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Studies on Cross linked Polymer Gel System for Water Shut off Job

Rahim Seikh and Vikas Mahto
Department of Petroleum Engineering, Indian School of Mines Dhanbad, Jharkhand, India

Abstract

The partially hydrolyzed polyacrylamide based gels using inorganic crosslinkers are better options for water shut off jobs to get the maximum recovery from oil fields. It form in-situ cross linked gel structure in the presence of trivalent metal ions like Cr^{3+} and sequential injection of polymer and cross linker solution have potential for permeability reduction in the reservoir for high water producing wells. Keeping these in mind, experimental work has been carried out to develop a polymer gel system using partially hydrolyzed polyacrylamide polymer and thiourea/$K_2Cr_2O_7$ Cross linkers. The experimental investigation reveals that significant permeability reduction at reservoir conditions is observed on the cores treated with this gel formulation.

1. Introduction

Water production is the most common problem of the majority of oil and gas wells and the purpose of water shut off job is to reduce the water production from those wells. Water production causes major economic and operational problems. It reduces the sweep efficiency hence reduces the ultimate oil recovery from the reservoir. It decreases oil production, and results in large amounts of produced water that need to be disposed. It also requires increased capacity of water separation and handling facilities. Other production related problems include high corrosion rats and increased tendency for emulsion and scale formation. Water production further aggravates the problem when it bypasses the hydrocarbons in the formation thereby increasing the fluid head which leads to creating extra backpressure on the formation resulting in decline in oil production. Sand production is also often associated with increased water production rates. The choice of a specific treatment depends on the source of water production, well bore / reservoir characteristics, and operation costs [1]-[2].

Numerous techniques are employed for solving water production problems. These range from simple mechanical means such as bridge plugs and squeeze cementing to more elaborate schemes involving down hole separation, dual production and horizontal drilling. Conventional water control techniques, like squeeze cementing and mechanical isolation with bridge or cement plugs have not been very successful in reducing the water production for a long period of time[3]-[4].

Recently, polymer gel treatment has emerged as most useful chemical method to reduce water production. Polymer gel systems are typically composed of a water soluble polymer and organic or inorganic cross linking agents which are dissolved in water. This solution is considered as gelant solution. After allowing sufficient time, the gelant sets into a semisolid mass and behaves as flow diverting or blocking agent. Polymer gel systems have penetration property greater than the mechanical methods to provide a deeper barrier against the excess water [5]-[12].

In this study, a polymer gel system was prepared using partially hydrolyzed polyacrlamide polymer polymer (PHPA) and chromium acetate and thiourea crosslinkers as combination of sodium sulphite and thiourea provides a redox system for getting a wide range of gelation time that may be used for near well bore treatment as well as in depth treatment during water shut off jobs.

2. Experimental Procedure

The solution of partially hydrolyzed polyacrylamide polymer was prepared in brine containing 200 ppm sodium sulphite and constantly stirred on a magnetic stirrer until uniform viscous solution was obtained. The polymer solution was aged at normal temperature for 24 hours. The solutions of chromium acetate and thiourea cross linkers were then prepared by adding preweighed samples of chemical in brine. The gelant was then prepared by mixing these crosslinkers into the polymer solution at specified ratio. The solution was then homogenized by constant stirring using a magnetic stirrer. The pH of gelant was maintained using NaOH and HCl solutions. The gelants were taken in glass tubes and kept in hot air oven at 80^{o}C for gelation and inspected visually the gel formation at regular intervals.

The time for formation of stiff gel was considered as gelation time.

To study the effectiveness of polymer gel system for water shut off job, core flow studies were carried out. In this study, gelant solution was injected into Berea core sample in the core holder of core flood set up for its plugging ability. The core holder is housed in a constant temperature oven which holds the core at the simulated reservoir conditions. After the relevant conditioning of core, it was flooded with brine and effective brine permeability was measured. Once the base permeability was established, a gelling solution was injected at slow rate, and then core treated with optimized gel solution shut in and aged for five days at 80$\pm$ 2^{o}C to give ample time for the gelling solution to set. Following the shut-in, brine was again re-injected and return permeability was measured at reservoir simulated conditions for calculating reduction in permeability.

3. Results and Discussions

The gelation time of polymer gel system depends upon the depth of well and the pumping time required for reaching the resulting mixture into the formation. Hence, gelation time was controlled by varying different concentrations of polymers and crosslinkers.

