SCIENTIFIC CONTRIBUTIONS OIL AND GAS
Vol. 42, Number 1, April 2019: 2 of 5
RESEARCH AND DEVELOPMENT CENTRE FOR OIL & GAS TECHNOLOGY LEMIGAS
Journal Homepage:http://www.journal.lemigas.esdm.go.id
ISSN: 2089-3361, e-ISSN: 2541-0520

THE EFFECT OF ELECTROLYTES ON POLYMER VISCOSITY FOR EFFECTIVENESS OF POLYMER INJECTION

PENGARUH ELEKTROLIT TERHADAP VISKOSITAS POLIMER UNTUK KEEFEKTIFAN INJEKSI POLIMER

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First Registered on January 23rd 2019; Received after Correction on March 5th 2019
Publication Approval on: April 30th2019

ABSTRAK

Penggunaan polimer pada injeksi kimia telah diketahui penting sebagai perubah viskositas untuk meningkatkan efisiensi penyapuan pada injeksi air dan injeksi kimia. Polimer yang paling umum digunakan dalam injeksi kimia adalah poliakrilamid terhidrolisis (HPAM) yang memiliki banyak muatan sepanjang rantai polimer. Di sisi lain, air formasi sebagai pelarut polimer mengandung elektrolit tinggi yang mempunyai pengaruh besar pada viskositas polimer, sekaligus berperan pada efisiensi injeksi polimer. Dalam studi ini, pengaruh elektrolit dari kadar garam dan kation divalen terhadap viskositas polimer diinvestigasi. Tiga jenis polimer dilarutkan di dalam air dengan berbagai macam variasi konsentrasi salinitas dan kation divalen yang selanjutnya diuji kompatibilitas, viskositas dan rasio filtrasi polimer. Hasil uji menunjukkan bahwa keberadaan elektrolit dalam air pada setiap konsentrasi tidak mempengaruhi kompatibilitas dan rasio filtrasi polimer. Adapun penambahan natrium klorida sebagai ion salinitas dan kalsium klorida sebagai kation divalen menurunkan viskositas polimer. Rendahnya viskositas polimer terkait dengan kemampuan polimer untuk mengembang secara hidrodinamik yang dibatasi oleh proses netralisasi tolakan internal dari elektrolit.

Kata Kunci: *polymer, injeksi polimer, injeksi kimia, EOR, elektrolit*

ABSTRACT

The use of polymer for tertiary oil recovery has been known to be important as viscosity modifier to increase sweep efficiency of water flood and chemical flood. The most common polymer used for chemical flood is hydrolyzed polyacrylamide (HPAM) that owing large number of charges along the polymer chains. However, formation water as dissolution water contain high electrolytes that has a great effect on polymer viscosity, as well as responsible to generate the efficiency of polymer flooding. In this study, the effect of electrolytes from saline and cation divalent to the viscosity of polymer was investigated. Three studied polymers were dissolved in various concentration of saline and cation divalent by analyzing the compatibility, viscosity, and the filtration ratio of polymers. The results showed that the presence of electrolytes in every concentration of water did not impact the compatibility and filtration ratio of polymers. Whereas, the addition of sodium chloride as saline ionic and calcium chloride as cationic divalent were both reducing the viscosity of polymers. The lower viscosity of polymer related to the ability of polymer to expand the hydrodynamic which limited by the neutralization of internal repulsion of the electrolytes.

Keywords: polymer, polymer flooding, chemical injection EOR, electrolytes

How to cite this article:

Alli, Y.F., 1, 2019, THE EFFECT OF ELECTROLITES ON POLYMER VISCOSITY FOR EFFECTIVENESS OF POLYMER INJECTION, *Scientific contributions Oil and Gas*, 42 (1) pp, 9-14 DOI: 10.29017/SCOG. 41.1.17-27.

