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Research Article

LABORATORY INVESTIGATIONS AND APPLICATION OF A NEW TECHNOLOGY TO IMPROVE POLYMER FLOODING IN THE NIGER DELTA RESERVOIRS

[1]Akpoturi Peters and [2, *]Rapheal Ehikhuemhen Asibor

[1]Department of Petroleum Engineering, Federal University of Petroleum Resources, Effurun, Delta State, Nigeria
[2]Department of Computer Science/Mathematics, Igbinedion University, Okada Edo State, Nigeria

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Abstract

Polymer flooding has been one of the most important enhanced oil recovery (EOR) technologies at Niger Delta oil field. However it was observed that an ordinary polymer solution did not efficiently flood the reservoir as it flowed easily through macro pores and emerged in the oil zone after continuous injection. This led to water breakthrough by fingering. This phenomenon was observed at most of polymer injection areas in the Niger Delta. In this paper, the test on the suitability of a special crosslinker (CL-1) to improve the polymer flooding performance is presented. A research was carried out in the laboratory to see how the CL-1 crosslinker may improve polymer flood performance. The crosslinker was mixed with some polymers to obtain a gel. All the polymers used in test are HPAM. The cross/inking states of CL-i and the different samples Of PAM were evaluated against a number of physical parameters. The experiments showed that when CL-i was used in polymer flooding, the modified polymer system showed a better improvement in viscosity, thermal stability and salinity resistance. A distribution device was also success fully manufactured to accurately add the dosage of CL-i into polymer solution automatically. When CL-i was added and the polymer solution was injected into the injection well with low pressure, the moveable polymer gel with high viscosity was formed in the formation. This penetrated deeply into the micropores of the reservoir, blocking the macropores and preventing or minimizing further polymer channeling. This resulted in a better sweep of residual oil and improvement in wellhead pressure.The modified polymer system technology was applied to Iyobosa oil field in Delta State since May, 2015. The field has 15 injection wells and 46 production wells; well spacing is 300 metres, and the reserve in place is about 5145x10^4stb. There are 6 injection wells which remained low injection pressures even after seven months polymer flooding. The modified polymer flooding system was applied to these six wells mentioned above. A better performance resulted, with the injection pressure rising from 870psi to 1378psi. The daily oil production from the producers increased while the water cut decreased. Due to this success, the technology is now applied in some other polymer flooding areas.

Keywords: Polymer, Pressure, Flooding, Macropores, Water cut, Injection Wells, Fluid, Flush and Reservoir.

INTRODUCTION

Polymer flooding, as a major EOR method, has been applied widely in the Niger Delta. Some injection wells become low pressure wells during polymer flooding because there are big macropores or super macropores in the reservoir. This occurs after a long injection period, accompanied by water flushing. There is observed a bad flooding effect by the normal polymer in use and a flooding slug and bad profile control can be seen. The polymer fluid severely channels through the big macropores and sweeps ineffectively, leading to a poorer performance than desired. To improve polymer performance a crosslinked agent (brand name, CL-i) was introduced into a polymer fluid in order to obtain a gelled system. On trial the new system improved the polymer flooding. The prepared crosslinker was characterized by its slow crosslinking and medium intensity, which resulted in an increase in injection fluid viscosity. To enhance mixing, a crosslinker distribution device was built. The prepared crosslinker distribution device was designed for metering accuracy and its use was to aid the improvement of the homogeneity of injected crosslinked polymer slug, and thereby enhance the slug flooding effect. A field test of this programme was carried out in 6 low-pressure-wells, in the Iyobosa areas, polymer flooding block in the Niger Delta Oilfield in May, 2018.

Corresponding Author:** ***Rapheal Ehikhuemhen Asibor
Department of Computer Science/Mathematics, Igbinedion University, Okada Edo State, Nigeria

A good effect was seen, such as increased injection pressure of 508 psi after adding CL-i and polymer to wells. The oil rate improved and the water cut decreased in the production wells. The measure also delayed early-polymer-channeling and improved the polymer flooding effect.

