·三次采油·

胜利油区化学驱油技术面临的矛盾及对策

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摘要：在化学驱技术水平现状分析、化学驱资源评价和实施效果跟踪的基础上，深入分析了制约胜利油区化学驱发展的主要矛盾。在长期室内试验研究和矿场实践中总结出“P+N”聚合物驱加合增效理论，针对制约化学驱发展的主要矛盾，开展了耐温抗盐聚合物、有机复合交联体系、强化泡沫驱、二元驱等研究工作，为胜利油区化学驱油技术的发展提供了有力的技术支撑，拓宽了化学驱油技术的应用领域。

关键词：化学驱；聚合物驱；复合驱；强化泡沫；胜利油区
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引言

胜利油区于20世纪60年代就开始进行化学驱油的室内研究工作，聚合物驱油技术经历了先导试验、扩大试验，目前已进入了工业化推广阶段。复合驱油技术也取得了突破，无论是小井距先导试验还是常规井距扩大试验都取得了显著的降水增油效果。截止到2003年7月，化学驱已累积动用地质储量2.19×10^8t，累积增油700×10^4t，增加可采储量1100×10^4t。但是由于油藏地层温度高，地层水矿化度高，综合含水高，大孔道较普遍，并且剩余资源油藏温度、矿化度、含水越来越高，化学驱难度也愈来愈大，制约了胜利油区化学驱油技术的进一步发展。

1 面临的主要矛盾

1.1 剩余资源丰而不富

第二次化学驱潜力评价表明，胜利油区适合化学驱的资源为10.76×10^8t，其中一、二类储量为5.4×10^8t[1]。评价时入选单元是作为整体考虑的，而同一单元内部，由于油层发育差、连通差、原油粘度或地层水矿化度高等原因，部分井组并不适合化学驱。目前化学驱动用储量2.19×10^8t，实际占用资源量达3.3×10^8t，平均有效利用率仅有65%。

到2003年7月，胜利油区剩余的一、二类资源2.1×10^8t，经分析，因井况、大孔道等客观原因不能动用的有10个单元，石油地质储量8428×10^4t。剩余一、二类资源12879×10^4t，如果有效利用率按65%计算，有效储量只有8371×10^4t。因此，要保持化学驱增油量的稳定，三类资源将是下步化学驱的主阵地。胜利油区适合化学驱的三类资源为4.57×10^8t，占总资源量的42.5%，这类资源地层温度高（>80℃），地层水矿化度高（>20000mg/L），在这样的油藏条件下采用常规聚合物驱油风险较大。

1.2 聚合物驱后缺乏提高采收率的成熟手段

胜利油区油藏非均质性严重，在水驱和聚合物驱过程中，注入水和聚合物溶液大部分进入高渗层，中、低渗透层波及程度低，影响了水驱和聚合物驱的驱油效果。另外，聚合物溶液不具备大幅度降低与地层原油间界面张力、增加毛管数的能力，洗油效率低。这两方面的原因决定聚合物驱不会有太高的采收率增幅。孤岛、孤东、胜坨三大主力油田平均水驱采收率33.5%，聚合物驱提高采收率按7.3%计算，聚合物驱后油藏仍然存在近60%的剩余油。孤东8－26－J9井聚合物驱后取心资料也表明，主力油层驱油效率可达到60%，而非主力油层驱油效率只有40%左右。因此需要发展新的高效采油技术。

室内试验和矿场实施的结果都表明，三元复合驱油技术增油的效果明显好于聚合物驱，可以更大幅度提高原油采收率，而且矿场实施也积累了一定的经验[2]。但三元复合驱技术成本高，而且矿场存在结垢严重和产出液乳化的问题，制约该技术在聚

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合物驱后的应用，其他可大幅度提高采收率的驱油技术尚处于试验阶段。

1.3 部分已实施单元动态非均质严重

在注水开发过程中，由于注入水的长期冲刷，加剧了层间和层内的非均质性，逐步形成了厚度小、渗透率高的“贼层”，这对于减缓平面指进和纵向调剖十分不利，增油效果较差。

目前实施的化学驱单元，经过长期水驱冲刷，大孔道窜流的现象普遍存在（表1），效果较差的孤东七区西 $Ng5^{2+3}$南、孤东七区西 $Ng5^{4}\sim6^{2}$北两个单元注聚前的累积注水倍数都在两倍孔隙体积以上，远远高于其他区块。如孤东七区西 $Ng5^{2+3}$南的孤东7-23-254井，注聚后的第2个月就见到了降水增油效果，但有效期仅3个月，1998年9月产出液中聚合物浓度超过200mg/L，含水率上升至96.5%，产油量下降。其他区块也存在类似的情况。