I. INTRODUCTION

Chemical flooding is one of the enhanced oil recovery (EOR) techniques to recover the oil production after water flooding. The chemicals were injected into the reservoir to alter the reservoir fluid or rock characteristic to recover the oil production (Zhu, et al., 2013; Olaire 2014; Battistuta 2015; Sheng, 2015). Polymer, along with surfactant and alkaline, was usually added to improve the mobility control of oil since the viscosity of formation water tends to be lower than the oil which is likely to produce the fingering effect, rather than piston-like displacement (Sheng, 2013a).

The most common polymer used for EOR are the synthetic polymers partially hydrolyzed polyacrylamide (HPAM) and its derivatives. HPAM is an anionic polymer with a large number of charges along the polymer chains. This typical synthetic polimer was favorable over typical biopolymer, xanthan gum, due to its cost less, resistant to bacterial attack and can be used for large-scale production (Abidin, et al., 2012; Sheng, 2013b; Rostami, et al., 2018) as well as expected to exhibit significantly greater viscoelasticity (Li, et al., 2016). However, HPAM as a flexible chain structure known as a random coil, is very sensitive to the brine salinity and hardness due to its nature as polyelectrolytes that will interact with ions in solution, also represent the disadvantage of using this kind of polymer in the oil and gas reservoir that generally owing some degree of salinity. The other factors that affects the viscosity of HPAM solutions are the degree of hydrolysis, solution temperature, molecular weight and solvent quality (Sukpisan, et al., 1998), including pressure (Cook, et al., 1992).

The present study investigates the effect of electrolytes from saline and cation divalent of the brine to the viscosity of polymer for effectiveness mobility control of chemical flooding application.

II. METHODOLOGY

Three types of polymers from SNF (Floopam 3630S, AN 125, and Floopam 3230 S) were used for the study. Synthetic formation water as baseline was formulated from "R" Oilfield in South Sumatera with the salinity and cationic divalent composition presented on the Table-1. Salinity of the brine is at 17600 ppm with the total hardness at 483 ppm. Analytical grade sodium chloride (NaCl) and calcium chloride ($CaCl_2$) were used for investigating the effect of salinity and cationic divalent (hardness) to the viscosity of polymers.

Table 1
Salinity and cation divalent composition of synthetic formation water "R"

Components	Unit	Results
Ca	ppm	240
Mg	ppm	243
Salinity	ppm	17600

A. Compatibility Observation

The ability of studied polymers to dissolve in the formation water is crucial to ensure the flow of chemical solution in the pore size reservoir core. Polymer was dissolved in various salinity and hardness concentration. The appearance of solution was visually observed and recorded.

B. Viscosity Measurement

The viscosity of polymers with the different concentration of saline and hardness were measured using viscometer Brookfield DVIII with shear rate 6 s^{-1} at reservoir temperature (60°C). The polymer solution was put in the tube and stirred for 4 minutes until reached the targeted temperature. All data was collected and analyzed.

C. Filtration Ratio (FR) Analysis

The presence of electrolytes from salinity and cation divalent of the brine can alter the solubility of polymer which was then investigated by the filtration ratio determination. The addition of saline at various concentration as well as hardness ($CaCl_2$) for the certain concentration of polymer were analyzed comprehensively. The polymer was diluted in the synthetic designed-brine and allowed to flow into the 3.0 µm filter paper under pressurized air 30 psi. The filtration ratio was then calculated by FR=(T200-T180)/(T40-T20), where Tx is the time to collect x ml of polymer solution.

III. RESULTS AND DISCUSSION

A. The Effect of Electrolytes to the Compatibility of Polymer

Solubility of polymers in targeted formation water is important to eliminate the possibility of polymer plugging in the pore size core. Polymer solution in different salinity and hardness as component of electrolytes were made and observed. The results showed that polymers are completely dissolved in variety salinity in the range of 0.5 to 3.0% w/w saline (Table 1). The similar results are displayed for the hardness's effect in the range 0.05 to 1.0% w/w to the solubility of polymers that made clear solution for all hardness amount (Table 2). It was found that there is no effect of electrolytes to the solubility of polymers in the targeted polymer concentration.