Laboratory experiment

Preparation of CL-i crosslinker

After studying and selecting some systems of crosslinkers, the CL-i crosslinker was prepared. The CL-i chemical is a chromium (Cr3) complex system. When the chemical is used for crosslinking, the Cr3 ions are released and crosslinks with carboxyls in HPAM polymer. The gel formed is a three dimensional net structure. The system is found stable and it is easy to control gelling. The CL-1crosslinker's parameters are shown in Table 1.

Performance Evaluation of Crosslinking system

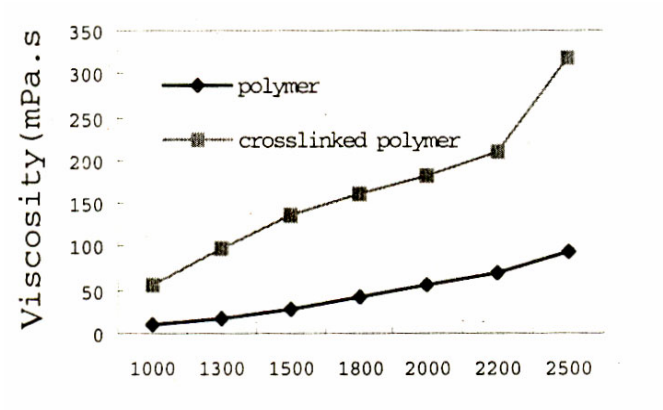
Viscosity-Concentration relation

The viscosity of the crosslinking system and the uncross linking system are tested and compared at the same conditions, The normal polymer in use for flooding is 3530S from America. Solutions of the CL-1/ 3530S polymer system and the normal 3530S polymer system are placed in thermo tank at a temperature holds 65 °C for 72 hrs' to crosslink.

Table 1. Parameters of CL-i Crosslinker

Crosslinker	Appearence	Dersity glcm 2a.	pH	Viscosity mPa.s3 .	CrContent (%)	Ratio of Crosslinking
CL-i	Darkgreen, viscous	1.23	7.0-8.0	.7.0	4.9	.3

The results are shown in Fig.1. The figure shows that the viscosity of the two systemsrises when the polymer concentration increases, but that of the crosslinking system is much higher.



Concentration(mg/L)

Fig.1. Polymer and Crosslinking

Polymer Viscosity-Concentration Curve;

Viscosity-Temperature Curve;

A crosslinking polymer solution was prepared. The concentration of 3530S is 1500mg/L, and the crosslinker is CL-1. The viscosity of the solution was measured in different temperatures after 72 hours crosslinking. The results are shown in Fig.2. It can be inferred that the system's viscosity and gel strength decreases when the temperature rises. At 80 °C the viscosity is low but still 10 times greater than that of plain polymer solution.

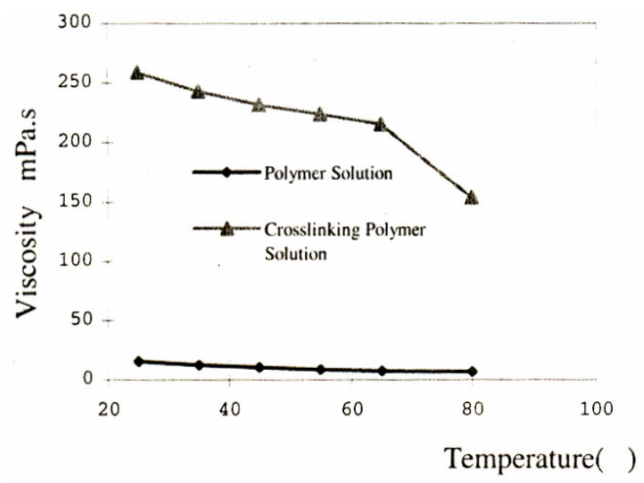


Fig. 2. Heat Resistance Curve

Salt Resistance

Polymer solutions were prepared by using different salinity water as 1000, 5000, 10000, 20000, 50000mg/L, where the concentration of 3630S is 1500mg/L. The crosslinker used in the test is CL-i. These solutions are placed in thermo tanks at the temperature of 65 °C.

