸液体系。

表1 酸化渗透率恢复结果

岩心编号	温度/°C	$k/k_0$					
		基液	正驱前置液	正驱处理液	正驱后置液	反驱后置液	反驱基液
SZ36-1-12-2	80	1	1.43	1.45	1.53	2.81	2.62
SZ36-1-12-4	80	1	0.78	0.60	1.56	0.42	0.5
SZ36-1-18-4	80	1	1.38	3.82	3.89	2.81	1.96
SZ36-1-12-6	80	1	0.87	2.66	2.29	2.67	2.46
SZ36-1-12-8	80	1	1.06	1.16	1.32	1.60	1.5
SZ36-1-18-6	80	1	0.42	1.17	1.73	1.83	1.68

与动管柱酸化相比,不动管柱酸化须进行试验,优化酸液浓度以减少对生产管柱及井下设备的腐蚀,通过在酸液中加入高效添加剂及改变各种添加剂的配比,使平台上较小规模的不动管柱酸化作业达到动用钻井船或拖轮大规模作业的酸化效果。

## 1.2 间隔注酸酸化效果评价

不动管柱酸化作业采用平台支撑作业,从而不动用钻井船或拖轮以控制作业费用。若平台作业场地有限,酸液必须在陆地上配制好,再运往海上平台进行酸化,或受海上天气的影响,作业中间间隔时间延长,因此必须对酸液搁置后酸化效果进行评价,了解酸液质量变化及其对酸化效果的影响。

配制的酸液不搁置,配制好后立即对岩心进行酸化,在酸化过程中间隔注酸,考察前置液、处理液和后置液关井一段时间再注入后续段液体时,酸液对酸化效果的影响。试验过程为:注基液→模拟关井35h再注前置液→模拟关井18h注处理液→模拟关井23h注后置液→反注后置液→反注基液→模拟关井45h反注基液。

试验结果表明,岩心酸化后渗透率均获得增加,酸化效果好,随着前置液、处理液和后置液的注入,渗透率不断提高,其酸化后渗透率比基准渗透率增加1.93倍左右。说明采用间隔注前置液、处理液和后置液都不会影响酸化效果,所选用的氟硼酸配方是一种较适合的酸液配方。

酸化效果试验 $k/k_0$ 与孔隙体积倍数的关系如表2所示。

表2 氟硼酸酸化渗透率恢复结果(80°C)

注酸过程	基液	正驱	正驱	正驱	反驱	反驱
		前置液	处理液	后置液	后置液	基液
间隔注酸时间		35	18	23		45
/h						
$k/k_0$	1	0.55	1.10	1.19	1.73	1.93

## 2 不动管柱酸化的残酸返排工艺

利用电潜泵返排残酸方案就是在酸化作业中不动管柱,注完酸液后直接启动原井中的电潜泵进行生产,为实现此方案需解决如下问题:

(1)保证酸化液对电潜泵机组及电缆产生伤害小,酸化后电潜泵能够正常启动;

(2)若返排残酸不及时,能通过采取一定措施保证不会对油层产生伤害。

在电潜泵生产井进行不动管柱酸化时,电潜泵的电缆和电泵的腐蚀是影响酸化后残酸返排和油井正常生产的最重要因素。为了评价酸液对电潜泵的影响,对小扁及大小扁电缆接头进行了腐蚀试验,考察酸液在一定条件下对电潜泵电缆的损害情况。本试验主要对主体酸即氟硼酸配方进行研究。采用现场提供的大小扁电缆接头,按规定的方法用防腐胶带密封好,放入装有5% HCl+5% HBF<sub>4</sub>+添加剂的压力容器中进行腐蚀试验,腐蚀10h后取出,测定氟硼酸对接头的腐蚀情况。腐蚀试验结果表明,在60°C、10MPa压力条件下,腐蚀10h后电缆接头电阻在1000MΩ以上,未出现漏电现象。同样,对小

