

# 液体转向酸化技术研究及现场应用

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**摘要** 介绍了液体转向酸化技术的转向机理,转向酸化室内静态试验和动态流动模拟试验成果,以及该技术在现场的应用情况。结果表明:液体转向酸化技术是改善注水井(油井)的吸水剖面(产油剖面),实现均匀布酸的极为有效的手段。

**主题词** 砂岩油气藏 剖面调整 液体 转向 临时堵塞剂 酸化 研究 应用

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酸化是砂岩油气藏增产增注的有效措施之一,但在对非均质地层尤其是大井段地层酸化措施中,流体的渗流特性决定酸液优先进入高渗透层,而中低渗透层很难进酸,出现严重的指进现象,使地层得不到充分的解堵或改造,从而在较大程度上影响酸化效果及有效期的长短。液体转向剂在泵酸过程中与酸液反应形成固体颗粒,在井筒周围形成滤饼暂时封堵高渗透层,使酸液进入中、低渗透层,达到均匀布酸的目的。转向剂滤饼在随后的生产过程中自行溶解,不会对地层造成伤害,从而使整个井段的地层渗流条件得到改善,提高酸化效果。现场试验3井次,成功率100%,取得了较好的技术经济效益。

## 一、液体转向酸化原理

在酸化作业过程中,液体转向剂 ZX-1 与酸液在低 pH 值条件下形成不溶于酸的颗粒: $ZX-1+H^+ \rightarrow ZX-1 \downarrow$  (酸不溶物),在酸液的携带下优先进入高渗层形成滤饼,迫使酸液进入中、低渗透层充分与地层和堵塞物反应,从而达到改善地层渗流特性的目的。酸化结束后随着油、水井生产的恢复,地层流体 pH 值升高,ZX-1 遇油(或水)自行溶解,不会伤害生产层。

## 二、室内静态试验

1. 悬浮时间试验 试验在 60℃ 条件下进行,量取酸液 50mL,在其中加入 5mL ZX-1,搅拌均匀后,在 60℃ 恒温水浴中,静置,观察并记录开始出现沉降时间、大部分沉降时间和完全沉降时间,结果如表 1。

2. 溶解时间试验 ZX-1 遇酸形成的颗粒完全沉降后,除去上面酸液,加入 100mL 清水摇匀,在一定温度下静置(即静态)或不断搅动(即动态)条件下,观察并记录完全溶解时间(见表 2)。

表1 ZX-1 在酸液中悬浮时间试验

酸液组成	温度 (°C)	开始沉降时间 (min)	大部分沉降时间 (min)	完全沉降时间 (min)
15%HCl	60	0.5	53	130
12%HCl+3%HF	60	0.5	52	130

表2 溶解时间试验结果

温度(°C)		30	40	50	60
完全溶解时间 (min)	静态试验	60	40	32	20
	动态试验	13	4	3	1

结果表明:在静态条件下,ZX-1 遇酸形成的颗粒在清水中溶解时间随温度的升高而加快;在动态条件下 ZX-1 均比静态条件下溶解的快,其溶解速度也随温度的升高而加快。

3. 粒径分布情况 ZX-1 在酸液中分布情况是通过 Malvern 2600C 型激光粒度仪测定的,ZX-1 颗粒粒径在 5.80~339 $\mu\text{m}$ ,平均粒径为 45 $\mu\text{m}$ ,远远大于一般砂岩地层的孔隙喉道直径(几微米),因此 ZX-1 难以通过一般砂岩地层的孔隙喉道进入地层深部。

为模拟地层,对 ZX-1 进行了转向酸化流动模拟试验,试验结果见表 3。

表3 流动模拟试验结果

井号	岩心号	$K_1$ ( $\times 10^3 \mu\text{m}^2$ )	$\varphi$ (%)	通酸量(mL)			$K_1$ ( $\times 10^3 \mu\text{m}^2$ )	$K_2$ ( $\times 10^3 \mu\text{m}^2$ )	渗透率恢复值 (%)
				HCl	转向剂	HF			
岔 47	9 $\frac{34}{37}$ -13	606.0	20.1	15	6	20	53.02	150.21	283.30
	5 $\frac{13}{30}$ -3	438.41	15.2						
岔 222	9 $\frac{16}{24}$ -8	56.19	12.73	20	4	20	2.79	4.798	172.0
	14 $\frac{13}{36}$ -3	190.59	17.92						
宁 51	2 $\frac{25}{44}$ -6	76	20.0	30	6	30	44.03	55.21	125.29
	1 $\frac{33}{44}$ -10	26	21.95						
留 93	7 $\frac{8}{28}$ -1	31.44	/	20	/	30	13.69	17.53	128.1
	7 $\frac{8}{18}$ -8	69.29	/						

表 3 是水溶性转向剂转向酸化模拟试验结果,试验是采用 2 块岩心并联进行的,试验程序为:同时反通 4% $\text{NH}_4\text{Cl}$  测  $K_1$ →同时正通盐酸、盐酸+ZX-1、土酸→关闸门反应半小时→分别正向通 4% $\text{NH}_4\text{Cl}$  测  $K_2$ 。岩心流动模拟试验结果表明:

(1)ZX-1 对地层没有伤害。遇酸形成的颗粒能在酸化后注水过程中完全溶解。

(2)ZX-1 能均匀布酸,转向酸化效果较好。采用水溶性转向剂酸化与采用普通酸化相比布酸较均匀,酸化后,高、低渗透率 2 块岩心渗透率相差较小。低渗透率岩心的渗透率提高幅度较大,转向酸化效果明显。

#### 四、现场试验

液体转向酸化技术现场使用过程中,液体转向剂与酸液在管线中混和,从油管泵入井内。工艺设计时可依据地层非均质的具体条件,进行一次或多次转向,从而达到充分改善砂岩地层渗流条件的目的。该技术现场应用3井次,成功率达100%。

晋45-306井是注水井,施工2井次,分层酸化,1997年9月25日酸化8号层,油层厚度12m,采用转向酸化时分2次转向。低替前置液 $8.5\text{m}^3$ ,水溶性转向剂 $1\text{m}^3$ ,高压挤处理液 $1.5\text{m}^3$ ,处理液 $22\text{m}^3$ ,水溶性转向剂 $1\text{m}^3$ ,前置液 $10\text{m}^3$ ,后置液 $10.5\text{m}^3$ 。9月29日酸化6号层,厚度为20m,施工时转向3次,低替前置液 $2.0\text{m}^3$ ,前置液 $6\text{m}^3$ +转向剂 $1\text{m}^3$ ,高压挤前置液 $10\text{m}^3$ ,处理液 $6\text{m}^3$ +转向剂 $1.5\text{m}^3$ ,处理液 $13\text{m}^3$ ,处理液 $6\text{m}^3$ +转向剂 $1.5\text{m}^3$ ,处理液 $15\text{m}^3$ ,前置液 $12\text{m}^3$ ,后置液 $11\text{m}^3$ 。施工后全井两层合注,吸水剖面得到显著改善(见图1),日注量由酸前 $15\text{m}^3$ 增加到 $106\text{m}^3$ ,日注水量提高了7倍。

晋45-96井也是注水井,施工井段为3281.8~3337.8m,厚度25m,共6层,施工井段为大井段、多层系,采用转向酸化后,吸水剖面也得到显著改善(见图2)。酸后效果由酸前日注水量 $12\text{m}^3$ 增至为 $123\text{m}^3$ 。

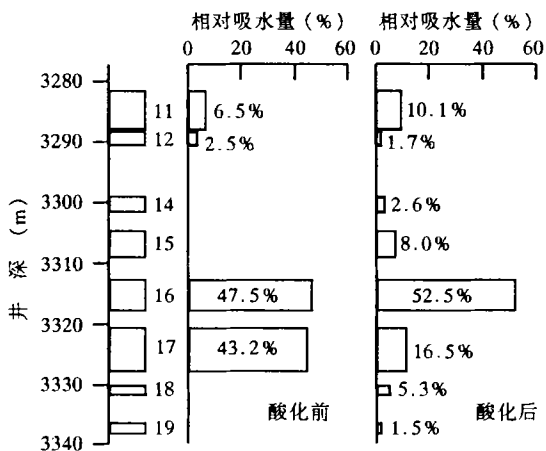


图1 晋45-306井吸水剖面柱状图

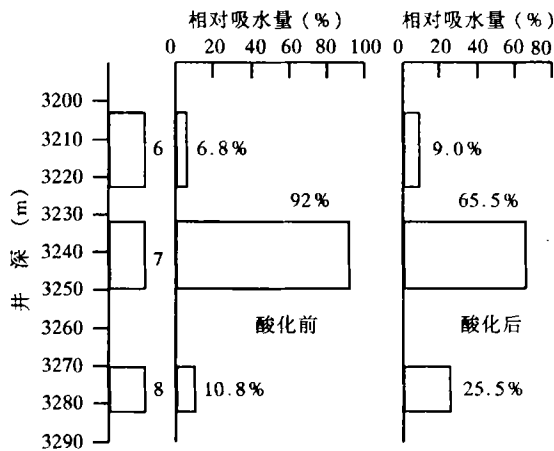


图2 晋45-96井吸水剖面柱状图

## 五、结论

通过室内试验和现场应用证明,液体转向酸化技术可靠,能有效地对酸液实现转向,达到均匀布酸,酸后效果明显。该技术施工方便,有效率高,是非均质砂岩油藏和孔隙型灰岩油藏的有效增产增注措施。

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## APPLIED RESEARCH OF OILY SLUDGE IN OILFIELD DEVELOPMENT

by Sun Xuejun, Yuan Jianguo, Zhang Jin, Tan Zhefeng, Lu Xilai

**Abstract** During production of an oilfield, the oily sludge settled at the bottom of the tank must be expelled. Because it is with great amount of slurry and oil, with high salinity, the oily sludge contaminates the environment seriously. This paper introduces a new technique, that is, change the oily sludge into a kind of viscous profile controlling agent through chemical treatment, and then use the agent to conduct profile control in high permeability injectors so as to plug the strong injectivity pore passages. Field application indicates: this technique is effective for increasing oil production and decreasing water output, and has better solved the problem of contamination and utilization of oily sludge. It has provided an economic and effective way for treating the contamination of oily sludge.