The viscosities of crosslinking polymer and plain polymer solution were measured after 72 hours crosslinking. Fig.3 shows the result that the viscosity of crosslinking polymer and plain polymer solution decreases as the salinity rises, but theviscosity of crosslinking polymer is higher than that of plain polymer when the salinity is same.

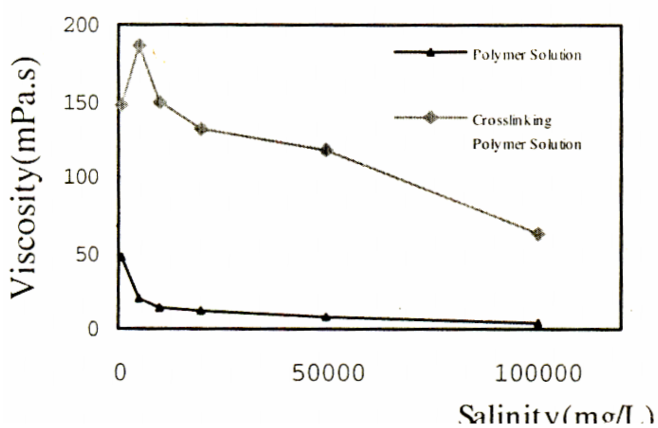


Fig.3. Salt Resistance Curve

Heat Stability

A crosslinking polymer solution was prepared with water salinity of 5272mg/L, where the 3530S concentration is 1 500mg/L, and the crosslinker is CL-i. The test tubes containing the crosslinking polymer solution were sealed, and placed in the thermo tank, and the temperature raised to 65 °C / 80 °C. The viscosity on different days is measured. Data is shown in Table 2.

Table 2. Heat Aging Test

Aging Time/d	Viscosity/mPa.s 65.		Viscosity/mPa.s 80		Remarks
	•p	•G	•P	•G	
0	7.853	/	7.1	/	
3	/	215.6	/	153.9	•p-HPAM
20	7.21	208.3	5.2	141.1	Viscosity
34	6.62	201.2	3.1	130.5	•G-
48	5.31	198.8	2.0	119.8	Crosslinking
62	3.9	190.1	1.7	110.2	HPAM
76	2.9	185.5	1.3	103.5	Viscosity
90	2.2	182.6	0.76	96.96	

The data in Table 2 shows that the viscosity of crosslinking polymer remains 80% of the original solution viscosity when the temperature is at 65 °C and the aging time is 90 days, and the viscosity remains 60% when the temperature is 80 °C. It can be inferred that the stability of the solution is getting poor when temperature rises, but the crosslinking polymer is more stable than the plain polymer solution; (the remaining viscosity of plain polymer is only 30% at 65 °C and 10% at 80 C of the original viscosity).

Design and application of crosslinker distribution device

A distribution device was successfully manufactured to add the dosage of CL-1 into polymer solution automatically and accurately. This was to enable the metering of crosslinker in order to improve stability and reduce error through enhancing two ends' pressure difference of the distribution container. The device has high precision dosage distribution at even small dosages. The experimental flow, in the lab is shown in Fig.4.

The equipment for the on-site test is shown in Fig .5.