扁电缆接头也进行了酸腐蚀试验,结果表明,采用新筛选的酸液配方在不动管柱的情况下进行酸化,不会对电潜泵的电缆接头造成腐蚀破坏,绝缘程度良好,所采用的配方是适用的。

通过后置液中加入与返排液配伍的破乳剂、高效助排剂等优化配方,并改善施工工艺,解决了残酸返排中的2个技术难题,在多口井进行现场试验获得成功,证明不动管柱酸化且直接应用电潜泵排酸是可行的。

### 3 不动管柱酸化工艺的成功应用

在室内试验的基础上,采用计算机模拟进行酸液暂堵分流优化设计,并在渤海油田进行了大规模应用,现场实施时根据储层特点及具体井况,及时调整施工压力、排量,实施连续混注分流。现场实施结果表明,分流效果明显,酸化增产效果显著。

歧口17-2油田P18井酸化前由于供液不足不能正常生产,酸化后日产液 $130\text{ m}^3$ ,日产油约 $100\text{ m}^3$ ;套压为 $1.3\text{ MPa}$ 时,动液面位于井下 $300\text{ m}$ 处,且能够连续稳定生产,达到死井复活的目的。绥中36-1油田酸化64井次,累计增油 $1235.52\text{ m}^3$ ,歧口17-2油田酸化7井次,平均单井增油 $50.8\text{ m}^3/\text{d}$ ;并且酸化后动液面有一定程度的提高,生产压差得到有效降低。

### 4 结论

(1) 采用不动管柱酸化作业可节省起下管柱的作业时间、降低作业费用、缩短关井时间,对生产影响小。

(2) 针对渤海油田的高孔、高渗特点,通过试验筛选了适宜不动管柱酸化工艺的酸液配方体系,现场应用表明这套酸液体系完全满足高孔、高渗油田深部酸化的需要。

(3) 不动管柱酸化工艺能够简化作业程序,克服船期、天气等因素的影响,满足海洋环保和经济高效开发的要求。

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(上接第46页)

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**Abstract** The accident of  $\phi 88.9$  mm square kelly break in well WS1 caused great economic losses, and a study was conducted to probe the causes of this accident. Macro analyzing method as well as micro method of using scanning electron microscope was applied to identify and analyze the kelly break—fracture, and the features of fatigue failure were identified. Test analysis was also carried out to determine the chemical composition, mechanical property and metallographic structure of the kelly, and it was concluded that the material strength and toughness is not sufficient enough. Study and test results showed that the break took place at the structure mutation location, and it was of brittle failure due to earlier fatigue fractures, and the main causes of kelly break were unqualified raw material and poor machining quality. This study can be used as a reference to prevent the happening of such accidents in the future.

**Key words** kelly break pipe sticking fracture analysis metallographic analysis

### NEW MODEL OF THE FILTRATE LOSS OF FRACTURING FLUID IN NATURALLY—FRACTURED AND LOW—PERMEABILITY FORMATIONS

by Li Yongming, Zhao Jinzhou, Guo Jianchun, (Southwest Petroleum Institute); Cui Huizhi, Wang Wanxun

**Abstract** The existing models for filtration rate modeling are based on the classic filtrate loss theory that filtrate loss velocity is inverse proportional to the exponent 1/2 of filtrate loss time, so they can't be used to filtration rate modeling in naturally fractured formations. To take account of fracturing fluid leaking into the formation through natural fractures and the matrixes, a new model is set up in this paper for modeling fluid filtration rate in naturally—fractured and low—permeability formations and its exact solution is present by means of orthogonal transformation, the new model is easier to convergence and has a fast counting velocity. It is shown from study that the fluid filtration rate in naturally—fractured formations should not use the classic filtration rate theory