表1 孤岛、孤东注聚单元注聚前注采强度对比

区块	累积注入孔隙体积倍数	年注入孔隙体积倍数	平均每米单井注水量/$m^3(d\cdot m)^{-1}$	剩余油饱和度，%	采油速度，%	采液速度，%
孤东七区西 $Ng5^{2+3}$南	2.54	0.45	23.9	47.0	1.8	45.60
孤东七区西 $Ng5^{4}\sim6^{2}$北	2.09	0.22	18.7	43.0	1.2	31.30
孤东七区西 $Ng5^{2+3}$北部	0.96	0.30	13.2	54.1	2.2	38.50
孤岛中一区 Ng3 扩大区	0.93	0.13	9.5	42.1	1.8	37.20
孤岛中二南、中	0.97	0.10	10.1	39.1	1.4	25.20

2 主要对策研究

2.1 耐温抗盐聚合物

在高温和高矿化度条件下，驱油用部分水解聚丙烯酰胺分子卷曲，粘度低，因此具有较强的温敏性和盐敏性。在聚合物分子链上引入耐温耐盐单体，或对聚合物分子疏水缔合改性等方式可以提高聚合物耐温抗盐性能[3]。从多种耐温抗盐聚合物中筛选出的1号样品，溶解性相对较好，在温度85℃、总矿化度19334mg/L的条件下能够达到进口聚合物3530S在温度70℃、总矿化度5727mg/L条件下的增粘能力。但是单井试注试验井口测试粘度与实验室用相同的水配制溶液粘度相比较低，注入井的注入压力变化不明显，因此耐温抗盐聚合物的现场推广应用还需要进一步的改进。

2.2 有机复合交联体系

耐温抗盐的另一个途径是有机交联体系。在聚合物中加入有机交联剂，经过分子之间的作用形成具有三维网状结构的有机交联复合体系，增加了分子的空间尺寸，从而提高溶液粘度和耐温抗盐性能[4,5]。经过大量的室内研究，研制了DK系列有机交联剂，与聚合物形成的交联体系凝胶粘度远大于单一聚合物的粘度，通过控制添加剂的浓度，可以控制成胶时间和凝胶的强度，既保证了成胶的速度，又保证了成胶后的长期稳定性。耐温抗盐性能评价结果表明该体系耐温抗盐性能较好（图1，图2），在实验范围内，温度和矿化度越高，体系成胶越快且成胶后强度愈大。