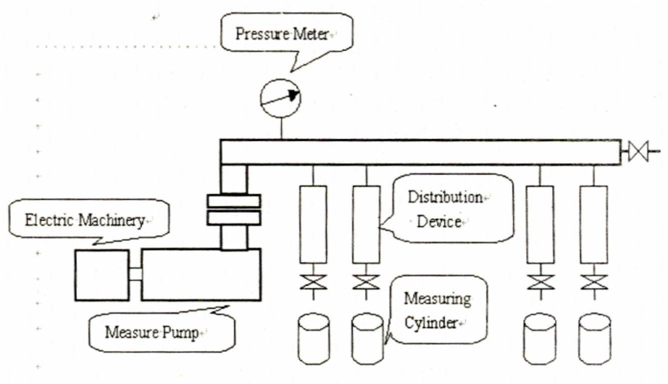


Fig.4. Experimental Set-up in Lab

Technology Index

When the crosslinker distribution device is used on-site, it can meet the following technology parameters:

Distribution error of 5%, system pressure resistance of 5Mpa, flow range 0.5— 100 L/h and distribution branch 3 - 20.

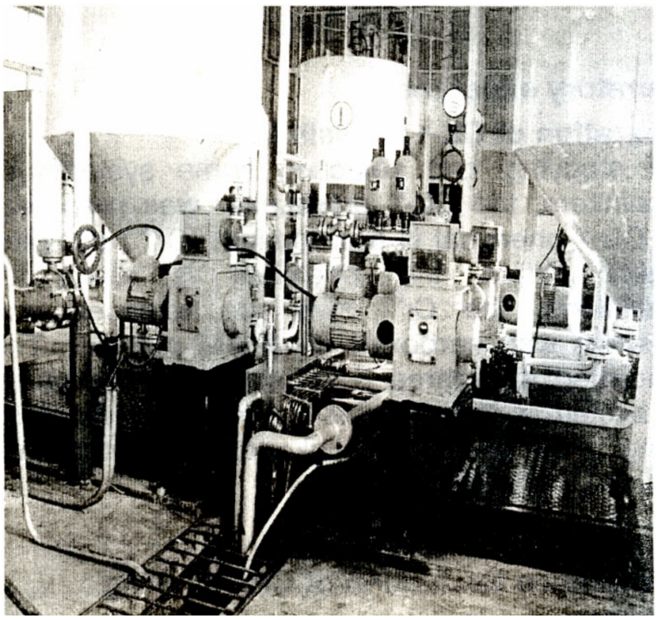


Fig.5. Crosslinker Microflow Distribution Equipment

Field Application

The technology was applied and Field tests showed good results of pressure increasing after injecting crosslinker in injector wells. Incremental oil with decreasing water cut resulted in the producers.

Pilot Site Description

The main oil bearing zones are Ng3144. The reserve in place is about 5145x104 stb. The oil bearing area is some 2.65km^2. The average porosity is 25-30%, average permeability is 1150-2200x10-3mD, thereservoir temperature is 72 °C. Well spacing is 300 metres. The pilot test of polymer flood was conducted in iyobosa since November 2018. There are 15 injection wells and 46 production wells. There was good result after a period of time with the polymer injection of the new system, but injection pressure remained low in some injectors, which resulted in polymer solution channeling and reduction in polymer performance.

Application Effect

The modified polymer flooding system was applied to the six wells which have low injection pressure. A better performance was seen, including injecting pressure rising from 870 psi to 1378 psi (see table 3) and daily oil production in the producers increasing, at lower water cut, after several months of injection (Fig 3).

Table 3. Pressure contrast of adding crosslinker wells

Serial Number	Well number	Before adding 2001.4	After adding 2001.11
1	C126-5-7	914	1740
2	C126-4-7	986	1146
3	C126-6-X3	595	1595
4	C126-10-X10	1102	1088
5	C126-6-5	870	1378
6	C126-3-6	754	1320
average		870	1378

Conclusion

Crosslinking system evaluation compared to pure polymer solution showed higher viscosity, and better resistance to higher temperature and salinity. A crosslinker microflow distribution device was manufactured for field test. It dispensed the crosslinker accurately and was effective for mixing the right formulations. During the period of the field test, the wells in which crosslinked polymer were added showed higher injection pressure. The water cut also declined relatively quickly and oil production per day rose in the producer wells. This indicates that suitably crossedlinked polymer was better suited for the polymer flood.

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