B. The Viscosity of Polymer in Various Concentration

Sufficient viscosity of polymer is required for increasing the sweep efficiency of the chemical flooding. The lowest concentration of polymer that produce the sufficient viscosity is favorable due to the economical reason. The polymers were dissolved in the synthetic brine based on the chemical composition of formation water. The viscosity of each polymer at various concentration are presented on the Figure 1.

As shown from the Figure 1, different polymer exhibits a different profile of polymer. The figure shows that polymer Floopam 3630 S had a higher viscosity compared with Floopam 3230 S and AN125 at the same concentration. At 2000 ppm of polymers, viscosity of Floopam 3630 is around 28 cP, whereas AN125 and Floopam 3230 S made 13 cP and 10 cP respectively. Different viscosity of polymers is strongly affected by the molecular weight of each polymers. The molecular weight of Floopam 3630 S is approximate at 20 million Dalton, higher than AN125 and Floopam 3230 which only has molecular weight at around 8 million Dalton. These results indicated that Floopam 3630 S, had a more efficient viscosity regarding to the less concentration of polymer needed to produce a certain value of viscosity.

C. The Effect of Salinity to the Viscosity of Polymer

Electrolyte charges of the brine mostly affected by the presence of ionic chloride as the

Table 2
Solubility of polymers in different salinity

Salinity (%)	Solubility		
	Flopaam 3630 S	AN125	Flopaam 3230S
	1250 ppm	1750 ppm	2000 ppm
0.5	Clear	Clear	Clear
1.0	Clear	Clear	Clear
1.8	Clear	Clear	Clear
2.5	Clear	Clear	Clear
3.0	Clear	Clear	Clear

Table 3
Solubility of polymers in various hardness

Hardness (%)	Solubility		
	Flopaam 3630S	AN125	Flopaam 3230S
	1250 ppm	1730 ppm	2000 ppm
0.01	Clear	Clear	Clear
0.03	Clear	Clear	Clear
0.10	Clear	Clear	Clear
0.50	Clear	Clear	Clear
1.00	Clear	Clear	Clear

dominant component of the brine. To investigate the effect of salinity to the viscosity of polymer, certain concentration of polymer was dissolved in various brine with different NaCl concentration at constant $CaCl_2$ concentration (500 ppm), represented as hardness component. The viscosity of polymers in various brine salinity are described on the Figure 2. It shows that in all types of polymer, the viscosity decreased with the increasing of salinity. The significant effect occurs on the viscosity of AN125 as the most sensitive polymer on the salinity, that reduced from 17.49 cP at 0.5% saline to 5.23 cP at 3% saline (70% decreased), whereas for Floopam 3630 S, viscosity at 0.5% saline was at 15.23 cP, reduced to 8.87 cP at 3% saline (41.76% lower). And the least affected polymer was Floopam 3230S with decreasing value at 38.41% from 0.5 to 3% saline.

At low salinity solutions, polymers have higher viscosity due to the charge repulsion of the carboxylic groups of HPAM polymer. When any cation is dissolved in the solution, the negative charges are neutralized or shielded, generating a compression of the flexible chains, resulting in a molecular shrinkage and thus decrease in the fluid viscosity (Sheng, 2011; Eiroboyi, et al., 2019; Nurmi and Hanski, 2019).