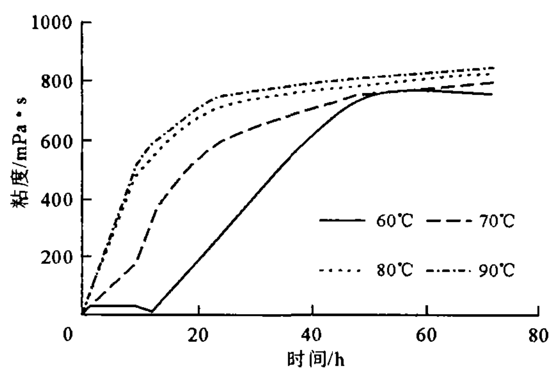

图1 温度对有机复合交联体系的影响

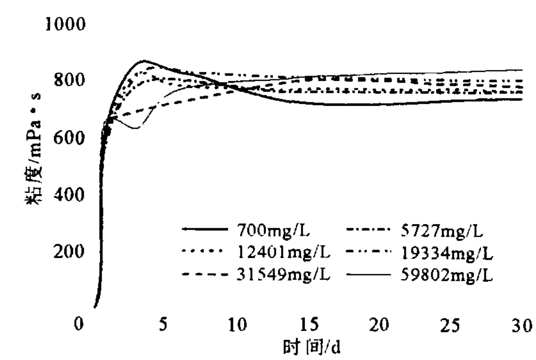

图2 矿化度对有机复合交联体系的影响

根据相似原理模拟直井注—直井采五点井网的

四分之一单元作为物理模拟对象,模型为500mm×500mm×100 mm,对角方向渗透率为(3000±300)$\times10^{-3}\mu m^2$,两侧渗透率为(500±200)$\times10^{-3}\mu m^2$;孔隙体积约为8L,孔隙度约为30%。试验结果表明,水驱最终采收率为24%,聚合物最终采收率为38%,有机复合交联体系最终采收率为58.2%。均质管式模型聚合物驱比水驱提高采收率11.5%,有机复合交联体系比水驱提高采收率19.7%,说明该体系具有较好的驱油效果,适合三类高温高盐油藏。

2.3 强化泡沫复合体系

在泡沫体系中加入聚合物形成强化泡沫复合体系,一方面提高泡沫的稳定性,另一方面提高泡沫体系的封堵能力。岩心试验结果表明(图3),强化泡沫复合体系的阻力因子与同浓度单一泡沫体系相当,但比同浓度单一聚合物的阻力因子大的多;其残余阻力因子比单一泡沫、单一聚合物高,证明该体系比单一聚合物和单一泡沫体系具有更好的封堵能力。

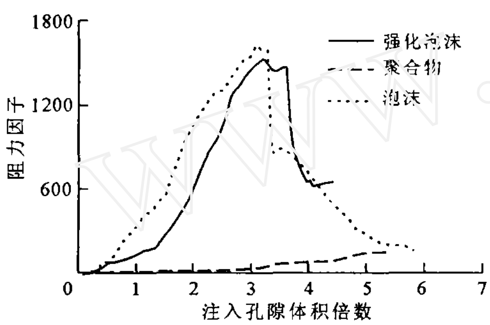

图3 强化泡沫的阻力因子

在渗透率分别为$2300\times10^{-3}\mu m^2$和$1000\times10^{-3}\mu m^2$的双管模型上开展的合注分采驱油对比试验结果表明,水驱后注入单一泡沫体系提高采收率7.1%;而注入强化泡沫复合体系提高采收率21.5%;聚合物驱之后注入强化泡沫体系,又可以提高采收率10.6%,证明强化泡沫体系具有比较好的驱油效果,适合在聚合物驱后及非均质较强的油藏应用。

2.4 二元驱

聚合物可以增加驱替液粘度,扩大波及体积,但不能提高驱油效率。表面活性剂能降低油水界面张力,提高驱油效率,但胜利油区油藏非均质性强,表面活性剂驱不能充分发挥洗油效果[6]。在聚合物中加入表面活性剂,既能进一步扩大波及体积,又能提高驱油效率,从而更大幅度的提高采收率,可以解决聚合物驱后提高采收率问题。在同等经济和相同段塞大小条件下,聚合物—表面活性剂二元配方与单一聚合物驱进行了对比驱油试验(表2),本次试验条件下,二元配方驱油效果好于单一聚合物。

表2 不同驱替配方相同经济条件下的对比表

模型编号	配方	注入段塞/孔隙体积倍数	提高采收率,%	
			OOIP	ROIP
孤东-6	0.15%P	0.3	11.7	33.1
孤东-11	0.3%SPS+0.1% 1#+0.15%P	0.3	18.1	41.7
孤东-7	0.3%SPS+0.1%1#	0.3	2.0	5.2
孤东-18	+0.15%P	0.54	15.2	40.9

聚合物—表面活性剂二元配方没有加入碱,克服了由于碱的加入导致现场结垢严重和产出液破乳困难的问题,而且降低了驱油成本。

3 应用前景

胜利油区有三类高温高盐储量4.57×10^8t,可实施储量2.97×10^8t,适用的技术包括耐温抗盐聚合物及有机交联体系,若提高采收率6%,可增加可采储量1800×10^4t;一、二类油藏可实施聚合物驱的储量3.5×10^8t,聚合物驱后进一步提高采收率适用的技术包括强化泡沫及二元驱,若提高采收率6%,可增加可采储量2100×10^4t;四类储量0.79×10^8t,可实施储量0.5×10^8t,适用的技术主要是强化泡沫驱,如果提高采收率10%,可增加可采储量500×10^4t。因此化学驱油技术在胜利油区具有广阔的应用前景,在实现"十一五"末油气当量重上3000×10^4t的目标中将发挥重要的作用。

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experiment of depletion exploitation characteristics in Qiaokou complex tight faulted block condensate gas reservoir with deep burial depth and low-permeability. The research results will provide foundation for material equilibrium evaluation on the effect of depletion exploitation.