**Key words** natural fracture fractured reservoir fracturing fracturing fluid filtrate loss

### APPLICATION OF ACIDIZING TECHNOLOGY WITH ORIGINAL PRODUCTION STRING IN BOHAI OILFIELD

by Liu Xin, Zhao Liqiang, (Southwest Petroleum Institute); Yang Zhai, Liu Yigang

**Abstract** Because of the specialties of offshore Oilfield development, matrix acidizing should be applied to get investment back quicker for Bohai Oilfield. Considering the shortcomings of using the other set of strings such as complexity, affecting production efficiency, high operating cost, the paper give a viewpoint of acidizing with original production string. It is important to selecting fluid system with big action radius and weak solvability for offshore oil field with high porosity, high permeability. By making experiments in laboratory, the formula fluorboric acid system is selected; moreover, corresponding fluid temporarily plug technology and acid flowback technology are discussed. The operation can be done on platform without drilling ship, the acid flow back is also be treated by original ESP. The effect of discontinuous injecting acid and wireline corrosion has been tested by experiment. Practice applying show these can completely meet the demand of similar of oil fields of Bohai, and which can be economic and make the operation easier than before.

**Key words** acidizing stimulation acidizing technology Bohai Oilfield

### TEST PRESSURE TECHNIQUE OF YANCHANG EPOCH RESERVOIR IN LONGDONG REGION

by Wang Junke, Wang Zhao, Wang Hongwei, Wang Ping, Kang Shijie, Dong Fuhai, (The Supervision Center, the Second Exploitation Factory, FuhaFuhaFuhaFuhaFuha)

**Abstract** Natural test techniques such as liner logging, annulus logging and pump pull out logging, have a lot of limitation in Yanchang epoch reservoir. Natural test ways have long close well time, affect yield of well, test curve isn't integrity, so we enhance the development monitors in the case of close well. Downhole pipe string structure, tool of test pressure and instrument choosing type and the operating process were introduced. Field test 5 wells in Xifeng Oilfield in 2004, practices show that test techniques in downhole close well can reduce output losing owing to long—term close well, and it's technologies simple, operating easier, cost lower and have a high-economic benefit, it also can reduce wellbore storage effect. Test data show radial drainage area and boundary reflection at short time, the precision of well test interpretative on skin factor and formation pressure was increased, it could provide reliable data for oilfield development.

**Key words** Yanchang Epoch Reservoir test pressure technique analytical approach

### PLUGGING REMOVAL AND INJECTION ENHANCEMENT TECHNOLOGY FOR THE WATER INJECTION WELLS IN BOHAI OILFIELD

by Yi Fei, Zhao Xiujuan, Liu Wenhui, He Ruibing, Li Chengjian, (Production Engineering Technology Service Company of CNOOC Bohai Branch); Liu Yigang

**Abstract** To solve the problem of difficult water injection in Bohai oilfield, a study was carried out on the plugging mechanism of water injection wells, and BHJ series plugging removal agents were developed based on the study. Laboratory tests were conducted on the performances of the series agents, e. g., of the organic plugging removal agent, its dissolving ability to asphalt and wax, its crude oil cleaning and gel—breaking ability; of the inorganic plugging removal agent, its dissolution to packing sand and core samples, its dissolution to inorganic scale and iron rusts, its iron ions stability, static slice corrosion, and tough scale conversion rate. Tests showed that BHJ series agents achieved a plugging dissolution rate as high as 90% and over. The series products have been used for 12 times in Bohai Oilfield, and the water sucking index of the operated wells went up remarkably, with a 100% operation success rate achieved. The field using proved their advantages such as high plugging removal efficiency, free of formation damage, wide application range, good permeability recovery, etc.

**Key words** Bohai Oilfield water injection well plugging removal injection enhancement

### STUDY ON BEST WORKOVER TIMING AND WORKOVER PROPOSAL FOR CASING DAMAGED WELL

by Liu He, (Mechanics and Electromechanical Engineering College of China Science and Technology University); Jin Yansong

**Abstract** Casing damage causes great economic losses, and for the casing damaged wells, it is necessary to choose a best timing and suitable techniques for workover. However, experience plays too important a role to achieve good result and accuracy. An economic evaluation model for the workover well is established using the non—linear planning method. Through