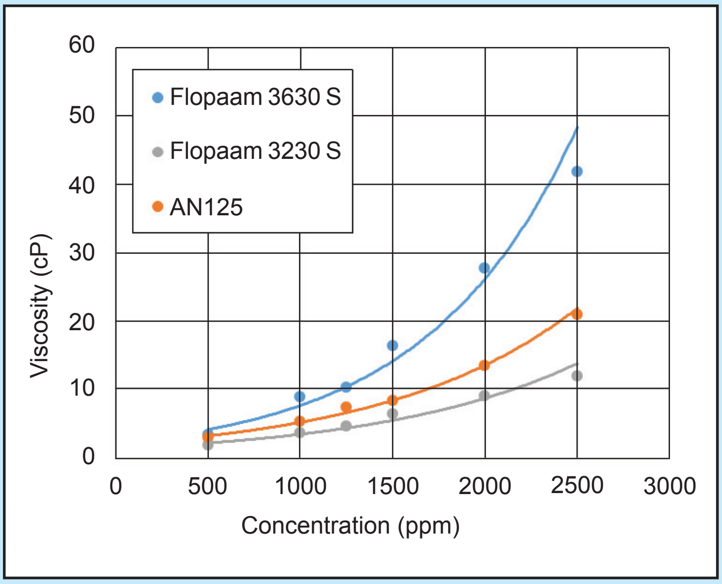

Figure 1
Viscosity of polymer at various concentration dissolved in the synthetic brine of "R" oilfield.

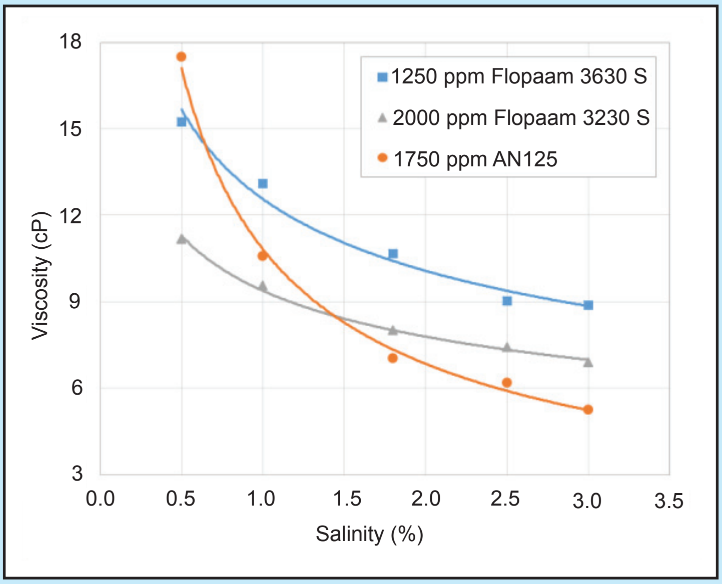

Figure 2
Viscosity of polymer at certain concentration in the various salinity (NaCl).

D. The Effect of Cation Divalent to The Viscosity of Polymer

The presence of cationic divalent calcium and magnesium in the brine has a great influence to the viscosity of polymers. As the second highest component of the brine, it is well known as the source of chemical degradation of polymer. It can be seen from the Figure 3.

Figure 3, shows that the increasing of hardness that represented by the addition of $CaCl_2$, decreased the viscosity of the polymers. In the presence of cation divalent from 0 until 500 ppm, the viscosity was significantly decreased, and starting to slowly decreased with the addition of more $CaCl_2$. It is therefore indicating that the focal point of hardness concentration was at around 500 ppm.

The ionic strength of the solution ($I_s = 1/2\sum m_i z_i^2$, where m_i is the molar concentration of the ion and z_i is its charge) that causing the viscosity reduction. For example, the ionic strength of 1 molar solution of $CaCl_2$ is three times greater than that of NaCl. It is therefore, $CaCl_2$ compresses the electrical double layer of polymer chain more than NaCl. Furthermore, the binding forces of the divalent ions are stronger, owing to their higher charge and polarizability (Sorbie, 1991; Sheng, 2011). Thus, the polymer chain can wraps in the presence of low levels of Ca^{2+}, due to its higher effectiveness in shielding the negative charge of the polymer chains than Na^+ (Nurmi & Hanski, 2019).

E. The effect of salinity and hardness to the filtration ratio

As the viscosity of polymers was influenced by the salinity and hardness, the solubility of polymers was then important to investigated regarding the possibilities of polymer to degrade and forming precipitation, especially with the presence of high cation divalent. The FR of certain concentration polymer in the various salinity and hardness brine were calculated and presented on the Figure 4.