Key words: condensate gas reservoir, low permeability, depletion, emulative simulation

Yu Jinbiao, Song Daowan, Qin Xuejie et al. Study on interpretation model of interwell tracer. PGRE, 2003, 10 (6): 42 ~ 44

According to Abbaszadeh-Dehghani M's layered analytical model, produced tracer concentration curves are analyzed. Based on integrated parameters of watered zone got by preliminary interpretation, single parameter of watered zone is obtained through secondary interpretation and Abbaszadeh-Dehghani M's analytical model is further developed. It proves this numerical method right to contrast with the results of oilfield cases. It provides a convenient and reliable mothod for quantitative interpretating heterogeneity of layered oil reservoirs.

Key words: interwell tracer, analytical method, optimization, secondary interpretation

Chen Guoli. Development characteristics and stable-production technology of natural water-drive oil reservoirs in Yingtai area. PGRE, 2003, 10 (6): 45 ~ 47

The key of successful development in natural water-drive oil reservoirs is to grasp the movement rule of edge and bottom water and to control and use the their active energy. Yingtai, Sifangtuozi and Yikeshu, these three oil fields in Yingtai area are all natural water-drive oil reservoirs with sufficient natural energy. In the initial stage of oilfield development, water cut is high with great escalating rate, which results in the oil production decline by a big margin. The technologies and measures for stable production of big and electric submersible pump, interlayer displacement by perforations adding, well infilling and out-laying are used for these development characteristics. The oil production rate is above 3% ~ 5% and keeps stable in longer period. The oil recovery efficiency by water drive reaches more than 50 percent.

Key words: natural energy, water drive, high water-cut period, flowing back by big pump, perforations adding, infill wells, stable production, Yingtai area

Li Daoliang. Watered analysis and countermeasures in the fracture of double porosity oil reservoir in Pucheng oilfield. PGRE, 2003, 10(6): 48 ~ 50

The middle Es_3 oil reservoirs in Pucheng oilfield are the microfracture-double porosity ones. Water channel is formed due to man-made cracks produced by hydraulic fracturing and original cracks. The oil wells in the direction of the cracks are easy to watered out, which may largely reduce the ultimate recovery efficiency. Through analysis of fracturing effect, development adjustment centered around flood pattern reforming is done in time with the result of raising 12.3% and 8.5% of the waterflood control degree and producing degree respectively, reducing 28.5% of the composite decline rate, and increasing 110t of daily oil production.

Key words: double porosity oil reservoir, low-permeability oil reservoir, man-made crack, crack monitor, watered direction, development adjustment, Pucheng oilfield

Wang Xuezhong. Study on oil displacement efficiency in upper Ng of Gudong oilfield. PGRE, 2003, 10 (6): 51 ~ 52

Oil displacement efficiency in upper Ng of Gudong oilfield is researched by the special core analysis, carbon-oxygen ratio and some other data. In upper Ng of Gudong oilfield maximum oil displacement efficiency by water drive is 0.646, that by ASP combination flooding is 0.735 and the present is only about 0.367. The main reasons of low oil displacement efficiency are that degree of uniformity of reservoir pore structure is low with uniformity coefficient of 0.279, oil-water viscosity ratio is up to 93, wettibility is water-wet to intermediate wet, oil-water interfacial tension is up to 21.1mN/m. Oil-water interfacial tension in the process of ASP combination flooding of small well spacing in Gudong may reduce under 1×10^{-3} mN/m. So the favorable direction of enhancing oil displacement efficiency is to reduce oil-water interfacial tension by ASP combination flooding.