**Subject heading** oil tank sludge treatment water injection well profile control application research

## SAND CONTROL USING CMAS ARTIFICIAL ROCK LAYER

by Lei Guanglun, Zhang Jianguo, Guo Yunyao, Fang Lixin, Ma Hanzhong

**Abstract** A new kind of inorganic sand control agent can be solidified to manmade porous rock in aqueous environment, so as to replace solid voidage of a reservoir, stop the sands from migrating and prevent the sands from producing. This paper introduces the self-solidification characteristics of the sand control agent, the mechanisms of sand control, formula optimizing research, effect of temperature on solidification of the artificial rock, research of antiaging and erosion resistance, as well as the wettability, effective permeability test and pore size distribution test of CMAS artificial core. Meanwhile, this paper introduces the field application and its results too.

**Subject heading** chemical sand control artificial barrier hardening research

## RESEARCH AND PRACTICE OF COMPOSITE CERAMSITE SAND CONTROL TECHNIQUE

by Fang Lixin, Wo Fenglin, Cui Jianbang, Bai Fenghua, Ma Hanzhong

**Abstract** The main cementing part of the composite ceramsite sand control technique is composed of the main cementing material, the water soluble auxiliary material and the adding agent. These materials can be cemented and solidified in aqueous environment, and form a cemented body with certain cementing strength and connection pores. This kind of cemented body is formed in the oil reservoir with larger solid voidage, can fix the loose sands in some degree, and thus attain the object of sand control. After further understanding the serious sand producing field at the stage of high water cut, it has been decided to implement the technology of plugging in deep reservoir and sand controlling near well bore with man-made rock layer. This technology possesses good sand control effect to producers flooded by water, and is especially suitable to production layers with the characteristics of obvious benefit from water injection, bottom water, large pore passages and serious sand production. This technology had been used in 80 wells for more than 110 times, increased cumulatively oil 96 100t, and earned directly economic benefit more than 32 million ¥ (RMB).

**Subject heading** Dagang oil field sandstone reservoir high water cut stage sand production artificial barrier sand control field testing

## RESEARCH AND FIELD APPLICATION OF LIQUID STEERING

## ACIDIZING TECHNIQUE

by Wang Zhongze, Kong Dezhi, Zhang Guixia, Zhang Jianmin, Wang Jingque

**Abstract** This paper introduces the steering mechanism of the liquid steering acidizing technique, the results of the static lab experiment of steering acidizing and the simulation experiment of dynamic flow, as well as the field application of the technique. Field application results indicate: the liquid steering acidizing technique is a very effective means for improving the injectivity profile (oil producing profile) of the injectors (producers) and distributing the acids evenly.

**Subject heading** sandstone reservoir profile control liquid steering temporary plugging agent acidizing research application

## RESEARCH OF OIL SOLUBLE TEMPORARY PLUGGING AGENT OSR—

1

by Xue Xinsheng, Pan Fengtong, Yue Shushen

**Abstract** The temporary plugging and acidizing technology can be used to solve the problems caused by formation heterogeneity during acidizing of oil wells, and improve the effect of acidizing. This paper presents the requirements to the oil soluble temporary—plugging agent: (1) Granulation should be good, the range of grain size should be wide. (2) Compatibility should be good, it should show as inert in water, acid and surfactant. (3) Temperature tolerance should be good, so as to be suitable for the high bottom hole temperature. This paper demonstrates the physical and chemical property, the shielded temporary plugging fractional flow action and the field application of OSR—1. The test indicates that OSR—1 is a good oil soluble temporary plugging agent, suitable for conventional acidizing, especially suitable for multi—layer heterogeneous reservoir. It can improve evenly the property of several layers, increase the number of oil producing intervals, improve the effect of acidizing, and play a certain role in inhibiting water producing from oil well.

**Subject heading** oil well acidizing temporary plugging agent performance research

## PERFORMANCE ANALYSIS METHOD FOR ESTIMATING HYDRAULIC FRACTURE AZIMUTH IN COMPLEX FAULT BLOCK SANDSTONE RESERVOIR

by Jiang Tingxue

**Abstract** Took fault block Ar—11 of Arnai oilfield in Erlan region as an example, took injector—producer group as a research object, applied comprehensively the injection—production performance curve analysis method, with the help of working fluid level, production data and reserve—percolation property parameters, etc., deduced from percolation mechanism that the main sweep direction of the injected water was the azimuth of the minimum horizontal main stress, then, deduced the azimuth of the hydraulic fracture. Verified from drilling deviation deduction method and reservoir numerical simulation method, the performance analysis method for estimating hydraulic azimuth was reliable and operable. It has provided new thought and method for the optimizing design of fracturing and for the adjustment and perfection of water flood development well pattern.

**Subject heading** complex reservoir performance analysis fracture azimuth estimate method application

## POLYMER FLOODING TEST IN LOW PERMEABILITY AND HIGH SALINITY RESERVOIR OF MALING OILFIELD