The results showed that the filtration ratio of polymers with the addition of saline and and hardness was not affected significantly, although the highest FR were obtained at 10000 ppm NaCl and 1000 ppm $CaCl_2$ for salinity and cation divalent, respectively.

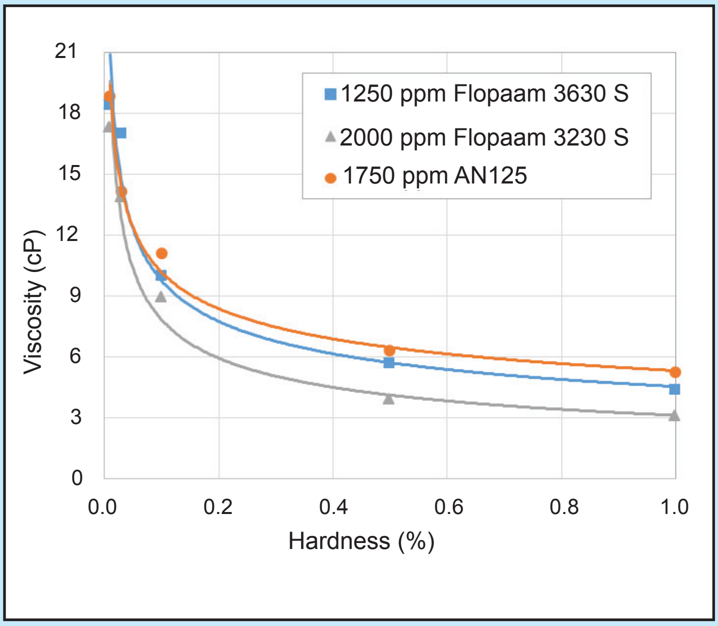

Figure 3
Viscosity of polymer at certain concentration in the various hardness ($CaCl_2$).

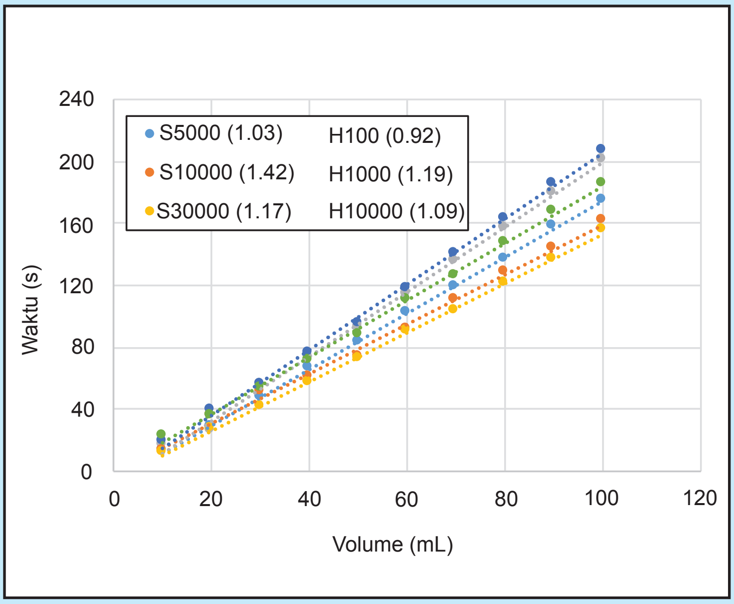

Figure 4
Viscosity of polymer at certain concentration in the various hardness ($CaCl_2$).

IV. CONCLUSIONS

Viscosity of polymer as the drive solution in chemical flooding was greatly affected by the presence of electrolytes from saline and cation divalent component. The results show that the increasing of saline and cation divalent exhibit a lower viscosity of polymer. However, the filtration ratio analysis shows that the addition of saline and hardness did not significantly alter the FR. It is therefore concluded that the cation divalent of the brine did not formed precipitation when reacted with acrylamide as the polymer backbone.

ACKNOWLEDGEMENT

Special thanks to all the staff members of Enhanced Oil Recovery Group for their contributions to this work and the development of this paper.

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