Table 1 Effect of cross linkers on the gelation time of 10000 ppm PHPA polymer solution at 80 ^{o}C

Polymer (ppm) A	Cross linker (ppm)		Brine Concentration (ppm)	pH	Gelation time (hrs)
	$K_2Cr_2O_7$	Thiourea			
10000	3000	3000	10000	6.9	6
10000	2500	2500	10000	7.0	6
10000	2000	2000	10000	7.1	8
10000	1500	1500	10000	7.2	11
10000	1000	1000	10000	7.4	35

Table 2. Effect of cross linkers on the gelation time of 8000 ppm PHPA polymer solution at 80 ^{o}C

Polymer (ppm) A	Cross linker (ppm)		Brine Concentration (ppm)	pH	Gelation time (hrs)
	$K_2Cr_2O_7$	Thiourea			
8000	3000	3000	10000	6.7	10
8000	2500	2500	10000	6.8	10
8000	2000	2000	10000	6.9	11
8000	1500	1500	10000	7.0	19
8000	1000	1000	10000	7.2	44

The effect of cross linker concentration on gelation time is shown in Table 1-3. The cross linker concentration has a significant effect on gel strength. When the concentration of both cross linker was decreased, the gelation rate and gel quality were also decreased. In other words, when cross linking agent concentration was increased, the stage of polymer gel changed from a state of flowing gel to stiff/rigid gel in lesser time due to increase in cross linking sites. This is due to the ability of chromium acetate and thiourea cross linkers to build a complex network with carboxylate groups of partially hydrolyzed polyacrylamide and the formation of three dimensional gel networks

The effect of polymer on gelation time is also illustrated in Table 1-3. The polymer concentration has a significant effect on physical properties of gel (gel strength and viscosity). As the polymer concentration decreases from Table 1 to Table 3, the gelation time increases. It may be due to availability of less cross linking sites in the gelants from Table 1 to Table 3 for cross linking reaction takes place. Thus, the gel formation reaction decreases which leads to increase of the gelation time.

Table 3 Effect of cross linkers on the gelation time of 6000 ppm PHPA polymer solution at 80 ^{o}C

Polymer (ppm) A	Cross linker (ppm)		Brine Concentration (ppm)	pH	Gelation time (hrs)
	$K_2Cr_2O_7$	Thiourea			
6000	3000	3000	10000	6.7	9
6000	2500	2500	10000	6.8	16
6000	2000	2000	10000	6.9	17
6000	1500	1500	10000	7.0	31
6000	1000	1000	10000	7.1	103

Table 4. Composition of gelant solution for insitu gelation studies in the Berea core sample

Components	Units	Composition
PHPA Concentration	ppm	8000
Brine Concentration	ppm	20000
$K_2 Cr_2O_7$	ppm	4000
Thiourea	ppm	4000

The experimental investigation under insitu gelation and core flooding are shown in Table 4-5. It was found that porosity of the core was 20% and initial permeability was 128.11 md. After flooding the polymer cross linker solution into the Berea core sample, it was kept inside the oven for 5 days. After insitu gelation, the brine was injected into the core to determine the plugging ability of polymer gel system. It was observed that permeability of the core after insitu gelation was reduced to 7.36 md and % reduction in permeability was 94.25 %. The large difference in initial permeability and post gelation permeability shows the plugging ability of the gel system.

Table 5. Effect on gel system on the permeability of Berea core sample

Sl. No.	Parameters	Unit	Observed Values
1	Porosity	%	20
2	Initial Permeability	md	128.11
3	Post gelation permeability	md	7.36
4	Permeability reduction	%	94.25
5	Residual reduction factor	---	17.40

The residual resistance factor is the ratio of initial permeability to brine before polymer gel injection and the permeability after polymer gel injection and it measures the permeability reduction by polymer adsorption in the petroleum formation. In this work, residual resistance factor was 17.40 and it shows the suitability of this gel system for water shut off job in the oilfields.

4. Conclusions

The following conclusions are drawn for the present investigations:

1. With the increase in cross linkers concentrations in the gelant solution gelation time for the formation of stiff gel decreases.
2. As the concentration of polymer in gelant solution increased, the gelation time for the formation of stiff gel decreased.
3. The permeability of the Berea sandstone core sample decreased significantly after insitu geltaion which shows its good plugging ability and may be used for water shut off jobs in the oilfields.

5. References

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