Key words: oil displacement efficiency, special core analysis, carbon-oxygen ratio, high-permeability sandstone reservoirs, Gudong oilfield

Zhang Yigen, Yuan Fuqing, Zhu Yangwen et al. Contradiction and countermeasure for chemical flooding in Shengli petroliferous province. PGRE, 2003, 10(6): 53 ~ 55

The primary contradiction which limits the development of chemical flooding in Shengli petroliferous province is thoroughly analyzed on the basis of analyzing state of the art on chemical flooding technology, evaluating chemical flooding resources and tracing the implementation effect. In the long-term laboratory study and field tests, the theory of combination for improving polymer flooding effect is summarized, namely the "P + N" theory. Temperature-resistant and salt-resisting polymer, organic combination crosslinking system, enhanced foam flooding and dibasic combination flooding are researched for solving the primary contradiction. These methods provide powerful technology support for the development of chemical flooding in Shengli petroliferous province and extend the applied field of chemical flooding technology.

Key words: chemical Flooding, polymer Flooding, combination flooding, enhanced foam

Wang Jian, Ren Zhichen, Lu Hongsheng et al. Determination of inaccessible pore volume and retention pore volume by the use of effluent concentration profile model. PGRE, 2003, 10 (6): 56 ~ 58

Results of polymer flooding numerical simulation and field dynamic prediction cannot be influenced severely because the physical-chemistry parameters of inaccessible pore volume and retention pore volume, which is necessary for polymer flooding numerical simulation, are difficult to obtain accurately. Based on the inter-miscible displacement theory of polymer flooding, the determination and analysis methods of effluent concentration profile model of polymer flooding have been presented in this paper. The effluent concentration profile model of polymer flooding in Daqing oilfield reservoir condition has been determined by experiment, and inaccessible pore volume and retention pore volume bas been obtained. The methods are simple, exact and easy to understand. The research achievements can be guidance for polymer flooding numerical simulation, project design and prediction of field test of polymer flooding.

Key words: polymer flooding, adsorption and retention, inaccessible pore volume, molecular diffusion, concentration, profile, model

Wang Haifeng, Yang Yong, Zhang Guoyin et al. Applied prospects of new type of Gemini surfactant in tertiary oil recovery. PGRE, 2003, 10 (6): 59 ~ 61

In this paper, the molecular structure of new type of Gemini surfactant is described. Critical micellar concentration, surface tension, solubility, solubilization, adsorption at solid-liquid interface, compatibility with conventional surfactants and its rheological behavior are analyzed. It points out the applied prospects of Gemini surfactant in tertiary oil recovery of oilfield.

Key words: Gemini surfactant, molecular structure, performance, application

Yang Ruimin, Zhang Xiuqiong, Yang Xifei et al. Performance characteristics of SDC - M type of natural mixed carboxylate under high temperature and high salinity condition. PGRE, 2003, 10 (6): 62 ~ 63

The main performance characteristics of the improved SDC - M type of natural mixed carboxylate are introduced in this paper. Laboratory experiment showed that as the SDC - M is mixed with dispersant DSB at high temperature and high salinity, the compound can dissolve better in sewage with different salinity, and if the proportion of SDC - M with DSB is proper, the ultra-low interfacial tension among the two and high bivalent cation can be achieved, so the compound has better displacement efficiency and can be applied to production well washing and single-well "huff and puff".

Key words: natural mixed carboxylate, high temperature and high salinity, interfacial tension

Yin Yanling, Zhang Guicai. A summary of chemical oil well water plugging and profile control agent. PGRE, 2003, 10 (6): 64 ~ 66

Considered from the angle of the colloid chemistry and the conformation of all plugging agents, all profile control and water plugging agents are classified again in this paper. The mechanism of various agents for water plugging and profile control and their present application in oilfield are introduced. It also presents that the development of the profile control and water plugging agents should focus on low cost, multifunction and high efficiency.

Key words: profile control, water plugging, plugging agent, development direction

Xiong Guocun, Rui Huasong, Nie Cuiping. Study on the formation damage mechanisms of Nanyi Mountain E_3^2 condensate gas reservoir in Qinghai. PGRE, 2003, 10 (6): 67 ~ 69

Nanyi Mountain E_3^2 gas reservoir in Qinghai is an unconventional fractured gas reservoir in Chaidamu Basin with high clay content. The permeability of formation rock is mainly controlled by rock fractures. So this pay-zone is subjected to damage in the course of operations such as drilling, completion and others. The basic characteristics of this pay-zone, including reservoir space, pore structure, types of clay mineral and sensi-